Exploring challenges in the interaction of forestry-related institutions in the employment of R&D in the South African forestry sector

by

Dandira Mushangai

(dandira20000@gmail.com)

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Supervisor: Prof Andre Kraak

Co-supervisor: Prof Stefan Schirmer

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Dedication

I dedicate this thesis to my mother Lucia, Betina Mushangai for her encouragement and love of wisdom, to my daughter Zvakanaka Mushangai for giving me the courage, and to the people of South Africa and Africa in their struggle for social, and economic development.

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I thank my supervisor, Prof Andre Kraak. The project commenced when I met Prof Kraak for the first time in Braamfontein, Johannesburg in 2014, to discuss my participation in the FPM SETA project he was leading. The project focused on a comparative analysis of forestry sectoral developments across the world, linked to local skills production and industrialisation. My research in the project was to do a comparative analysis of the forestry sectors of Sweden, Canada, China, and Gabon. The aim was to produce a monography of seven or so subsectors under the Fibre Processing and Manufacturing Sector Education Training Authority (FPM SETA). This was to obtain insights as to how South Africa could achieve forestry sectoral industrialisation. The work covered a number of academic and development areas ranging from value chains, global value chains, globalisation, industrial sociology, industrial policy, evolutionary economics, innovation, and post-school studies. It was from this work that my PhD research topic emerged in 2015. With guidance and financial assistance from Prof Kraak, the work progressed from the refinement of the PhD topic and proposal to the last chapter of this thesis. To Prof Kraak, I say, I do appreciate all the effort that you had put into this study.

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Declaration

I, Dandira Mushangai, declare that this is my own work and has not previously been submitted to another university or institution of higher education for a degree.

Abstract

The role of R&D in economic growth and development is increasingly acknowledged globally. With this is an acceptance that collaborative research ensures the benefits of R&D largely accrue to society as a whole. The growing recognition of the importance of R&D in economic growth and development through the generation and application of new knowledge, new skills, new processes, new technologies, functions, and new products by those involved in production processes has enhanced the drive by nations to build integrated systems of innovation. Systems of innovation encourage collaborative research through partnerships, cooperation, and participation in innovation networks. This is important in reducing R&D transaction costs and in ensuring that new knowledge, skills, processes, and products emanating from R&D activities are widely distributed within an economy.

This study aims to identify and explain the challenges in relation to the 'less integrated' nature (OECD, 2007) of South African systems of innovation which has resulted in 'weak coordination and linkages and limited resources and capacity' (Greenberg, 2010) in the South African forestry sectoral system of innovation (SSI), with the effect that the benefits of the system of innovation to the economy are still not known (OECD, 2007). The study analysed the challenges in the formation and maintenance of partnerships, collaboration and networks as some of the issues working against the integration of the South African National System of Innovation (NSI), hence the forestry SSI. The study employed a qualitative methodology and a number of qualitative methods and techniques, such as semi-structured interviews, and observations, and case studies were used in data collection. This was guided by the systems of innovation approach, particularly the SSI as the conceptual framework within a critical research paradigm. A thematic analysis indicated that the lack of integration and the existence of 'weak coordination and linkages and limited resources and capacity' that limit the application of R&D by firms in the forestry SSI for the benefit of the economy as a whole are not a result of a single factor but of a convergence of factors that cannot be addressed quantitatively by neat technical solutions. The lack of integration of the South African System of Innovation (SI) is thus explained in terms of multiple realities. However, some of the challenges, such as limited funding and skills, could be greatly lessened through collaboration at sectoral, national or at supra-national levels.

The historical and evolutionary approach adopted by the study allowed the tracing of the development trajectories of the forestry industry in South Africa since it started and the nature of racial interactions as determined by colonial and apartheid philosophies of separate development. This was important in understanding power relations under the colonial and apartheid systems in relation to knowledge generation and skills development and the differential economic outcomes linked to forestry resource development in the homelands and the white segments of colonial and apartheid South Africa. Historicising was also important in understanding the ideological changes brought in by the transition to democracy hinged on participatory approaches that informed policies such as the BBBEE. This also enabled the problematisation of the state of affairs in South Africa with regard to the emergence of a predatory and politically connected 'class for itself' (*comprador bourgeoisie*) dependent on state tenders as the main source of accumulation among the former revolutionaries (nationalists) *vis-à-vis* the empowerment of the ordinary South African and SMEs.

The democratisation processes have to some extent led to emergence of crony capitalism as exemplified by the state capture case. The evolutionary approach and the historicisation of forestry resource development in South Africa therefore enabled the debunking of some ideas that have persisted unchallenged with regard to the nature of skills development, knowledge generation and application, accumulation processes and the benefits of the South African SI to the economy. These myths have clouded our understanding of R&D processes and role in economic growth and development hence imposing limitations in constructing suitable intervention measures enabling the emancipation of South Africans from the triple threat of inequality, unemployment, and poverty. The study rejected the arguement by Kruger & Bennett (2015) that the South African forestry research system as it developed was exceptional and was not influenced by the Indian and European traditions. It again rejected the idea by Kruger & Bennett (2015) that the apartheid forestry research system was more integrated than the current research system. It also rejected the argument by the OECD (2007) that the benefits of the NSI, especially with reference to the forestry sector, are unknown. It further rejected the Sachs-Warner hypothesis (Sachs and Warner, 1995) that 'all' natural resource rich countries suffer from resource dependency curse and cannot derive industrialisation and economic diversification from the exploitation of their resources. Moreover, the study rejects the notion that the big companies established during apartheid times are always exploitative of small upcoming businesses in value chains and demonstrated that, if anything, and at times, these big firms and their partnership schemes have offered the most effective way of transferring skills and technologies to SMEs outside the skills system. The emergence of crony capitalism debunks the arguement that the current development crisis in South Africa is only explained in terms of colonial and apartheid policies. The persistence of such arguments clouds the processes of designing suitable measures important in integrating the South African system of innovation for the benefit of the economy. While the thesis does not contribute to a major revision of the theory and conceptual framework, it does illustrate, through the case of forestry and the nested case studies of R&D, new ways of thinking about this literature that takes account of South Africa's complexity.

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Abbreviations and Acronyms

ACIAR	Australian Centre for International Agricultural Research
AgriSETA	Agriculture Sector Education and Training Authority
ANC	African National Congress
ASIGSA	Accelerated and Shared Growth Initiative for South Africa
BBBEE	Broad Based Economic Empowerment Act
BCEA	Basic Conditions of Employment Act 75 of 1997
BNG	Breaking New Ground
CAMCOR	Central America and Mexico Coniferous Resources Cooperative
CERC	China Eucalypt Research Centre (CHE Council for Higher Education
CPA	Communal Property Associations Act of 1996
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DAFF	Department of Agriculture, Fisheries, and Forestry
DCS	Department of Correctional Services
DEA	Department of Environmental Affairs
DEEM	Design, Engineering, Entrepreneurship and Management
DHET	Department of Higher Education and Training
DLA	Department of Land Affairs
DST	Department of Science and Technology
DNA	De Ox-Ribonucleic Acid

DOL	Department of Labour
DRDLR	Department of Rural Development and Land Reform
DSBD	Department of Small Business Development
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
DTI	Department of Trade and Industry
ESTA	Extension of Security of Tenure Act 62 of 1997
FABI	Forestry and Agricultural Biotechnology Institute
FPM SETA	Fibre Processing and Manufacturing Sector Education and Training Authority
FSA	Forestry South Africa
FSC	Forest Stewardship Council
GATS	General Agreement on Trade in Services
GEAR	Growth, Employment and Redistribution
GMOs	Genetically Modified Organisms
HESA	Higher Education South Africa
HRDC	Human Resource Development Council
IAPs	Invasive Alien Species
IDC	Industrial Development Corporation
ICFR	Institute of Commercial Forestry Research
ILDP	International Leadership Development Programme
IMF	International Monetary Fund

IP	Intellectual Property
IPLRAD	Integrated Programme for Land Redistribution and Agricultural Development (2009)
IPR	Intellectual Property Rights
ISEDS	Integrated Small Enterprise Development Strategy (ISEDS *for 2005-2014*)
ISO	International Standards Organisation
IUFRO	International Union of Forestry Research Organisations
KBE	Knowledge Based Economy
Khula	Khula Enterprise Finance
LMIP	Labour Market Intelligence Partnership (LMIP) in South Africa)
LRA	Labour Relations Act (LRA) of 1996
LTA	Land Tenure Act 32 of 1996
MAREP	Management, Research, and Planning
MEC	Mineral-Energy-Complex
Mondi	Mondi Forests
MNC	Multi-National Corporations
MNEs	Multi-National Enterprises
NCT	NCT Forests
NDP	National Development Plan
NEMA	National Environmental Management Act (NEMA) 107 of 1998
NEMBA	National Environmental Management Biodiversity (NEMBA) Act 10 of 2004
NGOs	Non-Governmental Organisations

NIBUS	National Informal Business Upliftment Strategy
NIPF	National Industrial Policy Framework
NMMU	Nelson Mandela Metropolitan University
NPC	National Planning Commission
NRDS	National Research and Development Strategy
NSDS	National Skills Development Strategy
NSI	National System of Innovation
OECD	Organisation of Economic Development and Development
PCR	Polymerase Chain Reaction (PCR
R&D	Research and Development
RDP	Reconstruction and Development Programme (1994)
RDS	Rural Development Strategy (RDS 2000
RSI	Regional Systems of Innovation
SAFCOL	South African Forest Company Limited
SAPPI	South Africa Pulp and Paper Industries
SEDA	Small Enterprise Development Agency
SETAs	Sector Education and Training Authorities
SI	Systems of Innovation
SME	Small Medium Enterprises (used interchangeably with *small businesses*)
SSI	Sectoral Systems of Innovation
SSPs	Sector Skills Plans
STEM	Science, Technology, Engineering, and Mathematics
TWK	Transvaal Wattle Growers Association
THRIP	Technology and Human Resources for Industry Programme

TRIMS	Trade-Related Investment Measures
TRIPS	Trade-Related Intellectual Property agreement
UKZN	University of KwaZulu-Natal
UJ	University of Johannesburg
UNIDO	United Nations Industrial Development Organisation
Wits University	University of the Witwatersrand
WTO	World Trade Organisation

Chapter 1: A contextual introduction

1.1 Introduction

The study is justified for its focus on addressing a gap in our knowledge of the importance of interactions in systems' integration for effective employment of research and development (R&D) by firms in the South African forestry sector. The Organisation for Economic Cooperation and Development (OECD, 2007) noted that, despite massive investments for the past 20 years in building a national system of innovation (NSI), the benefits of R&D on the South African economy are not known because its system of innovation (SI)[1] is badly integrated. China has been better able to realise the benefits of R&D in growing its economy than South Africa because its system of innovation is more integrated (OECD, 2007). Systems of innovation interact together, such that weaknesses in the NSI may also manifest in other systems, such as the Sectoral Systems of Innovation (SSI). Therefore, in alignment with the diagnosis of the OECD (2007), Greenberg (2010) noted that South Africa's Agriculture and forestry Systems of Innovation has not been able to perform optimally because it suffers from 'weak coordination and linkages and limited resources and capacity'(p.ix). Ngomane (2003) supports this when he noted that the public services that dominate the agriculture and forestry extension in South Africa are beset by limited funding, lack of trained staff, absence of participation by farmers and the existence of weak linkages. All these assertions point to the disintegrated nature of the South African SI which constrains the employment of R&D by forestry-sector-based firms for improved efficiency and effectiveness in production. The benefits of R&D are said to accrue when a country's system of innovation is integrated (Higher Education South Africa, HESA, 2008). As a result of the lack of systems integration, the South African forestry, timber and pulp industries are inefficient, capable of extracting only 45% to 47% of value from a tree 'with the rest being lost as waste' (Sithole 2017, p.15).

Literature on innovation studies (Edquist, 2009; Nelson, 2003; Gereffi, 1994; Lundvall, 1992) alludes to the importance of R&D in propelling economic growth and development. Evidence from developing countries, such as China, Brazil, India, and the Asian tigers, point to the centrality of R&D in propelling economic growth and industrialisation (Aghion, 2009; Dalhman,

[1] According to Edquist (2009), a System of Innovation is made up of the determinants of innovation processes including, 'all important economic, social, political, organisational, institutional, and … factors that influence the development, diffusion, and use of innovations' (p.1).

2014). South Africa could realise the benefits of research and innovation if system failures relating to lack of integration, weak coordination, weak linkages, and limited resources and capacity are determined and resolved. The South African Department of Science and Technology has therefore emphasised the urgency of finding solutions for challenges, ‘’confronting South Africa’s failure to commercialise the results of scientific research and … inadequate production of knowledge workers capable of building a globally competitive economy’’ (DST, 2009, p. IV). This is an important issue in the forestry sector to ensure the employment of R&D to improve the quantity and quality of timber production, enabling the adequate supply of lumber for all the firms in the subsectors along the value chain. This is imperative now, considering that forestry production is threatened by a number of factors, among which are global warming and climate change; land and agrarian reforms; and environmental and water regulations (Meyers et al, 2003; Tewari, 2001). These factors have contributed to a reduction in the amount of land formerly allocated to plantation forestry in South Africa and with it the quantity of lumber produced. The employment of R&D is critical to enable firms in the upstream activities of the forestry value chain to apply new knowledge and technologies, to maintain production on a reduced land base and for firms in downstream activities to embark on the production of new and high-value materials and products in addition to traditional forestry products (Sithole, 2017). The production of new and high-value materials through beneficiation and increased value extraction would improve resource efficiency; hence the minimisation of waste materials by ensuring the conversion of waste products (for example, wood chips, and sludge) into use values (SAPPI Sustainability Report, 2016). The maximisation of value extraction from a tree reduces the amount of waste material, thus lessening the carbon footprint of the industry as a whole.

Nonetheless, success in producing capable researchers and in commercialising research is not dependent on a single component of a system but is a result of the interaction of a number of coordinated components and individuals working within what can be called a system of innovation (Bansu, 2014; Uctu, 2016). Integration facilitates interaction between the components of a system which forms the basis for collaboration, partnerships, and networks enabling the sharing of knowledge and the employment of R&D (Smits, Kuhlmann, & Shapira, 2010). The importance of interaction and integration is hinged on the recognition that learning within individual firms and within a network of firms alongside other organisations comprises the new basis for competitiveness and growth in the global economy and that learning is best achieved by collaboration with other firms and actors (Bergek, 2010; Nelson & Winter, 1977). Interactions are also critical because no single firm has access to the full set of knowledge and technologies needed to overcome production problems, but a collective of firms with other key actors do (Bergek, 2010). Consequently, knowledge production, technology transfers, and commercialisation are more effective when there are positive interactions between the components of a system of innovation (SI) (Edquist, 2006). Without interactions, the integration of a system is negatively affected and this hinders collaboration in learning, and the diffusion of knowledge and technologies. This is because the lack of integration makes it difficult for effective interactions among the forestry stakeholders and increases R&D transaction costs with a negative effect on the competitiveness of sectoral economies. As such, an integrated SI ensures the existence of channels for the components to contribute and to receive feedback on the effectiveness of the system and challenges in the employment of R&D (Edquist, 2006).

The failure of the South African SI to perform its functions effectively as a result of the lack of integration (OECD, 2007) and the existence of 'weak coordination', 'weak linkages', and 'limited capacity' (Greenburg, 2010) points to what SI scholars have variously referred to as 'system failures' (Smith, 2010), 'system weakness' or 'systemic problems' (Bergek, Jacobsson, Hekkert, & Smith, 2010). Edquist (1999) ascribed 'system failures' to the nature of systems' components and the interactions between them. This was also emphasised by Woolthuis et al (2005) who noted that system failures are mainly a result of, ''infrastructural failures'' (related to the provision of facilitative infrustructure); ''institutional failures'' (linked to regulations); ''interaction failures'' (related to connections and social capital); and ''capabilities failures'' (related tangible and intangible assets of the actors) (p.611). Nevertheless, Metcalf (2004) noted that the existence of the ecology of organisations and institutions without interconnections cannot be regarded as a system, for systems are characterised by the components interacting together within their environment. Since systems are defined by the interactions between the components, Smith (2010) is of the view that system failures are essentially problems of coordination. Problems in coordination may be a result of what the systems theorists refer to as 'blocking mechanisms' (Bergek, Jacobsson, Hekkert, & Smith, 2010). Blocking mechanisms are the systemic dynamics that prevent the growth and development of functions (Bergek et al, 2010). Examples of these may be the lack of strong political and learning networks limiting the generation, transmission, and application of knowledge. The existence of monopolies that increases the entry barriers for new players may also be a blocking mechanism within an economic system. Consequently, the role of intervention from a system's perspective is to identify blocking mechanisms so as to address the ''missing components or missing connections'' impacting negatively on the efficiency and effectiveness of a system (Metcalfe, 2004, as cited in Smits, Kuhlmann, & Shapira, 2010).

The lack of evidence of the benefits of R&D in the South African economy, as noted by the OECD (2007), should not be a disincentive for investments in R&D, lest the country fails to realise the demands of the knowledge economy. This study is focused on understanding blocking mechanisms which are interactional challenges bringing about a 'lack of integration' (OECD, 2007), 'weak coordination', 'weak linkages', and 'limited capacity' (Greenburg, 2010) in the South African Forestry SSI. The study focuses on interactions between big and small enterprises, investment financing, research and educational organisations, government agencies and other stakeholders, among others, in skills development, knowledge generation, and application to improve functions, processes, and products. This would also involve an analysis of the institutional ensemble defining these interactions. The aim is to analyse and evaluate the blocking mechanisms to justify interventions required to improve the performance of the system in the employment of R&D. This enterprise will address the gaps with regards to our knowledge of the challenges in the interaction between forestry-sector stakeholders in the integration of the forestry sectoral system of innovation for effective employment of R&D. In doing this, the study is guided by the SSI approach, which is an element of the SI approach, as will be clarified in the conceptual framework in Chapter 3.

1.2 Why forestry R&D is paramount now?

Evidence shows that, in most of the cases, research forms the basis for innovation (Smits, Kuhlmann & Shapira, 2010; Stoneman, 1995). According to North (1981) ''the Industrial Revolution was a result of the acceleration in the rate of innovation'' (p.159). Since innovation is partly a function of research, research becomes necessary in propelling the industrialisation of economies, as noted by North (1981), with regards to the British Industrial Revolution. Research is crucial in addressing the complexities, uncertainties and the changing understanding between innovation and improved production. Many studies conducted across the globe in relation to forestry and agricultural productivity provide ample evidence of the importance of R&D and human capacity in economic growth and development. Most of these studies (Plomion, 2016; Chang, 2010; Tripathi, 2008; Kiani, 2008; Grant, 2002; Zepada, 2001; Velanzo, 2001; Chavas, 2001; Fulginiti et al, 1998; Sedjo, 1997) point to the importance of R&D, human capacity development, technology transfers, extension services, chemicals, machinery, fertilisers, and roads, or a combination of these, as having been paramount to increased agricultural and forestry productivity. The supply of machinery, chemicals, the availability of roads, and research and extension services demonstrate the importance of the integration of both vertical and horizontal[2] players in a system. However, due to the empiricist nature of these studies, they fail to emphasise the significance of relations and interactions between those who formulate industrial policies, those who make roads, those who manufacture machinery and fertilisers, those involved in skills formation and in provision of extension services, those in funding activities, and those who regulate the systems in providing the concentrated drive in the employment of R&D by end-users (farmers and growers). SI scholars (Edquist, 2006; Shapira, Smits, & Kuhlmann, 2010) regard interactions and human relationships as the axioms upon which the employment of R&D revolves. The above-referred studies fail to determine the importance of the nature of relations and interactions between individuals in a system and between the various components of an SI in accounting for the successes or failures in the employment of R&D. These interactions and human relationships are the glue, holding together the components of an SI. Without an understanding of these interactions and human relationships, it would be difficult or even impossible to comprehend the blockages constraining systems' integration and hence effectiveness in the employment of R&D within the South African forestry sector.

However, for a nuanced understanding of the challenges in the development of businesses in the forestery sector of South Africa, it is imperative to determine their origin, especially the challenges related to small businesses in the hands of black people. An analysis into their orgin would enable the development of deep knowledge and deep understanding of the dynamics at play in the interaction of firms and other components of the system of innovation hence a comprehension of the blocking mechanisms in the employment of R&D. Some of the current

[2] According to Nadvi (1999), vertical linkages, horizontal linkages or multilateral linkages involve joint actions.Vertical linkages entail backward linkages with suppliers, subcontractors or any other service providers. Horizontal linkages may include linkages between two or more producers for joint marketing of products, joint purchase of inputs, and order sharing, common use of specialized equipment, joint product development and exchange of expertise and market information. Multilateral horizontal linkages may involve cooperation in cluster wide institutions including cooperation in business associations and businesses development service centers (Nadvi, 1999, as cited in Pietrobelli and Rabellotti, 2006).

challenges with regard to blockages in the employment of R&D in the South African forestry sector are to be found in the nature of South Africa's insertion into the global capitalist system and how the agrarian question of capital was resolved.

1.3 Capitalism and the agrarian question of capital in South Africa

The agrarian question of capital in the classical sense was concerned with agricultural transitions to capitalism and the ways in which agriculture contributes to industrialization (Pons-Vignon, 2014). The question is resolved when the transition to capitalist agriculture and industry is complete (Byres, 1991, 1996; Bernstein, 1996). Byres (1991, 1996) identified two main pathways by which this transition can occur. These are: accumulation from above when landowners became capitalists; and accumulation from below when peasant producers become capitalists through petty commodification. Transition by facilitating accumulation from above occurred in Prussia, Northern India and 19th century Germany (Cousins, 2007). The second path, that is, accumulation from below is often referred to as the American path occurring through class differentiation among peasants and other kinds of petty commodity producers (Cousins, 2007).

Cousins (2007) noted that in South Africa the agrarian question of capital was resolved from above. This has been corroborated by Pons-Vignon (2014) who noted that South Africa's transition to capitalism was imposed from above and that this was combined with the insistence that Africans should remain proletarians. Many of the current challenges with regard to agriculture and the forestry economy (skills shortage, unequal distribution of land between races, and the rule of traditional authorities) in particular have their roots in the agrarian question of capital and how this question was resolved in South Africa. The mechanisms and racial slant through which the agricultural transition to capitalism was accomplished in South Africa led Bernstein (2003a, as cited in Cousins, 2007) to define the South African case as 'extreme and exceptional'. Coercive mechanisms were employed by the state through the formulation and implementation of racially discriminative policies that promoted cheap labour, provided extensive subsidies and a bureaucratic regime regulating production, distribution, and trade in the interest of White agricultural capital (Pons-Vignon, 2014).

Lewis (1954) had postulated that transition to capitalism would be accomplished through the voluntary migration of excess labor from the inferior peasant economy to the superior capitalist economy. Nevertheless, evidence from Southern Africa speaks to the contrary as a lot of violence was employed to alienate Black Africans from their land to compel them to provide cheap labour on white-owned farms. Arrighi (1970) detailed the violent mechanisms that were used to compel the Africans in Southern Rhodesia to work for the emerging white capitalist economy. Some of these included land dispossession and exorbitant taxes. In South Africa, the backbone of the capitalist economy under colonial and apartheid systems was cheap African labour (Bundy, 1988). The colonial South African state used its legislative powers to dispossess the Africans of the means of production (land) so as to compel them to provide labour for the emerging white capitalist sector. The Land Act of 1913 reserved less than 8 percent of the land for Africans which was increased to a maximum of 13 percent by the 1936 Native Trust and Land Care Act (Wegrif, Russel, & Grundling, 2005). The rest of the land that is 87 percent was reserved for white settlement. To ensure the distribution of labour across South Africa the 1913 Land Act and the 1936 Native Trust and Land Care Act pushed the Africans into the reserves (Bantustans) which were spread across the country (Wegrif, Russel, & Grundling, 2005). The discrimination and dispossession of the black people in South Africa and elsewhere in Southern Africa were aimed at achieving two main goals. These were, to force Africans into wage labour by undermining the ability of peasant agriculture to support a large population; and to allow capitalist employers to pay low wages below subsistence by shifting the cost of reproduction to peasant economy of the reserves (Arrighi, 1970; Bundy, 1988; Pons-Vignon, 2014). Worthy of note is that, at a time when black African agriculture was systematically destroyed, ‘the white farming sector was built with the help of black labour, government gifts of land, subsidies, market protection, and drought relief handouts that continued to the apartheid era’ (Wegrif, Russel, & Grundling, 2005). As a result of the segregation policies, Pons-Vignon (2014) noted that by the end of the 1970s African peasant farming had been vanquished.

The current challenges with regard to the unequal distribution of land between races in South Africa and the resistance to democratic governments’ land and agrarian reforms are partially linked to colonial and apartheid accumulation structures. An understanding of the agrarian question of capital and how it was resolved in South Africa is therefore paramount if we are to comprehend the current structure of the forestry sector which is made up of a highly developed and mechanized section in the hands of White people existing in juxtaposition to an underdeveloped heterogeneous section made up of small formal and informal enterprises mainly the hands of black people.

1.4 History and firms' capability development in the South African forestry sector

The skewed colonial and apartheid patterns of accumulation created a dual economy situation in South Africa (Pons-Vignon, 2014; Bond, 2006; Fine & Rustomjee, 1996). The colonial and apartheid policies in South Africa (the Land Act 1913, the Cooperatives Act 1920, the 1925 Farmers Assistance Board, Bantu Education policies, among others) supported accumulation and development in the white sections of the economy through the provision of land, financial support, and R&D services. The same policies constrained accumulation in the homelands through land dispossession (Pons-Vignon, 2014). The Bantu education system hindered the generation and application of knowledge in the black section of the forestry industry, as black people were only trained to become labourers in the white section of the economy (Du Plooy & Zilindile, 2014; Grundy & Wynberg, 2001). The direction and nature of colonial and apartheid development was a result of the interaction between economic policy, education policy, and firms within a segregated SI. At the dawn of democracy, South Africa had a disintegrated dual forestry economy with a highly developed and mechanised white economy applying the latest technology on the one hand and an underdeveloped African economy on the other hand. The colonial and apartheid history still cast a long shadow over current development policies and practices (Natrass, 2014). History is thus important in understanding the current struggles to ensure development for the vestiges of the past continue to interact with the present, determining its direction. Douglas North (2004)'s concept of 'path dependence' posits that past routines, social relationships, and worldviews affect current economic behaviour and growth patterns. The current institutions retain relics of previous institutions which are difficult to change even when many issues have changed. This understanding is important in grasping as to why the colonial and apartheid patterns of interaction and accumulation have continued in the South African forestry sector despite efforts to democratise the economy. However, innovation systems evolve (Nelson & Winter, 1982); hence an understanding of these evolutionary dynamics is critical as the backdrop to comprehending interactional challenges or blocking mechanisms in determining the success or failure in employing R&D within the South African forestry sector. This is vital again in discerning the contextual origin and evolution (change and continuities) of the blocking mechanisms in the interaction between the various components and individuals in the forestry SI in knowledge generation and application. Without this understanding, it would be difficult to integrate the forestry sector to facilitate the employment of R&D by both the big and small enterprises in the sector.

Currently, the South African agriculture and forestry sector is made up of emerging farmers ranging from 50 000 to 120 000 in number (AgriSETA, 2016). Most of these small businesses (SMEs) are black-owned and lack access to development finance; managerial skills, enterprise development, and technical skills to be sustainable (AgriSETA, 2016; Genesis Analytics, 2005). The SMEs in the sector also lack networks or social capital in relation to business services and information provision (Chaminade & Edquist, 2010). The lack of quality information in relation to business opportunities has been associated with business failure (Story et al, 1987) while better information is associated with business growth, success and survivability (Street & Meister, 2004). As a result of these challenges, the SMEs in the forestry sector are largely incapable of producing quality products, hence their market entrenchment. The Genesis Analytics study (2005) noted that small and micro sawmilling enterprises produce sawn timber that is of lower quality, due to their informal nature, lack of equipment and the lack of skills. All of these challenges adversely affect the development of small-scale enterprises (SMEs) in the forestry sector and partly explain the collapse of many SMEs in South Africa in their formative stages (Kgosana, 2013).

The South African forestry sector also has a number of big firms with highly developed operations. The big firms, such as Mondi and SAPPI, are vertically integrated from plantations to their pulp and paper mills (Pons-Vignon, 2014). The vertical integration tends to clog the space for small businesses, especially in relation to the sourcing of timber required for their operations. Compounding this is that the big players have had long-term contracts with the state timber-producing company SAFCOL, a situation that further curtails the ability of small enterprises to secure sources of supply, thereby pushing them out of the market (Genesis Analytics, 2005). Further, the furniture sub-section of the value chain is dominated by large scale retailers, such as Joshua Doore and Bears, mass-producing standardised furniture items (Ward et al, 2018). The dominance of big retailers in the furniture sector was boosted by their financial capabilities, enabling them to provide credit, which has become the basis of profitability for the furniture sector since the 1990s (Ward et al, 2018). The manner in which the big firms operate has tended to crowd out small players with negative effects on the integration of the sector. The concentrated nature of the industry together with the greater focus on pulp and paper production by such firms as Mondi and SAPPI limits diversification and the development of small enterprises in downstream processing and manufacturing activities.

The dichotomy in the forestry sector largely expressing itself in the existence of large-scale international corporations owning their own science laboratories and technological hubs (Crane 2016; Bethlehem, 2000) and others with enhanced capabilities, such as Joshua Doore and Bears, in downstream activities of the value chain (Ward et al, 2018), existing in juxtaposition to small scale, mostly black-owned survivalist enterprises (Genesis Analytics, 2005) underlies the power dynamics and the divergence of interests among the players. The power dynamics and the divergence of interests in the value chain have been factors aggravating the disintegration, disorganisation, and disconnection of the components in the sector as a whole. The integration of South Africa's forestry sectoral system of innovation is consequently constrained by the, ''dual economy in which established, mostly white-owned businesses have greater access to resources and opportunities when compared to black-owned businesses'' (DTI, 2003, p. 27).

Conversely, some of the big firms in the sector are currently facing challenges with regard to old equipment, a lack of R&D capabilities (Kaplinsky, 2013), a declining resource base as a result of the land reform, water and environmental regulations, and climate change (Genesis Analytics, 2005; Meyers et al, 2001). These challenges call for an integrated approach to develop skills and R&D capabilities to enable the application of enhanced technologies in order to maintain or improve production in the forestry sector. Currently, the opportunity to achieve this in South Africa is hindered by the lack of an integrated system of innovation (Sithole, 2017; Greenberg, 2010; OECD, 2007; Ngomane, 2003).

1.5 Proposed solutions to structural defects

Various ways have been proposed to overcome the challenges with regard to the lack of integration of the forestry SSI in South Africa, but have not been successful. The democratic reformation since 1994 initiated a number of transformative economic and education policies to facilitate inclusive development but this has not ensured the dismantling of the colonial and apartheid accumulation patterns (Friedman, 2015). As noted by the Department of Trade and

Industry, there is still a need to transform South Africa's economy, which remains hindered by the burden of a ''dual economy'' (DTI, 2003, p.27) to ensure the integration of the ''second economy and the graduation'' of certain viable small enterprises into the formal economy (DTI, 2007, p.7).

There is a need to think of structural issues when seeking to overcome these challenges. De Soto (2002) offers one kind of perspective by pointing to access to the legal system as critical in the growth and development of the SMEs. According to De Soto (2000), the cost imposed by state regulation compels the small businesses to operate in the extra-legal/informal sector which makes it difficult to link up with other components of the innovation system (for example, financial and education institutions) in building their capabilities. Accordingly, De Soto (2000) advocates for a policy focus mainly intended on lessening the burden of state regulation to incentivise the SMEs to formalise their businesses as the backdrop to capability development. De Soto further campaigns for policy reforms aimed at lessening bureaucratic hurdles to reduce transaction costs with regard to the time and resources spent on business formalisation. Shapira (2010) conceded that these strategies have to include policies which address national or state regulatory, tax, bankruptcy, labour market and regimes within which SMEs operate, and direct policies with goals and resources targeted specifically at SMEs. Shapira (2010) and De Soto's (2000) policy focus is on creating conducive environments, incentivising the formalisation of SMEs by lessening the burden of regulation as the background to capability development.

However, history and contextual considerations are important in understanding the development of forestry-sector-based businesses in South Africa. For example, the critique of the ''two economies'' (Bond, 2006) in South Africa and the building of formalised pathways for informal businesses entails an understanding of how the structural development of South Africa is about the 'development of underdevelopment'. In other words, the second economy (of poor SMEs) exists because of the first economy. Moreover, the pattern of development of South Africa's economy has been determined by the structural dynamics of the 'mineral energy complex' (MEC) and the growth of monopolisation around this (Fine & Rustomjee, 1996). The 'mineral energy complex' position in the development of South Africa is closely related to Sachs and Warner (1995)'s hypothesis which posits that natural resource rich countries suffer from dependency 'curse' and are prone to 'Dutch diseases', hence the inability to achieve high growth rates. The Dutch disease theory states that increases in revenues from natural resources ‘deindustrializes’ a country’s economy by raising exchange rates thereby making manufacturing sectors less competitive. The skewing of the economy in this way also provides a critique to scholars, such as De Soto’s (1989, 2000) notion of opening structural space for the second economy. Put differently, to create space for structural diversification and deconcentration, even for the second economy to emerge, South Africa has to ensure a development path beyond the ‘mineral energy complex’. This has to take into consideration that the forestry industry was propped up by the colonial and apartheid governments to support the mining industry through the provision of energy and timber props (Malan, 2018; Kruger & Bennett, 2015). Chapter 2 details how the research needs of the forestry industry were met by the government and how colonial and apartheid approaches only catered for the development of the forestry section that was in the hands of white capital. Historicising is therefore imperative in understanding how the big white-owned firms with highly developed operations and the small underdeveloped black-owned SMEs came to co-exist in the forestry sector of South Africa. This is also important to comprehend the influences from other sectors, such as the mineral and energy sectors, on the configurations of firms in the forestry sector in relation to their origin and development. This understanding can be comprehended within the confines of the SI approach, especially in appreciating the role of the government and institutions for deliberate intervention with a focus on SMEs outside the mineral and energy sectors to address the lop-sided nuture of colonial and apartheid development.

Since the history of the forestry sector tells that the development of the big firms in the sector was carried out with the underdevelopment of small businesses in the homelands, a solution to the underdevelopment of small businesses in this sector of South Africa partially lies in facilating upgrading of small businesses by forging links with established firms to facilitate knowledge and technological transfers from the big and established businesses to SMEs.

1.6 Upgrading

Moreover, Mitsuhashi (2006) proposes ‘upgrading’ as a way of enabling the sustainability of SMEs. Mitsuhashi (2006) defines upgrading as the improvement in activities to yield higher returns and sustained income growth. Upgrading involves the ability of a firm to produce better and faster with less cost and to move into other markets that are difficult for others to enter (Mitsuhashi, 2006). Upgrading involves the ability of a firm to produce better and faster with less cost and to move into other markets that are difficult for others to enter (Mitsuhashi, 2006). Upgrading is mostly linked to the ability of firms to participate in value chains. Value chains have been defined as linkages and processes of upgrading (innovation) from primary production and services, to higher value activities (Porter, 1985). The process of upgrading ensures that greater benefits in production are accumulated in more value-added downstream productive activities. Countries that have been able to develop and upgrade their productive capacities have been able to reap the benefits of industrial processing as they are able to sell value added products at higher prices than countries limited to resource extraction (Alasia & Hardie, 2011). The concept of value chain and the advantages of participating in the downstream activities of a chain throw some doubts on the outdated Ricardian approach to development based on comparative advantage. In modern productive regimes, economies of competitive advantages are much more regarded as they enable countries to gain much by engaging in product, process and functional levels with higher entry barriers. Linked to the idea of value chain is the concept of Global Value Chains (GVCs).

Gereffi (1999 as cited in Pietrobelli and Rainbird, 2013) defined GVCs in terms of a 'set of inter-firm relations connecting the processes of production and distribution in global industries leading to final product market. The GVC literature (Gereffi, 1994, 1999; Ramirez & Rainbird, 2010) mainly locates the processes of upgrading and innovation to factors exogenous to the firm and its local environment. The proponents of the GVC literature such as Girreffi (1999) and others mainly regard innovation is a function of the participation of local firms in GVCs. It is deemed that by participating in GVCs, research and innovation skills are transferred from the lead firms within the value chain to their suppliers. Further, the demand for quality products and the ability to deliver on time compels local firms to upgrade their production activities for failure to do so would result in sanctions being imposed on them by the leading firms in the GVCs.

However, creative destruction through participation in value chains is not a straight forward process as the protagonists of value chain approach seem to imply. As noted by Mitsuhashi (2006) the GVC leaders might not be comfortable in transferring research and development information that might result in their suppliers becoming their competitors. Further, Gereffi (1994, 1999) himself noted the power asymmetries within the different modes of governance of these value chains. Some forms of governance are democratic and allow skills acquisition and innovation by local firms. Mitsuhashu (2006) some forms of governance prohibit innovation by local firms especially at functional levels that informs the most profitable aspects of these chains. To consider is, who makes the rules, who enforces the rules, and who benefits? As such, power dynamics are important vectors in understanding as to why some forms of governance promote knowledge and skills acquisition hence upgrading whilst others tend to hinder such an undertaking.

Moreover, the implication of the global value chain approach that in the globalized world, regulation nolonger resides within the nation state but by some other non-state entities is problematic. Worthy of consideration is that, firms exist within defined boundaries such that the idea of territoriality remains important in understanding development (Henderson, 2002). The local vestiges, cultures and institutions are always important regulatory mechanisms imposing limitations on local firms (Whitely, 2009; Acemoglu et al, 2004). With regard to learning, the curriculum at universities in South Africa is formulated in conjunction with a nation's department of education. The Global Production Network (GPN) of economic geographers such as Henderson et al, (2002) has therefore emphasized local institutions, business systems and the state as important actors in research and development. This GPN approach recognizes the spatial nature of firms' insertion in global value chains. It takes into consideration the business system approach with regard to national and sub-national industrial clusters (Pietrobelli & Rabellotti, 2012). The GPN approach recognizes that upgrading and development is not linear as GVC approach seems to imply. The process is more complex occurring at multilevel, multidimensional and multilayered structures. As such, it is worthy considering that though participation in global value chains may offer direct and indirect opportunities for upgrading, learning, skills acquisition and upgrading are not straight forward processes. This very fact exposes the limitations of the GVC approach in accounting for factors that bring about innovation and creative destruction.

Evidence from across the world seems to suggest that certain conditions have to be met first by a firm within its domestic environment if it is to participate successfully in global value chains. Terheggen (2011)'s Gabonese case study noted that the Gabonese forest firms failed to upgrade despite their participation in global value chains due to the lack of research and development capabilities emanating from the non-existence of an efficient national system of innovation in

Gabon. Gabon lacks competent schools and universities which are important components of a system of innovation skills formation process. On the contrary the success of the Chinese and Korean firms in global value chains has been attributed to superior technologies i.e. superior research and development capabilities emanating from the strength of their national systems of innovation (Aghion, 2009). Taken to their logical conclusion, these dynamics imply that innovation by local firms and the success of a firm's partivipation in GVCS is mainly determined by factors within a firm's domestic operational environment. Though participation in GVCs has its own advantages in terms of upgrading, participation in GVCs may not be the magna-carta or panacea to local economic problems with regard to research and development and the impact thereof.

Evidence points to the fact that upgrading by the small firms in the second economy of South Africa is partly constrained by the low level of skills and their limited interaction with the big firms (AgriSETA, 2016). Interaction between the big and small firms in the sector enables knowledge and technology transfers from the established firms (AgriSETA, 2016). Upgrading by SMEs in the forestry sector of South Africa is also curtailed by limited infrastructure and capital investments. The challenges in the provision of infrastructure and investment for the deconstruction of the duality (big firms versus SMEs) in the forestry sector are a systemic level blockage. SI scholars, such as Chaminade and Edquist (2010), noted that the problems faced by small businesses with regard to infrastructure and limited investments could be addressed by policies which focus on building competence centres, investing in business incubators or network infrastructure important in the provision of services and the dissemination of business information. The DTI (2003) supports technology transfers, incubation, and the commercialisation of business services as a way of strengthening the SMEs.

Further, issues such as access to resources, services, education, and training to encourage the employment of R&D in the sector have to be addressed to propel business development in South Africa (DTI, 2003). This would enable the augmentation of capabilities of enterprises through strengthening enterprise development, managerial, business, and technical skills to be sustainable (DTI, 2003; AgriSETA, 2014).

In an attempt resolve the skewed nature of the ownership of the means of production mostly defined along racial lines South Africa instituted the Land and agrarian reforms starting from the

1990s. The understanding was that these reforms would assist in removing some of the blocking mechanisms as an important step in building the capabilities of businesses in the forestry sector by levelling the palying field to overcome the challenges in the transfer of knowledge and technologies from established firms to the less established firms within South Africa's dual economic system. Without some of these forms of interventions, it would be difficult to build the capabilities necessary for effective employment of R&D by the small businesses in the forestry sector. Though upgrading and participation in global value chains are crucial in building the capabilities of small businesses in South Africa, the starting point should be the institutional reforms needed to facilitate the ownership of the means of production by the formerly marginalised groups and institutions reforms aimed at building the capabilities of businesses of the people from these groups.

1.7 Land reform and implications on forestry R&D

The land and agrarian reform programmes in South Africa as strategic interventions by the government to address historical injustices by creating an inclusive economy have brought in new dimensions in the interaction of the various components and actors in the forestry SSI. The reform programmes have worsened relations between the major players in the sector as the big firms are suspicious of the government's motives. This has generated unnecessary schisms, making it difficult for cooperation between the government and small and community businesses on the one hand, and the private concerns on the other hand. The reform programmes are changing the ownership structure of plantation forestry and this is affecting property rights, thus bringing uncertainties which are disincentives to investment in the sector (Binswanger, Bourguignon & Van den Brink, 2009). The land and agrarian reforms are also reducing the amount of land formerly allocated to forestry under apartheid, as some of the beneficiary communities and SMEs are opting out of forestry into agriculture, which brings quick returns to investments (Financial Mail, 10 Sept, 2015). The communities and SMEs which are the beneficiaries of the programme lack the requisite skills (Hall, 1998) to embark on large-scale commercial plantation forestry. As a result, De Beer (2012), quoting Forestry South Africa (FSA, 2009) data, indicates that the average size of plantation forestry in South Africa has already decreased from the 1994 mark of 1.5 million hectares. These factors cast some doubts over the capacity of the plantation forestry base to supply the requisite lumber to maintain production along the value chain in the future. R&D capabilities are therefore important in determining what is to be done to increase output and the quality of the resource on a reduced land base and in understanding how the dry areas formerly considered unfavourable for commercial forestry can also support the plantation economy. R&D capabilities are also critical in limiting the impact of forestry productivity in relation to global warming and climate change.

1.8 Climate change

Economic development has to factor in the limits to growth and progress to ensure efficiency and effectiveness in the exploitation of resources. South Africa, like any other country, is not insulated from the problems of resource depletion, global warming, and climate change. As a result of unsustainable farming and human consumption activities, the carbon dioxide in the atmosphere has already reached calamitous levels and is threatening human civilisation and the existence of species on earth (Greer, 2010). In South Africa, the unsustainable farming practices of the past have resulted in the degradation of land. More than 0.7 million hectares of land are degraded and have been left bare by sheet and gully erosion (AgriSETA, 2016). About 4.61 million hectares of natural vegetation, mainly indigenous forests, woodlands, and grasslands, are degraded, and a further 0.9 million hectares are degraded by mine tailings, waste rock dumps and surface-based mining (AgriSETA, 2016). Plantation forestry has been accused of depleting water resources and altering landscapes, thereby reducing biodiversity (Mander, 2017; Pooley, 2012). It is partly for these reasons that the White Paper on Science and Technology (DCAST 1996) has emphasised the importance of reconciling economic growth with the current challenges pertaining to environmental degradation, the need to guarantee human safety and to ensure the sustainable exploitation of limited natural resources. DCAST (1996) emphasised that,

> Economic and environmental efficiencies are interrelated, thus innovative practice must include environmental management, it is important that South African enterprises are able to adopt and implement best-practice technologies for environmental management and waste minimization (Department of Arts, Culture, Science and Technology (p.15).

These challenges call for conservation and environmental protection for sustainable production. This is critical to ensure that capital accumulation activities do not destroy common resources. The SI scholars Shapira, Smits, and Kuhlmann (2010) noted that research and innovation are critical in maintaining the competitiveness of firms whilst at the same time offering, ‘’broader societal and environmental solutions that, in turn, may stimulate further economic opportunities’’ (p. 499). Plantation forestry has the multiplier effect of generating economic growth, rural development and contributing to resolving the triple threat of unemployment, inequality, and poverty, especially in South Africa’s countryside. This may happen partly as a result of the successful employment of R&D to promote innovation for improved environmental protection and for greater firm productivity as a way of growing opportunities in the sector.

Nevertheless, the challenges with regard to global warming and climate change cannot be addressed by focusing only at local levels and calls for collective and collaborative approaches that encompass the regional and post-regional collectives. Systems mainly evolve because of internal dynamics, but factors exogenous to the system also affect the structural evolution and the functional reconfiguration of a system. Myrdal (1957) emphasised the interplay of internal and external factors and suggested that, ‘’the main scientific task is ... to analyse the causal inter-relations within the system itself as it moves under the influence of outside pushes and pulls and the momentum of its own internal processes’’ (Bergek et al, 2010, p. 131). As a result of the adoption of sustainable forestry management (SFM) at national, regional, and international levels, forestry policy has moved forestry production from a sectoral to a multi-sectoral policy area that requires inter-sectoral coordination, policy integration, and regime interaction (Tikkannen, 2010). Interactions at national, regional, and international levels have become important and decisions made at these levels have important ramifications for local skills development and R&D activities (Gluck & Rayner, 2009, cited in Tuomasjukka, 2010). In the international sphere, the International Standardisation Organisation (ISO) and the Forest Stewardship Council (FSC) regulations impose new imperatives requiring firms to adopt sustainable forestry practices if they are to access lucrative international markets. These requirements entail R&D capabilities and skills development to ensure the protection of the environment and of workers, in line with the international standards. Thus, an understanding of forestry-sector-based firms’ dynamic capabilities has to take into consideration the interaction of the national with the regional and international systems of innovation, for it is at these levels that knowledge is also generated and has to be assimilated and adapted to local situations.

1.9 South Africa's skills deficit

The South African skills system has been fragmented, partly as a result of the legacies of colonialism and the apartheid system which denied black people access to quality education (Du Plooy & Zilindile, 2014; Lotz-Sisitka, 2009; DST, 2008; White Paper, 1996). The colonial and apartheid skills formation processes continue to cast some shadow over the current skills formation processes (Natrass, 2014). The employment of R&D depends on the availability of the requisite skills within an economy. The development of R&D capabilities depends on a well-developed and coordinated skills system. Coordination implies interactions. Nattrass (2014) noted that the apartheid racial discriminatory policies left South Africa, ‘’with a persistent skills shortage’’ (p. 13). On the eve of democracy, the total enrolment in higher education as a proportion of the 20-24 age group was 17% (CHE 2014, p. 62). Participation was highly skewed with 9% being Africans, 13% Coloured, 40% Indians and 70% being Whites (CHE, 2014, p. 62). While black people (African, Coloured and Indian) comprised 89% of the population, black students constituted 52% of the total of 473 000 students in 1993 (CHE, 2014). African South Africans, though comprising 77% of the population, constituted only 40% of enrolments, while White South Africans comprising 11% of the population constituted 48% of enrolments (CHE, 2014). Epistemological blockages[3] within the South African Skills system continue to be a challenge for many from the formerly disadvantaged groups. These subtleties impact on the ability to transform the apartheid racial dynamics in skills formation and consequently the integration of society as a whole, all with a negative impact on development. As noted by Friedman (2015), the lack of opportunities for many of the formerly excluded racial groups in democratic South Africa, ‘’continues to limit the society's capacity to grow economically, socially and culturally (p. 23)’’.

Despite policy reforms by the democratic governments aimed at inclusive development, these have not managed to resolve the vestiges of the past with regard to accessing higher education. The National Education Policy Act No 27 of 1997 Section 4 (c) had been aimed at, ‘’achieving

[3] In this thesis, these are considered as interactional blocking mechanisms that constrain access to powerful propositional knowledge offered by educational institutions and required for successful participation in the modern world.

equitable education opportunities and redress of past inequality in education provision'' as guided by the Bill of rights in the Constitution of South Africa (RSA, 1996a, p.10). The Bill established the right to education (Du Plooy & Zilindile, 2014). The issue of access has also been underscored by the transformative discourse related to race and employment equity in post-apartheid South Africa, as guided by the Employment Equity Act of 1998. Regardless of the good transformative policies, the major challenge in South Africa has been the implementation needed to actualise transformation. As such, South Africa's SI is still badly integrated (OECD, 2009).

Notwithstanding the institutional changes wrought by democracy in South Africa, the changes have not succeeded in democratising epistemological access[4]. The National Plan for Higher Education (2001) set a target of 20% gross participation rate by 2011/2016 (MoE, 2001) for the 20-24 age cohorts. There have been improvements in the overall participation rate from 15% in 2001 to 27.3% in 2011, and that of Africans from 9% in 1993 to 14% in 2011 and coloured from 13% in 1993 to 14% in 2011. In contrast, the participation rate of white and Indian students in 2011 was 57% and 47% respectively (CHE, 2014, p. 3). The number of black students at formerly white universities is still below their proportion in relation to the population as a whole. This is mainly a result of the demand for high pass marks in science and mathematics as a requirement for enrolment at 'elite universities'. Lotz-Sisitka (2009) attributed the lack of basic mathematics and science skills among black students to the continued legacy of Bantu education. There is a need for the Department of Basic Education to strive to enhance the science and mathematics levels at schools in formerly disadvantaged areas and for the democratisation of access to higher education to cater for the previously disadvantaged groups. The Fees Must Fall campaign of 2016 has been about democratising access at universities, especially the former white universities, as a solution to continued apartheid dichotomies.

The lack of political leadership has been partly blamed for the continued disintegration of the South African skills system under democratic governments (Sender, 2014; Greenberg, 2010). As a result of the lack of integration, the South African skills system has not been able to produce the requisite number of equipped researchers to propel innovation in various sectors of the

[4] The thesis employs Lotz-Sisitka (2009) and Morrow (2007)'s definitions of epistemological access. Lotz-Sisitka (2009) defined epistemological access as access to particular forms of knowledge, the propositional or more abstract forms of knowledge. Morrow (2007) defined epistemological access in relation to access to knowledge valued in the modern world.

economy (White Paper, 1996). This has had negative consequences on the development of the critical mass required in knowledge production to improve the ability of South African firms to absorb new knowledge and technologies to increase productivity. Consequently, the contribution of South Africa's R&D to economic growth and development in the last two decades has been less pronounced in comparison to developing countries such as China, South Korea, and Brazil (OECD, 2007; Sender, 2014).

The shortage of R&D capabilities in South Africa has been emphasised in various policy documents, such as the White Paper on Science and Technology (DACST, 1996), the Human Resource Development Strategy (2001), the National Research and Development Strategy (2002), the Immigration Act of 2003, the DST's 10 Year Innovation Plan (2008), the National Development Plan (NDP) (2011), and the White Paper on Post-School Education and Training (2013). The White Paper on Science and Technology (DACST, 1996), reinforces the need for high-level R&D skills when it speaks of the need for, ''new approaches to education and training … that will equip researchers to work more effectively in an innovative society'' (p.15). The lack of R&D capabilities was also highlighted by the National Research and Development Strategy (NRDS, 2002), which stated that:

> Our human resources for science and technology are not being adequately renewed … An overwhelmingly white, male and aging scientific population is not being replaced by younger groupings more representative of our demographics … Currently, there is less than one researcher for every thousand members of the workforce, as compared with five in Australia and ten in Japan (p.15-16).

Generally, the headcount of researchers in South Africa has declined from 21 697 in 1991/92 to 19 406 in 2001/02 while that of full-time equivalent (FTE) has declined from 9748 in 1991/2 to 8708 in 2001/2, a drop of 11% (Liebenberg, Pardy & Kahn, 2010, p.152). This indicates a decline in research capabilities. This regression has negative consequences on the employment of R&D in the South African economy. With the decline, it means fewer people involved in research and less knowledge being generated for new processes and products.

With regard to the forestry sector that informs this study, the Immigration Act No 13 of 2002 identified a critical shortage of agricultural scientists, agricultural engineers, forestry technicians, and environmental scientists (Immigration Act, 2002, June 2014). The AgriSETA (2014), which has a small component of forestry for which it is responsible, acknowledged the shortage of plant breeders, geneticists, plant pathologists, plant scientists, and R&D managerial skills. Ramaila, Mahlangu and du Toit (2011) also noted that, ‘’several prominent scientists in research into … forests and woodlands have left the country or are approaching retirement’’ (p. 28). This has been worsened by the reduction in forestry funding by the government (Tewari, 2002), henceforth a reduction in the number of extension officers employed in the sector and important decoding and transferring the complex knowledge from research organisations to small scale growers and farmers in the sector.

R&D capabilities are important in articulating the formation of new aligned skills and the improvement or displacement of old skills and technologies in rekindling the firm’s capabilities. The predicaments of the South African forestry sector call for a number of R&D skills, if productivity is to be enhanced. Some of the skills will range from R&D skills in the integration of genomics[5], genetics[6], quantitative genetics,[7] breeding under specific conditions incorporating a range of growth, adaptation and wood quality traits, hybridisation, and cloning technologies, environmental stewardship, skills in dealing with fire outbreaks, and appropriate silvicultural practices in understanding and reducing the length of rotations required to produce quality timber. The realisation of the extent of the skills shortage and its impact on R&D capabilities in South Africa resulted in a concerted effort to address this challenge so as to realise economic growth and development.

1.10 South African research and innovation effort

South Africa intensified the effort to address the skills gap and the lack of R&D capabilities during the Mbeki presidency (1999-2008). In his reflection, Mbeki noted that,

[5] Genomics address all genes and their relationships to understand the combined influence on growth and development.

[6] Genetics analyses the functioning and composition of a single gene and influences on growth characteristics.

[7] Quantitative genetics studies the inheritance of traits. It deals with phenotypes and takes into consideration the environment and the genetic make-up on growth and development.

> Critical in this regard (wealth creation in the context of globalization) is the matter of human resource development. We have to exert maximum effort to train the necessary numbers of our people in all the fields required for the development, running, and management of modern economies (NRDS, 2002, p. 3).

The skills reformation programme reflects the centrality of R&D capabilities as critical ingredients to the country's development plans. This is well articulated in a number of policy documents. The National Skills Development Strategy (NSDS III, 2011) Outcome 4.2.4 speaks to the need to, ''ensure that relevant research and development and innovation capacity is developed and that innovative research projects are established'' (p.13). Moreover, commitment number 6 of the Human Resource Development Strategy (HRDS II) states that, ''we will improve the technological and innovation capability and outcomes within the public and private sectors to enhance our competitiveness in the global economy and to meet our human development priorities'' (NSDS III, 2011, p. 13). The focus on R&D capabilities is on developing an efficient and effective NSI capable of propelling industrialisation in different sectors of the economy.

South Africa, starting from the late 1990s, adopted an expansive skills reform[8] programme investing heavily in both basic and higher education with a focus on Science, Technology, Engineering, and Mathematics (STEM) as the basis for R&D capabilities. In this regard, Kraak (2014) noted that several task teams have been set up by the Department of Higher Education and Training, and the Human Resource Development Council (HRDC) with the aim of reforming the country's skills system. It was deemed that this will eventually bring about policy coherence, aligning education policies with economic policies to meet the demands of a modern economy and society. The significance of policy coherence in economic growth was underscored long ago by Hirschman (1958) when he argued that any country that is capable of aligning economic policy with practice is more likely to achieve development.

[8] This thesis employs Brown's (1999) definition of skills formation, meaning, 'the development of social capacity for learning, innovation, and productivity' (Brown, 1999, p. 235). This definition, according to Brown, is important for it considers the importance of both productivity gains and innovation in production techniques, service delivery, product development, and blue skies research as sources of wealth. By considering skills formation as a social capacity, the definition therefore rejects that skill formation is only a technical competence but an interactive process embedded in the social, cultural, economic and political configurations of a society.

The need to speed up the realisation of skills and R&D capabilities in all sectors of the economy resulted in South Africa adopting a sectoral approach in 2000, which identified a number of strategic sectors to focus on in stimulating economic growth and development (NSDS III Review, 2018). The sectoral approach underlines the interaction of players within a sector in skills formation, knowledge generation, transfer, and application (DHET, 2015). This approach resulted in the setting up of the Sector Education and Training Authorities (SETAs) in 2000 (DHET, 2015). The mandate of the SETAs was partly defined as the identification of critical research and innovation areas, the development of innovative economic projects; and the setting up of skills programmes to produce research with a positive impact on economic and development goals (NSDS III, 2011). This role is supposed to be performed in *consultation* with firms and other players in a sector (DHET, 2015). Consultation implies the importance of interaction in R&D and the development of interactive capabilities among the stakeholders in a sector. The sectoral approach can only work effectively if there is cooperation between the various components and actors making up a sector. Accordingly, a sector has to interact with itself, for itself and with other systems outside its boundaries to build capabilities by absorbing positive externalities from other sectors in an economy. Interactions in a sector are also deemed necessary because they may facilitate the production of user-friendly technologies for application by small-scale firms whose technological absorptive capabilities are still low (Ngomane, 2003).

Since the late 1990s, South Africa has committed massive resources in terms of both money and time to achieve an efficient NSI as the basis for building a knowledge economy (OECD, 2007). Despite these investments, South Africa has not been able to produce the required number of equipped researchers to undertake research to boost the economy. As noted by the then Minister of Arts, Culture, Science and Technology, Ben Ngubane in his foreword to the NRDS,

> Innovation needs people – well-trained, effective scientists, engineers, and technologists. There is increasing evidence that our progress in producing scientists, engineers and technologists is not yet satisfactory. We, therefore, need a number of interventions to strengthen the transformation of our science and technology capacity to achieve increased numbers of people working in key fields that are of importance to the future (DACST, 2002, p. 5).

It is in this environment where consideration has to be given to challenges in the interaction of forestry-related organisations in the production of skills and the employment of R&D for forestry resource development.

Mainstream economists, with their focus on the firm, informed by the linear models of innovation have tended to disregard the context and regulatory systems in which firms conduct their innovation activities. To them, innovation is mainly a result of learning processes in a firm. However, it is notable that enterprises hardly innovate basing on their endogenous knowledge (Bergek et al, 2010; Edquist, 2005). This is mainly because of 'technological complexity' and 'technological dynamics' (Bergek, 2010, p. 122). Technological complexity implies that it is harldy possible for firms to posses all the knowledge required for innovation internally (Bergek, 2010). Technological dynamics entail that knowledge is dynamic and always changing in complex ways that cannot be comprehended in all their dimensions by a firm. As a solution, Bergek et al (2010) recommend cooperation and collaboration within the system as in support of knowledge infrastructure, such as universities, government laboratories, science councils, standard-setting organisations, and research and knowledge diffusion mechanisms as platforms of exchange and sharing. These organisations and platforms, according to Smits et al (2010), form part of the strategic intelligence infrastructure, which is important in the discernment of technological opportunities, their possible applications, and strategies for their actualisation. An understanding of innovation dynamics at the firm level is thus enhanced by comprehending the interactions and blocking mechanisms at structural levels.

A failure to understand R&D dynamics at both firm and structural levels stifles the capabilities of a firm *vis-a-vis* the responsiveness of other firms within the same sector and from other regions and countries. Intrinsically, for firms to enhance their productivity and to remain competitive there is a need for an integrated R&D system. This would allow for effective interactions facilitating the generation, acquisition, and application of knowledge and technologies permitting firms to keep on mutating, reinventing themselves in relation to changing circumstances. However, the existence of large-scale international companies, micro, small, medium, and informal enterprises within the South African forestry SSI calls for a more diversified skills base if production is to be maintained or improved for the benefit of the value chain as a whole. The diverse stakeholder base makes it difficult for coordination within the sector as a whole.

The high-level R&D skills required for radical innovations have to be aided by the formation of business and technical skills enabling businesses to operate efficiently. There is a need for design, engineering, entrepreneurship, and management (DEEM) skills (OECD, 2007) in downstream processing and manufacturing activities to improve resource efficiency. DEEM skills are the non-R&D capabilities important in the provision of, ‘’applications-oriented knowledge, and technology transfers, specialised test and certification equipment to meet … quality requirements in production’’ (Kraak, 2012, p. 21). It is these capabilities that define a firm’s ability and rapidity in responding to internal and external challenges to embark on new processes to produce new and market-aligned products. The ability of a firm to link up, connect, and innovate and to respond effectively to changing environments determines output in terms of quality and quantity, and the firm’s capacity for labour absorption and its competencies in local and international spheres (DCAST, 1996). These capabilities and competencies do not develop naturally or by sheer luck but are a result of effectively coordinated activities to bring about new and improved processes and products. The former technikons in South Africa and institutes such as the Council for Scientific and Industrial Research (CSIR), the Forestry and Agricultural Biotechnology Institute (FABI), the Institute of Commercial Forestry Research (ICFR), and the Agricultural Research Council (ARC) provide pure R&D, incremental improvements and technology transfer services that are more aligned to the demands of the industry (Kraak, 2012). In the forestry and agriculture sector, these functions have also been the role of agricultural and forestry colleges. The attainment of DEEM capabilities requires high levels of institutional interaction between firms and other agencies within the skills system (Kraak, 2012). According to the OECD (2007), small firms would benefit from the DEEM services because the reduction of risk would enable them, ‘’to go one step further which they would not have gone on their own’’ (Kraak 2012, p. 21).

The flaw in the South African skills reformation programme has been the neglect of the DEEM or ‘polytechnic’ function playing a crucial adjunct role to the more formalised and higher-order R&D function (Kraak, 2012). This has been referred to as ‘academic drift’, a process by which former technikons (now University of Technologies, UOT) (Kraak, 2012) and agricultural and forestry colleges (DAFF, 2008) are neglecting their former functions and mimicking the role of universities by offering degrees. The UOT sector is thus not providing the technical and career-oriented skills required by the economy (CHE, 2016). The emergence of the entrepreneurial university has been an attempt to address the gap created by the drift in the functions of former technikons and agricultural colleges. However, the challenge is that universities in the main lack the practical operational knowledge required in running a business (OECD, 2007).

The Technical Vocational Education Training Colleges (TVET)[9] designed to provide training of a highly practical nature, mainly in the trades as automotive mechanics, fitting and turning and carpentry are beset by numerous inefficiencies. For example, evidence shows that 188 188 students were registered for Report 190/1 (N3 and N6) and NC (V) 4 level examinations in 2016, of which 179 285 sat for examinations and 111 460 completed them (DHET, 2018, p. 42). The overall completion rate for national qualifications was 62.2% (DHET, 2018, p. 42). The low throughput rate, which is a result of pipeline blockages, points to inefficiencies in the TVET system. Overall, the result has been a constant shortage of intermediate and artisan skills that are also demanded by the industry (CHE, 2016). The long-term supply of intermediate skills is further curtailed by the fact that TVET colleges are shunned as 'institutions' of choice by learners for various reasons, including the lack of funding, poorly trained staff, and the lack of job placement opportunities. These various inefficiencies have to be addressed to build public confidence in the TVET post-school system, for the benefit of the economy.

Brown (1999) also noted the growing acknowledgement of interpersonal, teamwork and creative skills in bringing about incremental innovations alongside technical skills. The formation of these skills cannot be seen as technical or individual competencies learnt in formal ways as the human capital theory would like to believe (Bowles, 1971). These skills are embedded in the broader structural dimensions of society and are largely interactive (Collins, 1971). Individual actions are embedded in political, economic, and socio-cultural contexts that are governed by formal and informal regulations (Brown 1999, p. 235). These skills are largely social capacity hence the importance of social capital. This capital is crucial in production, for Brown (1999) conceded that social capital like physical and human capital is productive, ''as it is able to make the achievement of goals that would not be possible in its absence'' (p. 235). The significance of

[9] Formerly Further Education and Training (FET).

social and interactive skills with regard to innovation is demonstrated in Chapter 6 in relation to community forestry in South Africa. As such, Mushangai (2015) concluded that what is required in South Africa to grow the economy in an inclusive way are ‘structural changes that take into consideration that everything is enmeshed in everything else’. Everything being ‘enmeshed in everything else’ implies institutional ensembles integrated by interactions, smoothing the exchange and application of knowledge and technologies within a system.

1.11 Objectives of the study

The study gives attention to a myriad of factors ranging from globalisation, climate change and changing policy environments, lack of capabilities, historical vestiges, land and agrarian reform, and stakeholder diversity, etc, impacting on the interactive capabilities and competitive competencies of firms. These factors are analysed in terms of interactional blocking mechanisms in relation to system failures and the importance of interactions in the integration of the forestry SSI. An understanding of these factors as blocking mechanisms will increase insights into interactive processes; hence options in crafting ways in integrating the SSI for improved efficiency and effectiveness in innovative practice. It is deemed that this understanding would enable the realisation of the benefits of R&D by firms in the forestry sector of South Africa and the economy as a whole. The study is centred on:

Understanding challenges affecting effective interaction in R&D by universities, research institutes, government agencies, and firms in the South African forestry sector.

1.12 Problem statement: A Reinstatement

The literature on innovation studies (Nelson, 2003; Gereffi, 1994; Lundvall, 1992,) alludes to the importance of R&D in propelling economic growth and development. However, despite massive investments for the past 20 years in R&D and in building an NSI, the benefits of R&D to the South African economy is still not known (HESA, 2006; OECD, 2007). This according to the OECD (2007) is because the South African SI is ‘less integrated’. Other systems of innovation such as the SSI are influenced by the NSI but also influence the NSI such that systems failures in the NSIs may also manifest in an SSI. Therefore, Greenberg (2010) in line with the conclusion arrived at by the OECD (2007) noted that South Africa’s Agriculture and forestry SI suffers from ‘weak coordination and linkages and limited resources and capacity’ hence limitations in knowledge transfers and the employment of R&D for the benefit of the firms in the sector. South Africa could realise and optimise the benefits of research and innovation if systems failures relating to weak coordination, weak linkages, and limited capacity are determined and resolved. The evidence from developing countries such as, China, South Korea, India, and the Asian tigers, points to the centrality of R&D in propelling economic growth and development (Aghion, 2009; Dalhman, 2014). The lack of evidence on the benefits of R&D in the South African economy should not be considered a disincentive for investments in R&D lest the country fails to realise the demands of the knowledge economy. The benefits of R&D are said to accrue when a country's SI is integrated (HESA, 2008). This study is focused on understanding the interactional challenges in the coordination and integration of the components of the forestry SSI and how this affects the employment of R&D by firms in the forestry sector of South Africa. The study is conducted with the aim of addressing key knowledge gaps on the importance of effective interactions in the integration of South Africa's forestry SI and the employment of R&D by forestry firms.

1.13 Research questions

Integration is a core focus of the thesis. Integration is about connections and the nature of the interaction between the various components of a system. The study is guided by the following core question:

- *What have been the challenges affecting effective interaction in R&D by universities, research institutes, government agencies, and firms in the forestry sector of South Africa?*

Other research questions:

- *What are the key challenges faced by the Agriculture Sector Education Authority (AgriSETA) Seta and the Fibre Processing and Manufacturing Sector Education and Training Authority (FPM SETA) in facilitating interactions in R&D skills formation in the forestry sector of South Africa?*

- *How have institutions and policy frameworks been facilitative of partnerships, collaboration, and networks in the employment of R&D by firms in the forestry sector of South Africa?*

- *How can the challenges in the interaction between forestry development stakeholders be addressed for effective employment of R&D?*

The answers to these questions will assist in improving and updating our understanding of the interactive relationships in the employment of R&D.

Chapter 2: History of Forestry Research and Development in South Africa: A Review

2.1 Introduction

It is possible to explain the evolution of the plantation forestry economy in South Africa using the lens of innovation theories. From the early days of its establishment, the exotic germplasm that forms the forestry plantation economy in South Africa faced a number of challenges (Van der Merwe, 2011; Bennett, 2010). These challenges included the lack of relevant knowledge to adopt and adapt exotic germplasm to different climatic regions, the lack of scientific knowledge to select fast-growing species (Showers, 2010), the pests and pathogens that destroyed exotic tree species (Bethlehem, 2000), and the challenge to balance the demands of the forestry economy with biodiversity and environmental conservation (Bennett & Kruger, 2015). The growth of scientific forestry knowledge in South Africa as a result of concerted R&D activities and of interactions with the international community saw the forestry industry grow into a multi-billion-dollar industry applying the latest scientific knowledge, by the 1970s (Burger 1998; Meyers et al, 2001; Bethlehem, 2000). Despite facing significant challenges, the industry is considered one of the best managed in the world (Bethlehem, 2000).

Currently, the forestry sector is confronted by a myriad of problems. Globally, there are challenges pertaining to labour rights, people's rights of access, global warming, and climate change linked to sustainable forestry development (Tikkanen, 2010). In South Africa, there are political challenges related to the need to address historical imbalances emanating from the skewed and racially aligned colonial and apartheid policies (Cousins, 2007; Hall, 2004). Further, there has been a resurgence of environmental movements critiquing the detrimental effects of plantation forestry in relation to water, biodiversity and access rights of formally disadvantaged people and neighbouring communities (Van der Merwe, 2011; Hall, 2004; Tewari, 2001).

The increased movement of people and goods because of globalisation is also bound to bring in new diseases from other regions that affect the plantation economy (Ramsfield et al, 2016). It is in this environment that we have seen an effort by the government of South Africa in conjunction with the industry and Higher Education Institutions (HEIs) to generate scientific knowledge to confront these challenges (Kruss, 2005, Klerck, 2005). Scientific research is supposed to be an ongoing process capable of predicting and confronting future problems. Research and innovation are ongoing processes to boost the dynamic capabilities of firms to confront new challenges as old ones are resolved in the process of production.

This chapter aims to explore three main issues about the history and role of research and innovation in the South African forestry plantation economy. The chapter historicises how the capacity for R&D was generated in the sector and analyses examples of research that revolutionised the South African forestry sector and how collaboration was important in this. Historicising R&D is important since research systems are evolutionary, as emphasised by evolutionary economists (Nelson & Winter, 1997; Nelson, 2018) and SI scholars (Lundvall 2004; Chaminade & Edquist, 2010; Malerba, 2005). The evolution of systems is a result of new knowledge generated in coordinated interactions replacing the old and outdated knowledge systems defining production in an economy (Schumpeter, 1934, cited in Elliot, 1987). The chapter rejects the idea that South African Forestry R&D was unique and exceptional in its origins, as argued by Bennett and Kruger (2015). It also rejects notions by Rajan (2006), Barton (2002), Brown (2001), and Roach (1989) that the theoretical orientation and practice of forestry in South Africa was European and Indian. The chapter argues that South Africa developed a hybrid forestry regime through interactions among members comprising its forestry research system and with international forestry research communities in the fusion and application of local and internationally produced forms of knowledge. Interactions were also important in adopting and adapting internationally produced knowledge brought in by foreign-educated professionals through experimentation, ‘conjectures and refutations’ (Popper, 1989).

2.2 Interaction of history and context in knowledge production

The importance of forestry research, knowledge production, and development in South Africa is not new; it has been defined and redefined by a people and their governments in accordance with the burning concerns of the times as they are defined by historical circumstances and experience with development (Mushangai, 2015). As noted by Mushangai (2015),

> Ideas do not emerge from a vacuum; they are rooted in people’s beliefs as determined by their histories and experiences. Some ideas emerge and vanish over time but the central maxims upon which these ideas were hinged remain and form the basis upon which new developmental paradigms are found (p. 28).

Forestry knowledge production systems in South Africa were a result of the interaction of the settlers with their environment. South Africa's natural forests were limited from the beginning of European settlement at the Cape. The timber shortage was acutely felt from the early days of Jan van Riebeeck's arrival and the establishment of a Dutch supply post at the Cape in 1652 (Showers, 2010; Brown, 2001). The arrival of the Dutch in 1652 brought about an era of extensive commercial exploitation of natural forests (Van Der Merwe, 2010). Van Riebeeck was the first to recognise the slow growth of indigenous timber and to import various exotic tree species to test and plant in the Vereenigde Oost-Indische Compagnie[10] gardens so as to improve timber supply in the Cape (Britton, 2006, Annexure C, 2). The heavy exploitation of the limited yellowwoods and stinkwoods by the settlers soon forced Van Riebeeck as the administrator at the Cape to issue a *Placaat* (legislative measure) in 1658 to protect gardens, lands and trees from destruction (Grundy & Wynber 2001; Britton, 2006, Annexure C, 1). However, the *Placaat* as a legal institution by Van Riebeeck, failed to avert the destruction of natural forests as demand kept on escalating (Britton, 2006). The 1658 *Placaat* and others after compelled the settlers to plant trees to supplement timber supplies (Britton, 2006). As such, tree species like oaks, stone pines, cluster pines, camphor and others were imported from Europe and India and planted 'in their thousands' by the early settlers to meet their needs (Malan, 2018, p. 37).

The planting of trees by Van Riebeeck and his companions were the first experimental tests in the history of afforestation in South Africa, hence the origins of the plantation economy and of forestry R&D. Those who succeeded him, such as Van der Stel, issued more *Placaats* to encourage the planting of trees to halt the destruction of natural forests. For example, the 1689 *Placaat* was designed to compel every grantee of land to plant 100 oaks per year (Britton, 2006). The growing of exotic trees continued throughout the Dutch period and was extended from 1806 onwards by succeeding British governors at the Cape who introduced more exotic trees for afforestation. The Australian blue gum was introduced to the Cape in 1836 by the then governor Sir Lowry Cole (Malan, 2018).

The *Placaats* as legal institutions by Van Riebeeck and those after him were a result of the interaction between the settlers and their local and international environments. Interactions with the local environment made the settlers realise environmental limitations with regard to their

[10] Dutch East India Company

developmental needs. The challenges and conflicts that ensued between the administrators and the woodcutters (Van der Merwe, 2011) during this time emanated from the limited nature of the resource and compelled the settlers to realise the imperative of conservation (Van der Merwe, 2011). From these interactions, the settlers became convinced of the potential to improve natural environmental services through conservation and afforestation hence the institution of legal instruments to achieve the same. Interactions with the international community enabled the importation of various exotic germplasm from Europe and India to the Cape. The legal instruments were outcomes of human interaction with their environment to coordinate the actions of various stakeholders to conserve the scarce natural timber resources and to improve supplies. Legal institutions were thus incentives for collective action for a perceived common good.

What can be learnt from the history of the early settlers at the Cape is that the growth of plantation forestry in South Africa can never be explained in isolation from environmental conservation. The activities of the early Dutch settlers at the Cape laid the foundation for the development of two kinds of forestry later in South Africa, which are conservation forestry and plantation forestry. These branches of forestry can be objectively traced to the 17th century and emanated from the interaction of the settlers with their environment and the international community.

2.3 The introduction of scientific forestry

Mayers, Evans and Foy (2001) have argued that, ‘’purposeful afforestation efforts in South Africa began in the late 19th century in order to provide an alternative to … disappearing natural local forest resources, and costly imported timber’’ (p. 9). However, as noted in the preceding section, the period from 1652 up to 1806, when the British took over the Cape from the Dutch, purposively laid the foundation for conservation and the plantation economy in South Africa. The difference between the period 1652 to 1806 and 1806 to 1870 was the introduction of scientific forestry by the British after their annexation of the Cape in 1806 (Showers, 2010). Scientific forestry was mainly defined by the increased regulation of timber harvesting as some ‘Crown forests’ were reserved to provide for the needs of British naval shipyards (Van Der Merwe, 2011). Scientific forestry was much more concerned with the ‘’regulation of indigenous tree uses and the designation and protection of forest land’’ (Showers 2010, p. 296). This was to be achieved through the appointment of ‘Permanent Commissaries’ and foresters ‘’with full power to superintend, direct and manage the several forests'' (Joubert 2017, p. 1). However, worthy of note is that not a single professional forester was appointed as a conservator until the 1880s (Showers, 2010). It was only in the 1880s that professional foresters, starting with De Vasselot in 1880, were appointed to take charge of forest management in the Cape Colony (Smith & Van der Lei, 1997). With the appointment of professional foresters in the period after 1870 was the increased experimentation with exotic germplasm to generate systematic forestry knowledge. The foresters, such as Colin McNaughton, Henry Fourcade and others, such as John Phillips, played a crucial role in the development of forestry R&D from the late 19th century into the 20th century. In the words of Van der Merwe (2011), ''systematic forest research (was) build upon decades of valuable forest monitoring work first done by Colin McNaughton and Henry Fourcade in the late 19th century and then by John Phillips and FS Laughton'' (p. 14). According to David Hutchins, the period after 1870 was defined by large scale systematic planting of exotic germplasm and this was led by the state (Hutchins, 1905).

However, to argue that purposive afforestation started in the 1870s will be missing the point. As shown in the preceding section, purposive afforestation to conserve the environment and to improve timber supplies was initiated by the Dutch settlers at the Cape in the 17th century. The period after 1870, which Mayers et al (2001) had argued to be the one when purposeful afforestation was initiated, was rather a culmination of a chain of developments started by Van Riebeeck and his companions in the 17th century. The dynamics shaping forestry knowledge production systems in South Africa were located within this broader political economy of conservation and afforestation, whose origins lies in the activities of the early Dutch settlers in the process of interacting with their environment and the international community. As will be shown in this chapter, research studies that revolutionised the forestry economy of South Africa were focused on these two branches of forestry, those being, conservation forestry, and plantation forestry.

2.4 Scientific forestry research and development

Since the 1870s in South Africa, the government, the industry and research organisation have played a crucial role in the development of forestry resources through partnerships and collaboration in knowledge generation and application (Bennett & Kruger, 2015; Bennett, 2010; Liebenberg, Pardey, & Kahn, 2010). As noted earlier, research is either revolutionary or evolutionary[11]. Revolutionary research (R&D) results in fundamental paradigm shifts in development practices (Castellacci et al, 2005; Freeman, 1987; Nelson, 1993; Metcalfe, 1998) while evolutionary research (R&D) results in incremental gains to the existing stock of knowledge (Metcalfe, 1998; Nelson, 1993; Freeman, 1987). Whether revolutionary or evolutionary, research is based on the existing stock of knowledge, which it transforms dramatically or incrementally. Research, knowledge production, and development enhance the dynamic capabilities of firms by facilitating the processes of innovation and creative destruction through the generation and application of new and advanced knowledge, skills, methods, processes, and products (Metcalf, 1998; Mahdjoubi, 1997). The history of timber shortage in the Cape Colony and in South Africa, together with the interaction of the early settlers with their environment and the international community, were fundamental in the generation of specific R&D capabilities and knowledge that transformed the South African forestry sector in a revolutionary way (Showers, 2010; Van der Merwe, 2010; Britton, 2006).

Capacity is very important for R&D to take place. The question then is how did the colonial and apartheid regimes in South Africa manage to build the capacity for forestry R&D, and what was the importance of interactions and collaboration in this process.

2.5 Forestry research capacity in colonial and apartheid South Africa

In South Africa, forestry R&D started in the Cape Colony in the 17th century before its extension and integration in the Union of South Africa in 1910 (Showers, 2010; Bennett, 2010; Brown, 2001). From the second half of the 19th century, forestry services in the Cape Colony were provided by a team of foreign-educated professionals trained either at the Royal Engineering/ Coopers Hill College (England) or at the French Forestry School at Nancy (Nancy School of Forestry) (Bennett & Kruger, 2015; Innes, 2013; Roach, 1989; Hutchins, 1905). The Coopers Hill education was customised for the nascent Indian Forest Services (Innes, 2013). The Coopers Hill forestry education was broadened when the school merged with the University of Oxford in 1905 to enable the provison of forestry education to all officers serving throughout the British Colonial Empire (Innes, 2013). The early professional foresters educated at the Nancy School of Forestry who worked in the Cape Colony included David Hutchins, Comte de Vassellot and Charles Lane Poole (Roche, 2009; Dargavel, 2009; Roach, 1989). In the 19th century, the Cape

[11] See, Section 2.2.1

government also relied on foresters who joined from England, France, and India[12] (Bennett & Kruger 2015). Those who started their careers in India before coming to South Africa included David Hutchins and Joseph Storr Lister (Roche, 2009; Roach, 1989). Others, such as Charles Legat, had been educated at Edinburgh (Scotland) and came to South Africa in 1898 (Jordaan, 2012). Henry Fourcade arrived at the Cape in 1880 from France and served under the Comte de Vasselot who was the Superintendent of Woods and Forestry in the Cape Colony (Bennett & Kruger, 2016). Also to consider is that from the late 19th century forestry professionals were 'poached' from other countries, an activity about which India ''complained bitterly for breaching diplomatic etiquette'' (Bennett & Kruger, 2015). Taking into consideration that many of the early professional foresters in the Cape Colony were trained either at Coopers Hill (England) or at the Nancy School of Forestry (France) and that many others came to South Africa via India, Roach (1989) concluded that by ''1890 the major influences on South African forestry came from France and British India'' (p. 18). However, though it is undeniable that South African forestry was influenced by European and Indian forestry traditions, as will be shown below and with regard to the discursive nature of knowledge production, South African forestry R&D was not totally European or Indian in its orientation but was a fusion of both foreign and locally produced knowledge and technologies.

It is important to note that it was only after the spread of forestry conservation and plantation forestry to the colony of Natal, the Orange River Colony and to Transvaaal from the Cape Colony following the conclusion of the Anglo-Boer war in 1902, that a concerted effort was directed towards building local R&D capabilities by sending students to study abroad. Evidence at hand shows that only Colin McNaughton, a former Cape forester, was sent for forestry studies at Coopers' Hill in 1882, before the reconstruction period (Bennett & Kruger, 2015, p. 76). However, starting in the early 20th century more students were sent to European and American universities to augment forestry research capacity for South Africa (Bennett & Kruger, 2015). Among the notables were Christian Wicht, who studied at the Oxford University, the Royal Saxon Academy of Forestry at Tharandt, and at the University of Wageningen (Pooley, 2012); WE Watt, who studied at the Oxford University; Colin C Robertson, Eardley Wilmot, Ian J Craib

[12]The Department of Plantations and Forests was constituted by the Cape government as a Ministerial Division of Agriculture (Hutchins 1905:9). A separate Cape Department of Forestry was organised in 1881 and was led by Comte de Vassellot on a ten-year contract (Hutchins 1905, p. 9; Roach 1989, p. 28).

and JJ Kotze, who studied at Yale University; and John V Phillips who studied at the University of Edinburgh (Bennett & Kruger, 2015). The combined R&D activities of these scientists and other early professionals transformed South African forestry R&D in a fundamental way that continues to cast a long shadow over present-day approaches to forestry science and forestry policy-making in South Africa. Thus, R&D capacity in South Africa was partly a result of the country's interaction with the outside world. Despite the extensive interaction between South Africa and the international community in the production of R&D skills and of scientific forestry knowledge, the South African foresters also worked hard to produce their own locally distinctive forms of knowledge to address local forestry challenges. The Bioclimatic modelling approach, as discussed in the next section, has been regarded by Bennett and Kruger (2015) as one of the early South African foresters' own innovations with regards to afforestation.

2.6 Bioclimatic modelling to afforestation

Afforestation is not something that is indigenous to South Africa, hence there was a need in the 19th century by the early foresters for new knowledge to adapt exotic tree species to southern hemispheric conditions (Roach, 1989) to counter the shortage of timber and fibre. According to Bennett (2010), the first experimental studies in the Cape Colony (South Africa) were aimed at improving the acclimatisation of exotic tree species in Southern Africa. It is said that, from the observations based on the growth and performance of exotic germplasm in the Cape Colony during the last quarter of the 19th century, professional foresters, such as David Hutchins, Joseph Storr Lister, Colin McNaughton and Henry Fourcade (Bennett & Kruger, 2015) and others, such as John Croumbie Brown in Natal (Showers, 2010), realised that acclimatisation was linked to climate and the local environments. Burgess and Wingfield (2001) noted Hutchins as one of the early foresters in the Cape Colony who realised the significance of matching exotic germplasm with specific areas in South Africa. Hutchins identified Transvaal and Northern Natal as providing suitable conditions for Mexican pines (Burgess & Wingfied, 2001). Hutchins went on to introduce *Pinus Patula* to South Africa in 1907 and to recommend *Pinus Elliot*, which was first planted in 1916 (Burgess & Wingfied, 2001). In Natal, this led to the formation of the Acclimatisation Society of Pietermaritzburg which ‘’cooperated with the Botanic Garden in Durban and carried out trials of new species and varieties to assess suitability for the cooler and less humid inland and upland areas during the 1860s’’ (Showers 2010, p. 8). Based on observations from experimental plantings done during the last quarter of the 19th century, the Cape foresters developed a complex bioclimatic methodology for selecting and growing exotic germplasm in South Africa (Wilgen & Richardson, 2012; Wingfield, 2003; Burgess & Wingfield, 2001). The methodology involved the identification of provenances of the exotic species in their natural environments to identify suitable climatic conditions to match within Southern Africa. The methodology also involved the identification of the different genera within a species, which proved to be very difficult when working with eucalyptus (Bennett & Kruger, 2015). These trials, according to Burgess and Wingfield (2003), were the fundamental phase in the development of forestry biotechnology in South Africa. However, worthy of note is that, in doing this, the Cape foresters worked with their foreign counterparts, especially those from countries where these tree species came from. For example, Hutchins maintained close correspondence with Joseph Maiden, who was the Director of the Botanical Gardens in Sydney (Australia) and a forestry advisor to the New South Wales government (Brown, 2001), whom he instructed to ‘’carefully select and label the seed packages’’ that were sent to South Africa (Bennett & Kruger, 2015, p. 29). There was therefore continued interaction with the outside world, which allowed for the diffusion of knowledge and technologies and the sharing of best practices between foresters from different regions.

Further, with regard to bioclimatic research, Colin Robertson (a South African student), during his Master’s studies at Yale University, had to visit Mexico in 1906 to study the Mexican climate in relation to ‘’various pines worthy of importation’’ by South Africa (Bennett 2010, p. 192). In 1924, Robertson was also sent to Australia by the then Minister of Agriculture, Thomas Smartt, where he spent six months studying the genetic variation of eucalypt species and their climates to establish the growth influences in South Africa (Bennett & Kruger, 2015). Later on, Loock (1950) reported on his 1947-detailed investigation of Mexico and British Hondurus and acknowledged the native pinus genus of the region suitable for growing in South Africa. He recommended 19 species from the Mexican region which he considered for afforestation or ornamental purposes in South Africa (Wilgen & Richardson, 2012). As a result of the need to match plantings with suitable climate conditions, the Department of Agriculture published its first silvicultural map of South Africa, in 1931, which divided the country into distinct zones according to ‘’temperature and rainfall averages, and assigned species for afforestation to zones according to their expected performance’’ (Bennett & Kruger 2015, p.106). With the same objective, the 1948 Committee on Afforestation in South Africa recommended the classification of climatic zones as the basis for rational interpretation of planting trial results (Wilgen & Richardson, 2012).

On the basis of experiments with plantings, early foresters, such as Hutchins, Legat, Lister, and Fourcade, criticised European and Indian forestry regimes as too theoretical and unfeasible in South African conditions (Bennett, 2010). From the views expressed by these early foresters with regard to European and Indian forestry traditions and from an analysis of their work, Bennett and Kruger (2015) concluded that foresters in South Africa developed their ‘’own identity in contradistinction to their European or British Empire counterparts’’ (p. 7). Nonetheless, to argue that South African forestry developed completely in ‘contradistinction’ to European or Indian forestry traditions would be missing the point with regard to the discursive nature of knowledge production. Knowledge production is an interactive process, whereby existing hypotheses are always tested for their validity and explanatory power. In the Marxian/Hegelian tradition, this is expressed in the thesis-antithesis-synthesis framework. In addition, Karl Popper (1989) talks of ‘conjectures and refutations’ in knowledge production, meaning the continuous testing of hypotheses to refute or determine their applicability and explanatory power. Therefore, worthy of note is that knowledge production proceeds in logical conflicts and contradictions. The European forestry tradition provided the fundamental base whose theoretical frameworks were tested practically in the South African context. This means that forestry research was rooted in this tradition. It is critical also to acknowledge that afforestation and acclimatisation of foreign tree species were not exceptional to South Africa, for it is noted that France had experimented with these processes in the years after the French Revolution of 1789. As noted by Roach (1989),

> The most sophisticated system combining all known methods was to be found in France where, in the years preceding the Revolution, coppice and standards practice was combined with sustained yield management of mature deciduous and silver fir forests (p.15).

As such, the argument that South African forestry from the early stages was unique and deviated from the European and Indian traditions applies partially with regard to plantation forestry. The argument also fails to realise that, in South Africa, forestry developed as a ‘compo’ whereby conservation was equally considered an important component. With regard to this, it should be noted that the Comte de Vasselot, as the first qualified Superintendent of Woods and Forestry at the Cape Colony, applied the French forestry conservation tradition in his work[13] (Smith & Van der Lei, 1997). Dargavel (2009) also noted that Lane Pool, ‘’readily adapted the French tradition to imperial forestry when he was appointed the district forest officer in the Transvaal Province in 1907’’ (p. 17).

Further, Pooley (2011) noted that, up to the second half of the 20th century, the American Clementsian[14] ideas on plant succession were still applied in nature conservation in South Africa. Even Bennett and Kruger (2015) themselves conceded that John Phillips’s biotic community ideas, which went on to influence policy on forestry conservation and management in the 20th century in South Africa, were Clementsian[15] in their origins. This shows that ideas do not emerge from a vacuum but are recursive and a result of interactions.

Moreover, the development of the climatic modelling approach as a result of afforestation and innovations emanating from the criticism of the European forestry tradition was not unique to South Africa. In Australia, leading foresters Edward Harold Fulcher Swain and Lane Poole had clashed in 1929 over Lane Pool’s emphasis on basing plantation forestry on proven scientific principles. Swain advocated for Australian forestry policy to be pragmatic, based on ‘’the rock bottom of established conditions in the industry and forest’’ (Dargavel, 2009, p.19). This demonstrates that the criticism of European forestry tradition was not exceptional to South Africa, as purported by Kruger and Bennett (2015). It is important to realise that inapplicability does not mean lack of influence but a realisation emanating from attempted application of existing ideas and principles. Despite their revolutionising effect on forestry production in South

[13] De Vasselot’s section system was put into effect by the Forest Regulations of 1883. The essence of the section system was to achieve healthy forests by maintaining a balance between exploitation and forestry regeneration. It forms the origins of sustainable forestry production in South Africa by allowing timber to be removed only at a rate that matched the growth of the indigenous forest (Joubert, 2017). Also, between 1881 and 1891, De Vasselot introduced a programme of systematic management focusing on the regeneration of indigenous forests and the establishment of new plantations. However, De Vasselot’s contract was not renewed in 1891 because of the lack of money as the then government did not regard timber as a profitable resource (Brown, 2001).

[14] Clementsian ideas were ideas of the Nebraskan ecologist who argued for linear progression of vegetation in nature from simple to complex stages towards a stable climax community in equilibrium with environmental condition. These ideas were important in early conservation effort in in South Africa.

[15] The biotic community ideas were based on the notion that plants in their natural environment were interdependent species and if undisturbed evolve into a holistic, organismic system.

Africa, the ideas of the early foresters were not very exceptional to South Africa, as argued by Bennett and Kruger (2015). What can be agreed on is that colonial location reshaped scientific forestry through scientific adaptations to local environments, as suggested by Roche (2004), hence the importance of knowledge mediation.

It is important to remember that the Tokai School of Forestry in South Africa opened in 1907 partly because of the growing dissatisfaction of South African foresters with European and Indian forestry education with regard to practical considerations (Brown, 2001). Nonetheless, the closure of the Tokai School in 1911 reaffirmed the dominance of the long tradition of European forestry in South Africa. In 1909, Lionel Taylor, the Conservator of Forests for Transvaal, in arguing for the closure of the school, noted that ‘’it is most desirable to appoint a highly trained and experienced expert from Europe who can come to this country with unbiased views’’ to head the school (Bennett & Kruger 2015, p. 87). He went on to criticise the Cape Colony’s ideas of exceptionalism, noting that the Cape’s forestry department was ‘’30 years old but no nearer to the solution of many of their problems than they were when they started’’ (Bennett & Kruger 2015, p. 87). Despite some successes, the Cape foresters had not managed the identification and classification of the different eucalypt genera by the 1920s (Burgess & Wingfield, 2002). There was, therefore, a requirement for cooperation between local foresters and foresters from other countries where these tree species were coming from, if the identification and classification of the eucalyptus genera were to be achieved in South Africa. This realisation was seen in the growth in employment of foreign-trained students, such as Wicht, Robertson, and others, by the Department of Agriculture and of foreign professional botanists, such as John William Bews (from Scotland) at the University of Natal in the 20th century. All of these factors point to the discursive nature of knowledge generation. It can, therefore, be argued that professional forestry in South Africa was not modelled ‘on other parts of the Empire like India, Mauritius, and Australia’, as claimed by Carruthers (2016), nor was it exceptional, as argued by Bennett and Kruger (2015), but was a fusion of both international and local knowledge. This is clearly demonstrated in the discussion of the history of the Tokai School below.

2.7 R&D capacity building and the Tokai Forestry School

The establishment of the Tokai forestry school in the Cape Colony in 1907 was a result of negotiations between the governments of four South African states (Cape Colony, Natal;

Transvaal; Orange River Colony) and the governments of Southern Rhodesia, and Basutoland (Bennett & Kruger, 2015). This emanated from the growing realisation of the importance of the forestry plantation economy in the development of these states. The dissatisfaction with European forestry research and management practices also compelled the foresters at the Cape to clamour for a school that would meet the customised needs of Southern Africa and other countries in the Southern Hemisphere[16] (Brown, 2001). This emanated partly from a realisation that the growth of tree species was partly influenced by the climatic conditions prevailing in local environments. There was, therefore, a need for a school that resonated with the demands of extra-tropical climates, a component which was not catered for in European schools (Bennett & Kruger, 2015). Further, the Southern African governments were worried about the costs of sending students to study abroad. The three-year forestry course offered in Europe cost the Cape government over £700 per student (Brown, 2001). This was too exorbitant a figure at the time (Brown 2001). As such, the Tokai School was partly established as a cost-mitigating measure.

Despite early conflicts about the site of the school, it was later agreed that Tokai was more suitable than anywhere in the Transvaal (Brown, 2010). This was in recognition that the Cape plantations were 30 years more advanced compared to those in Transvaal (Bennett & Kruger, 2015). Further, at Tokai, Joseph Storr Lister had established an arboretum with a variety of timber trees in South Africa (Britton, 2006; Roach, 1989). It was deemed that the Cape Colony plantations would enable students' practical experience and lectures in silviculture (Brown, 2001). Students would also have a chance to work in the nearby indigenous forests of Knysna at George (Bennett & Kruger, 2015). Moreover, at Tokai students were to ''gain practical experience around Cape Town by exposure…to the drifts sands and reclamation project in the Cape Flats'' (Bennett & Kruger, 2015, p. 82). The school was established in 1907 as an extension of a faculty at the South African College and had a board of management (Carruthers, 2016). The school offered a two-year course in forestry after which the graduates were to receive a certificate or a diploma in forestry (Smith & Van der Lei, 1997).

[16] Though most of the scholars have argued that there was no school which focused on non-European conditions, Roach (1989) noted that the Nancy School was prominent in the 19th Century because it was the only school which did not concentrate on the management of northern European pine.

2.8 The School curriculum

The Tokai School offered a two-year diploma forestry course which included ten subjects among which were Botany, South African Geology, Forest Laws, Silviculture, Forest Accounting, Surveying, Mensuration, Nursery Practice, Map Drawing, and Forest Protection (Foulds & Nagel, 2013; Van Der Merwe, 2011). However, for the awarding of the diploma, students had to complete practical work in fencing, nursery work, care of animals, elementary surveying, planting, and sowing, tending woods, mensuration practices, road path construction, and carpentry, (Foulds & Nagel, 2013). Moreover, students had to submit work reports on work exposure (Foulds & Nagel, 2013). These requirements show that the course was mainly technical, focused more on applied knowledge than on universal scientific principles**.** This focus on applicability contributed to the schism between the Cape government and the government of the Transvaal, which eventually culminated in the closure of the school in 1911. The Transvaal government thought that the Tokai School's lack of emphasis on universal scientific principles was behind the failure of the foresters in South Africa in addressing the South African forestry challenges (Kruger & Bennett, 2015).

The emphasis of the Tokai School curriculum on local geography and silviculture rather than what was done at Coopers Hill, England was in line with Hutchins's belief that foresters should understand the local environmental condition by studying the local ''principles of South African arboriculture … meteorology, botany, entomology … geology, and surveying'' (Brown, 2001, p. 436). The focus of the curriculum on the local environment was a reflection of the influence of the bioclimatic methodologies of the Cape foresters, such as Hutchins, and the missionary botanist John Croumbie Brown in Natal (Showers, 2010).

The Tokai School opened with seven students, of which five were from the Cape Colony and one from the Transvaal and the other from the Orange River colony (Carruthers 2016; Brown, 2001). Only four students graduated in 1909 and four students were enrolled in 1910 (Bennett & Kruger, 2015). As will be shown below in the section on Silvicultural research, some of the graduates from the school, such as AJ O'Conner, working together with foreign-trained professionals, such as IJ Craib, revolutionised Wattle silvicultural practices in Natal in the 1920s, hence the conclusion that forestry R&D in South Africa was a fusion of local and universal knowledge.

The Tokai Forestry School confronted a number of challenges leading to its closure in 1911. David Hutchins, who was the only professor in forestry, left the school in 1906 for a Colonial Office appointment to report on Kenyan forests (Roche, 2009). The South African College to which the school was an extension maintained that, for the quality of instruction to be guaranteed, there was a need for at least one forestry professor and a lecturer to be employed on a permanent basis in line with international practices (Bennett, 2010). The states of Natal and Transvaal despised GA Wilmot, who replaced Hutchins as the head of the school, for being too junior and lacking the gravitas to maintain the prestige of the school, if it was to attract students from across the empire's Southern Hemispheric countries (Brown, 2010). A proposal for funding by the Cape Colony in 1909 (Cape would provide £499, Transvaal £299, ORC £199, Natal £199, Southern Rhodesia, now Zimbabwe, £59, and Basutoland, now Lesotho, £25, with all contributions adding up to a total of £875) to secure an expatriate forestry professor was rejected by the Orange River Colony and the Natal government (Bennett & Kruger, 2015). However, Southern Rhodesia and Basutoland supported the measures (Bennett & Kruger, 2015). Despite criticising the school for its focus on localised knowledge in a way that ignored universal scientific principles, Transvaal provided the school with £300 for the year 1909-1910 (Kruger & Bennett, 2015). Despite the contribution by the Transvaal government, increased disagreements between and among the South African states and neighbouring governments led to the closure of the school in 1911 (Bennett & Kruger, 2015).

Important to note is that the reason given for the opening of the Tokai School hinged on the argument that offshore training of foresters was too expensive and the 'need to provide education that suits South African conditions'; yet at its closure those involved complained about the cost of running the school and the lack of knowledge production based on universal scientific principles (Smith & Van der Lei, 1997). Although financial issues might have played a role in the closure of the school, an analysis seems to point towards disagreements on the methodology of knowledge production as the main reason. Even though the school was established to offer quality education, this education was, however, not theoretically grounded in universal scientific principles; hence the education was described by Foulds and Nagel (2013) as a 'fairly theoretical course' (p. 4). The government of Transvaal provided funding for the school for the year 1909-1910, but it mercilessly criticised the curriculum's bias towards particular South African conditions and advocated for a curriculum that depicts universal scientific principles, with

European experts who ‘’work on scientific principles without following the groove into which officers in the Cape Forestry Department have run for 30 years and which had led to no practical solution of vital problems’’ (Bennett & Kruger 2015, p. 85). Despite the focus on local conditions by the Cape foresters, there remained a commitment to ‘epistemological universalism’[17] in forestry knowledge generation in certain sections of the South African society during this period.

Further, it is also difficult to believe that the Tokai School curriculum was not in any way influenced by European and Indian ideas, as Bennett and Kruger (2015) would like to suggest. Of consideration is the fact that most of the lecturers at the school had obtained their training at European schools and some had acquired their forestry experience while working in India. David Hutchins, the professor and head of the school when it opened, had obtained his education at the Royal Coopers Hill College (England) and had worked in the forestry department of India before coming to South Africa (Roche, 2009). Moreover, GA Wilmot, who took over as head of the school when Hutchins left in 1907, had obtained his education at Yale University (Bennett & Kruger, 2015). It, therefore, becomes difficult if not impossible to conceive that the prior knowledge of these professionals obtained at European, Indian, and American institutions did not have any influence on forestry studies at the Tokai School. Moreover, it is very difficult to concede that the subjects offered at the school, such as Silviculture, Mensuration, Botany, Nursery Practice, and Forest Laws (Foulds & Nagel, 2013), were not in any way influenced by the designs and content of these subjects at European and American schools where the lecturers at the school had been schooled. Instead of arguing for the local origins of South African forestry R&D, as done by Bennett and Kruger (2015), it is much more plausible to argue that, even if the Tokai School curriculum was heavily tilted in favour of locally produced knowledge, it was also somewhat influenced by internationally produced knowledge brought in by the leading lecturers at the school, such as Hutchins and Wilmot.

The disagreements that ensued between the states with regard to the school reflect the importance of integration, coordination, and interactions, if an SI is to run smoothly, as emphasised by system scholars, such as Chaminade and Edquist (2010). An SI has to ensure

[17] According to Charles Kenny (World Bank 2001), ‘epistemological universalism’ is a concept derived from the scientific revolution focused on the production of ‘true’ knowledge by following the ‘rules’ of science. The knowledge is universal considering that it is not a reflection of a particular time or place.

open communication channels for stakeholders to contribute and to receive feedback (Bergek, Jacobsson, Hekkert, & Smith, 2010). These channels ensure that disputes are mediated and resolved amicably. The failure of the Transvaal government to communicate openly about its displeasure with the appointment of GA Wilmot, whom they regarded as too junior to head the school (Bennett & Kruger, 2015), resulted in the failure to resolve disputes, hence the closure of the school in 1911. Further, disagreements in approaches to local and universal knowledge skills also point to the discursive nature of knowledge production. Knowledge production occurs in the process of learning to resolve societal contradictions manifesting themselves in the form of various conflicts and contradictions (Engeström, 2011). The disagreement over the Tokai School was a reflection of the conflicts over which type of education was the best, either European forestry education or education based on locally produced knowledge. However, it should be emphasised that learning is a process emanating from history and human experiences; hence the argument that the history of South Africa's interaction with foreign influences and its own experience with forestry R&D were important determinants in the development of forestry production in the country. Learning is cumulative (Blind, 2010) such that present-day models of knowledge production represent the development and perfection of old learning models.

The dissatisfaction with the types of knowledge and the methodology of knowledge production at Tokai led the Department of Agriculture to embark on a new policy whereby all top positions in the department were to be occupied by students educated at Yale, Oxford, Edinburgh and other American and European universities (Smith & Van der Lei, 1997). Students who later went to study at American and European universities, such as Christian Wicht; John Phillips, Ian Craib (Pooley, 2011; Sherry, 2010) and others, revolutionised South African forestry knowledge production and resource management. These brought with them knowledge with universal implications, which they blended with locally produced knowledge in transforming the South African forestry sector. Nonetheless, despite the influence of foreign-educated foresters, the early foresters' bias towards South African conditions continued to resonate in South Africa's forestry R&D up to this very day. This was a realisation that scientific forestry is a technical field in its outlook, hence the demand for both technical and academic knowledge, as noted by Inness (2010). The importance of technical skills in forestry development is demonstrated in the focus on apprenticeships with regard to the education that was offered at the Cedara School of Agriculture and Forestry, which was opened in 1906 in Natal.

2.9 Cedara College of Agriculture and Forestry

In a bid to augment forestry research capacity, the colonial government in Natal opened a college that offered forestry studies at Cedara almost at the same time as the Tokai School. According to Carruthers (2016), Cedara College opened in 1906 and offered forestry apprenticeships. However, the KwaZulu-Natal Department of Agriculture and Rural Development (2016) noted that Cedara College opened as a school of agriculture and forestry in 1905 and that the original prospectus advertised lectures in Forestry, Horticulture, Dairying, Veterinary Science, Chemistry, Elementary Mathematics, Bookkeeping, Farm Surveying, Zoology, and Fish Husbandry. Like the Tokai School, Cedara College offered a two-year course, which included one forestry lecture a week. Messrs Kelly, Sim, and Stayner provided lectures in forestry studies at Cedara College (Prospectus of the School of Agriculture and Forestry, Cedara, Pietermaritzburg, 1910, cited in McCracken, 2010, 1986). Tom Sim, who was the conservator of Natal and had 45 men employed in 22 forest stations in Natal, was the head of the Cedara School's Department of Forestry (McCracken, 1986, 2010). However, the economic depression of 1906 led to changes in forestry R&D in Natal, as Sim was accused of overspending and his post as conservator was abolished in 1907 (McCracken, 2010, 1986). As a result, responsibility for forestry and forestry studies was passed to ER Sawyer, who was the head of Cedara School and to GH Davis, the new afforestation officer (McCracken 1986, 2010). The administration of Cedara College was transferred to the Department of Agriculture (DOA) from the Department of Education (DOE) in 1913 (Liebenberg et al, 2010).

The importance of Sim's work at Cedara College and in the development of forestry R&D lies in his devotion to establishing forestry on a permanent basis in Natal (Brown, 2001). Thus, by 1906 Sim had managed the demarcation of 65 000 acres as Crown forests in a bid to stop the destructive exploitation of natural forests (McCracken, 1986, 2010). He also recognised that the future of forestry in Natal lay in plantation forestry. As such, he initiated plantation schemes at Cedara, Empangeni and at Weza in Natal (McCracken, 1986, 2010). By 1907, when his post was abolished, Sim had laid a strong foundation, which ensured the survival of forestry in Natal after his dismissal (McCracken, 1986, 2010). The dismissal of Sim in 1907 is crucial in understanding the dynamics with regard to interaction in relation to R&D funding in South Africa today. Interactions in R&D are greatly limited by the models of R&D funding. As noted above, the Tokai School was closed partly because it had become too expensive to run. Some models of funding are highly unpredictable and this has a problem with regard to the continuity of research projects. Researchers are compelled to work on short-term projects rather than on addressing long-term challenges and this may have the effect of limiting the employment of R&D in forestry development, as some projects may be abandoned halfway. In the case of Natal, Sim continued with his work after dismissal, as a nurseryman (McCracken, 1986, 2010), though it is expected that he confronted a number of challenges due to lack of government support in the form of funding.

In Natal, as in other colonies in South Africa, forestry R&D was influenced by forestry developments in the Cape Colony. Influence is a result of interactions. The influence of the Cape Colony on forestry in Natal was noted when Henry Fourcade, a Cape forester, was appointed in 1889 by the Natal government to report on forestry in Natal (McCracken, 1986). In his 1890 report, Fourcade recommended the preservation of natural forests and the setting up of plantations for railway sleepers (McCracken, 1986, 2010). It may be assumed that the drop in the significance of the forestry studies at Cedara, especially after the dismissal of Sim in 1907, was also linked to the growth in dissatisfaction with the focus of the school on local knowledge, as was the case at Tokai during the same period.

The dissatisfaction with locally focused applied knowledge production seems to have resulted in the gravitation towards a policy on the employment of foreign professionals to take up lectureship positions in forestry and related disciplines at the Natal University College, after the dismissal of Sim. For example, the Scottish John William Bews came to South Africa for a professorship position in botany at the University College of Natal in 1910 (Pooley, 2011). The influence of Bews should be recognised, as he was the first to write the national vegetation survey of South Africa in 1916, when he applied Clementsian ideas (Clements argued for linear progression of vegetation in nature from simple to compound communities in equilibrium with environmental conditions) in relation to plant succession (Pooley, 2011). The influence of foreign ideas in the development of forestry R&D in South Africa should be acknowledged as the failure to do so would amount to a distortion of the reality, which we are seeking to comprehend. The knowledge brought in by foreign professionals resulted in the interaction of the local and universal knowledge production processes, leading to the emergence of a hybrid knowledge and forestry skills system in South Africa with a focus on both technical and academic skills. Carruthers (2016) noted that the Cedara School offered apprenticeships. Apprenticeships are technically focused hence the importance of intermingling the technically focused knowledge forms with knowledge based on universal principles and procedures in strengthening forestry R&D in Natal. Apprenticeships at the Cedara College provided the know-how type of knowledge (Lundvall, 2004) accumulated mostly at the point of production through observation, imitation and practical demonstrations. However, this form of knowledge failed to address the ‘why’ questions with regards to the challenges in the adaptation of exotic germplasm and the classification of eucalyptus species in South Africa. The employment of foreign professors, which led to the intermingling of the contextually produced knowledge with the context-independent forms of knowledge, was an appreciation of the fact that production problems are resolved both at abstract and practical levels by invoking explicit and implicit routines in the firm. This was something that the early foresters in the Cape Colony seemed to have ignored because of their focus on the generation of technical skills and applied knowledge devoid of universal scientific principles and procedures. An understanding of these different forms of knowledge leads us to the rejection of the notion that forestry R&D as it developed in South Africa was exceptional nor was it European or Indian in orientation. South African forestry R&D was a result of the connection between local and international knowledge, taking into consideration a number of local factors, such as the environment in addressing forestry challenges.

2.10 Forest organisations and capacity building after the Tokai School

Despite its official closure in 1911, the Tokai School continued to offer elementary courses in forestry. The expansion of forest plantations after World War I created a huge demand for forestry technicians (Smith & Van der Zel, 1997). The shortage of facilities at Tokai resulted in the setting up of the Saasveld School of Forestry near George (Cape Town) in 1932 (Smith & Van der Zel, 1997). The school offered a two-year course, of which the first year of study was spent on training in the classroom and the second year on practical training in forests and plantations (Smith & Van der Zel, 1997). Some of the subjects that were offered by the school included Forestry Mechanics, Nature Conservation, Labour Relations, Occupational Safety and Open-Air Recreation (Forestry Annual Report, 1968, Forestry Annual Report, 1970, cited in Smith and Van der Zel, 1997). The Saasveld School was transferred to the Port Elizabeth

Technikon in 1986, where it began to offer a Diploma in Forestry and other postgraduate forestry courses (Smith & Van der Zel, 1997). In 2005, the school became a college of the Nelson Mandela University (NMU) (Langin & Ackerman, 2010). The current NMU curriculum reflects the demand for technicians (Underwood et al, 2010).

The orientation of the curriculum at the Saasveld School of Forestry in the 1930s was on applied knowledge, as was the case with the Cedara School. However, important to note is that the Tokai School, the Cedara School, and the Saasveld School did not consider African education and this had a negative impact on the development of the plantation economy in the homelands. As noted by Grundy and Wynberg (2001), ‘’indigenous forest management in the former “Homelands” came under a conservation regime that was plagued by lack of effective management and ignored the local communities’’ needs for natural resources to sustain their livelihoods’ (p. 3). This was the initial stage in the development of the idea of the two economies, which characterises the current South African forestry sector today.

2.11 African Forestry Education

African forestry education was not considered in South Africa up to the period after World War II (Showers, 2010). The colonial administrators ‘’thought that there was no need for instruction because they had learned these skills while working on white farms’’ (Showers, 2010, p. 309). This was just an extension of the racially discriminative policies. Such policies that excluded black people included the Land Act (1913), the Cooperatives Act (1920) that excluded black farmers from participating in farmer cooperatives, and the 1925 Farmers Assistance Board that offered soft loans to white people only (Liebenberg, 2010). These acts are important in understanding the role of institutions in R&D. Institutions may facilitate or hinder the employment of R&D. Colonial and apartheid institutions led to skewed development outcomes as they facilitated the employment of R&D only in white segments of the economy. However, the growth of afforestation in Bantustans in the 20th century led to the demand for the management of forestry resources in designated African areas, especially after World War II (Smith & Van der Zel, 1997). This resulted in the setting up of the School of Forestry at Swartkop plantation in Pietermaritzburg, in 1946, to train black foresters for forest service provision in the Bantustans (Langin & Ackermans, 2010; Smith & Van der Lei, 1997). Nevertheless, at Swartkop, students were trained to accept responsibility, to assist in forestry development and to raise forestry awareness in the Bantustans (Smith & Van der Lei, 1997). The school offered a two-year Diploma in Forestry on similar lines as the Saasveld School. Nonetheless, Bantu education and its deleterious effects on development have been recorded (Lotz-Sisitka, 2009). The current poor outcomes in terms of innovation and forestry productivity in the former homelands are intractably connected to the education that was provided in Bantu schools. The Swartkop forestry school was closed in 1969 and the facilities were transferred to Fort Cox Agricultural College (Smith & Van der Lei, 1997). Forestry and agricultural studies are still offered at Fort Cox. The development of two systems of forestry education underlies the Apartheid logic that created separate organisations for whites and blacks. The next section deals with the development of university education grounded on scientific principles.

2.12 University education

The arguments regarding the cost of sending students to study abroad were advanced in 1931 in arguing for a local university offering forestry education (Smith & Van der Lei, 1997). The policy of sending students for training abroad embarked on by the government after the closure of the Tokai School was reversed after the 1931 Conference of Foresters in South Africa, which recommended the provision of training at a local university in South Africa (Stellenbosch University Annual Review, 2012). This was deemed a cheap way of developing skills in a way that would expose students to local conditions and forestry problems (Stellenbosch University Annual Review, 2012). The 1931 Forestry Conference identified the University of Stellenbosch as an appropriate provider of forestry studies (Smith & Van der Lei, 1997). This led to the establishment of the Forestry Department in 1932, with financial support from Dr Hans Merensky and from the national Department of Forestry (Wicht, 1958). The Department was led by Prof EJ Neethling (Wicht, 1958). The department became the Institute of Forestry and Wood Technology of the University of Stellenbosch in 1949 (Wicht, 1958). The institute attained the status of a full faculty of forestry in 1956 (Wicht, 1958). For the running costs, the institute was aided by funds from the university, donations from private forestry organisations and individuals, and a subsidy from the Department of Education, Science, and Art (Wicht, 1958). From 1953, students obtained bursaries from the national Department of Forestry to study at the Faculty of Forestry at the University of Stellenbosch (Smith & Van der Lei, 1997). The financial support from private forestry organisations and individuals, and from the national Department of

Forestry and the Department of Education, Science and Art, demonstrates the importance of the collaboration between government and the private sector in skills and economic development.

At first, the University of Stellenbosch's forestry education was focused on silviculture to produce saw logs, but with the growth of sawmilling and the ''secondary and tertiary production of sawn and manufactured timber products'' after World War II, the course was revised to include three main subjects, in order to cater for these developments (Wicht, 1958, p. 314). These were Silviculture, Management, and Wood Technology. As part of strengthening the training at the University of Stellenbosch, various appointments were made between 1950 and 1954. These included the appointment of a Professor of Forestry (Merensky Chair of Forestry); a Professor of Wood and Technology (Chair of the Transvaal and Free State Chamber of Mines); a Senior Lecturer in Forestry; a Lecturer in Wood Technology and a Lecturer in Forestry (Wicht, 1958). Currently, the University of Stellenbosch offers B.Sc. Forestry; B.Sc. Forestry - Nature Conservation; B.Sc. Wood Science; and a Bachelor of Engineering in Chemical Engineering (Innes, 2010). The curriculum reflects the need to develop forestry scientists as opposed to technical skills (Underwood et al, 2010).

From the beginning, most of the programmes at forestry colleges have been concerned with the profit motive of the white-owned commercial section of the forestry economy but recently (1990s) there has been curriculum re-contextualisation to try to encompass forestry in a holistic way that also reflects the needs of community forestry and the participation of formally disadvantaged communities (Langin & Ackerman, 2010; Underwood, 2010). These changes have been influenced by certain institutions, such as the adoption of the democratic constitution in 1996, laying the foundation for inclusive and equitable growth for all communities in South Africa. This development points to the importance of institutions in shaping the direction of developments in forestry R&D.

What is important to note is that the opening of the Tokai School in 1907 was a result of the demand for locally produced knowledge but its closure in 1911 was partly a result of the need for foreign education. The opening of the Saasveld and Swartkop technical schools and of the faculty of forestry at the University of Stellenbosch in 1932 offering academic forestry education reflects underlying contradictions between practitioners in forestry R&D in relation to what has been referred as 'epistemic cultures' by Knorr-Cetina (1997). These cultures, as defined by

Knorr-Cetina (1997), are made up of ‘arrangement and mechanism bonded together by affinity, necessity and historical coincidence which in a given field make up “how we know what we know”. They are cultures that create knowledge, models, and procedures’. An illustration of the operation of epistemic cultures has been provided by Knorr-Cetina (1997) in relation to the work of financial traders on a stock market. Traders are continually required, ‘’to define the market, not only in the sense of trying to read it and understand it but also in the sense of making it, testing it, by testing it, moving it and manipulating it’’ (Knorr-Cetina & Brueger, 2002, p. 5). The process is so complex that traders are always questioning their own interpretation of market shifts. In doing this, the traders rely on theoretical knowledge in understanding the performance of different markets and on the knowledge that they build up by working the market each day.

These epistemic processes allow for the production of new knowledge. The lack of understanding of these epistemic processes is behind the arguments that South African forestry R&D was exceptional in its origin and development or that it was foreign in its origins. Forestry R&D in South Africa rather developed from the adaptation of universal scientific principles to the South African context and it developed because of the forestry researchers and practitioners questioning and reflecting upon their own interpretation and understanding of forestry development in their own contexts. In doing this, they were guided by universal scientific forestry principles brought in by foreign-educated professionals and the knowledge they had accumulated in the practice of forestry development in South Africa. From the understanding of these epistemic processes, it becomes difficult if not impossible to argue to the contrary that South African R&D developed as a fusion of universal scientific knowledge and local knowledge produced by forestry researchers in the process of doing. This then brings in the imperative of differentiating technical and academic knowledge, which forms the subject of the next section.

2.13 Differences between university and technical forestry education

The setting up of the Saasveld and Swartkop forestry schools offering technical and functional training and that of a faculty of forestry at the University of Stellenbosch offering academic education reflects the importance of both basic (blue skies) research and applied research in forestry knowledge generation and resource development. Universal scientific principles should be married to local conditions in addressing local challenges, if development is to be achieved.

The conflict that ensued between foresters in the Cape advocating for the Tokai School and the government of Transvaal advocating for European forestry education was a conflict over the nature of scientific knowledge, whether it should be basic or applied. The establishment of technical schools at Saasveld and at Swartkop, and a faculty of forestry at the University of Stellenbosch that offered academic education points to a realisation that both forms of knowledge were important in forestry resource development.

Forestry training at the Saasveld and Swartkop schools of forestry was technical and functional with the aim of equipping foresters, senior foresters, and forest technologists with skills in the distribution of work, scheduling of work programmes, the management, and control of finances of a forest station and management of forest stations (Smith & Van der Lei, 1997). Those who acquired the training had to ensure that silviculture and forestry protection was enhanced. They were equipped to apply forest policies (Smith & Van der Lei, 1997). The forestry course offered at the University of Stellenbosch was intended for forestry managers. The emphasis was on originality and creativity (Smith & Van der Lei, 1997). Forestry managers are supposed to be involved in the crafting of scientific evidence-based policies and to evaluate the policies to devise new technologies. While technical courses equip learners to apply technologies in a particular environment, academic courses train learners to be analytical and to be able to adapt and to work in wide-ranging environments. The technically oriented trained students are interested in answering the question as to *how* – a process that is achieved by applying or combining existing knowledge in practical ways, whereas academics are much more interested in the question *why* – a process that is achieved by developing new knowledge about natural systems through applying scientific laws (Gertler, 2008).

Nevertheless, this complex distinction between technical and professional forestry training is becoming difficult to distinguish with the growing use of MSc programmes which are either bridging training or used for supplementing existing foresters' knowledge (Innes, 2010). Further, the differentiation of the technical diploma-based programmes and academic degree programmes does not consider the fact that universities now provide credits to diploma holders studying for degrees (Innes, 2010). Important to consider is that many first jobs by university-trained foresters are in technical positions. Moreover, many practising foresters complain about too much unnecessary material taught in a degree programme, whereas important field skills are not taught in depth (Innes, 2010). The institution of both technical and professional forestry schools in South Africa in the 20th century emanated from the realisation of the importance of both types of knowledge in the development of forestry resources. There is a need in South Africa for both technical and professional skills, taking into consideration the demand and supply market dynamics, hence the need for constant interaction of forestry skills organisations with the industry players and the government in determining skills requirements. Once skills are acquired and the knowledge has been produced, there is a need for them to be applied to improve production processes. The need to ensure that research skills and knowledge were effectively employed in enhancing forestry productivity resulted in the colonial and apartheid governments of South Africa financing a number of research activities through the setting up of research stations and projects.

2.14 Research Stations and projects

A number of research stations and institutes were set up by the colonial and apartheid regimes to augment forestry R&D in South Africa to address specific forestry challenges. The Jonkershoek Forestry Influences Station began the research on forestry hydrology in 1935. The Fynbos Biome Project commenced in the 1920s (Pooley, 2010). Formal research in tree breeding in South Africa was initiated in 1957 when the South African Forestry Research Institute (SAFRI) started the pine improvement programme (CSIR, Twenty Years, 2011; Van Der Merwe, 2011). The SAFRI tree improvement programme was based on comprehensive efforts of the 18th and 19th centuries in introducing exotic tree species and the provenance studies which began in 1927 (CSIR, Twenty Years, 2011). The National Timber Research Institute (NTRI) was also established in 1960 (Van Der Merwe, 2011). SAFRI’s research and breeding programmes and the studies of NTRI were transferred to the Council for Scientific and Industrial Research (CSIR) in 1989, where they were combined to form the new CSIR operating unit, Forestek. Tree improvement research at Forestek continued into the 1990s (CSIR, Twenty Years, 2011).

The CSIR was established in 1945 in Pretoria through public funding (Liebenberg, 2010). The CSIR forestry research focused on tree improvement in relation to cloning, genomics, quantitative genetics, remote sensing, climate change, and adaptation (CSIR, Twenty Years, 2011). The government led most of these early research initiatives. The private sector only began to be actively involved in research from the 1950s onwards with the establishment of the Wattle

Research Institute in 1947, which became the Institute of Commercial Forestry Research (ICFR) in 1980 (Dyer & Wingfield, 2005). Private-sector participation in forestry production was mainly influenced by positive market dynamics, especially the rise in timber prices after World War I (Tewari 2002). Private afforestation proceeded rapidly after the 1960s (Tewari, 2002). The next section demonstrates the importance of R&D in forestry resource development.

2.15 Researchers that revolutionised the South African forestry sector

Starting from the mid-1930s and partly because of interaction with the outside world, South Africa had managed to build the research capacity with a number of researchers capacitated to undertake research into the challenges that confronted forestry resource production and management in the country. Both foreign-trained researchers, such as CL Wicht, and locally trained researchers, such as AJ O'Connor (from the Tokai School of forestry), played a crucial role and their research revolutionised forestry production in South Africa as will be shown in sections below.

2.15.1 The Forest Hydrological research by Dr Christian L Wicht

Forestry hydrological research in South Africa emanated from the conflict between farmers and foresters (Kruger & Bennet, 2015; Pooley, 2011). The success of the plantings starting from the beginning of the 20th century coupled with the droughts of the 1920s led to complaints by farmers who believed that, instead of improving the climate (as was initially assumed by the British missionaries, such as Robert Moffat), plantation forestry was drying up streams leading to the shortage of irrigation water (Showers, 2010; Chapman, 2007). Farmers argued that exotic trees transpired 'a substantial amount of water' leading to the shortage of water for agriculture (Scott, 2004, p. 6). On the other hand, foresters complained that overgrazing and the practice of burning to stimulate pastures by farmers was a threat to water supplies and a danger to plantations and nature conservation (Chapman, 2007). When the 1935 British Empire Conference on Forestry convened in Durban, South Africa, the Minister of Agriculture, Colonel Denys Reitz, exhorted the delegates to deliberate on the question of veld fires in the Union (Pooley, 2012). However, the conference delegates advised that it was more critical to research into the effects of afforestation on water and soil conservation (Bennett & Kruger, 2015). The conference delegates agreed that the question of afforestation and water conservation would be more beneficial not only to South Africa but to the world at large (Bennett & Kruger, 2015). This very fact demonstrates the importance of local and international interactions in knowledge generation. In response to the suggestion by the 1935 British Empire Conference delegates, an experiment was set up at Jonkershoek in 1935 and became the Jonkershoek Forest Influences Station. Christian Wicht, an alumnus of Stellenbosch, Oxford, Tharandt, and Wageningen Universities, directed the experiment (Bennett, 2010).

At Jonkershoek, Christian Wicht tested the assertion that plantation forestry was a stream flow-reduction activity (Pooley, 2012). He also tested the assertion by Viehmeyer and Johnston (Californian scientists) that vegetation removal from catchment areas would increase water supplies (Pooley, 2012). The paired catchment experiment design was similar to the one employed at Wagon Wheel Gap, Colorado, USA and at Emmental in Switzerland (Chapman, 2007). The experiment involved the determination of natural relationships of two catchments before treatment. One of the catchments is then treated with trees. The resultant change in the relationship between the two catchments would then be attributed to the effect of afforestation on stream flows.

The experiment proved that plantation forestry is a stream flow-reduction activity. Stream flows were reduced by 200-500 mm per year, depending on rainfall (Scott 2004:24). One hundred to 80% of flow reductions were greater in proportion to the basin planted, the growth rate of trees, and the amount of precipitation (Scott, 2004). The experiment discovered that riparian vegetation 'exaggerated' the effect on flows with an area of a plantation near streams having double the effect of the same area of mid-slope planting (Scott, 2004). It was also discovered that fire treatment on indigenous vegetation on catchments improves stream flows (Pooley, 2004). Other important discoveries were that all types of vegetation use water and have to be managed (Bennett & Kruger, 2015). The experiment vindicated the farmers and proved that plantations were drying streams and that fire was important in the management of forestry and water resources. The discoveries have had a huge impact on forestry resource management in South Africa. Based on Wicht's 1945 Royal Society Report and research at Jonkershoek, the Forestry Department agreed that controlled veld burning was acceptable (Pooley, 2012). In the Circular number 15 of 1948, the Department of Agriculture formulated a policy on burning (Pooley, 2012).

The result of the Jonkershoek experiment influenced the operation of the government with regard to the management and development of plantation forestry resources. The government responded by setting up two interdepartmental committees to work out programmes on forestry resource management. This was a realisation that forest resource development was a cross-departmental issue requiring interdepartmental collaboration, cooperation, and coordination. The 1961 Report of the Interdepartmental Committee on the Conservation of Mountain Catchments in South Africa, recommended for a national plan on the management of catchment areas, with the effect of transferring the management of catchment areas even on private lands to the national government (Pooley, 2012). The Ministerial Interdepartmental Committee on Afforestation and Water Supplies, which reported in 1968 (Bennett & Kruger, 2015), noted that the afforestation of catchment areas with exotic trees affected hydrological cycles. The 1961 and 1968 reports led to measures being taken to improve forestry management; to limit uncontrolled afforestation and control invasive species and the impact on scarce water resources. The Mountain Catchment Areas Act 63 was promulgated in 1970 and the 1941 Forest Act was amended in 1972 to give effect to the recommendations of the committees. The Mountain Catchment Areas Act demarcated the extent of catchment areas under the joint management of landowners and the Forestry Department. The Act brought in the concept of ecosystems management and its amendment of 1981 emphasised land conservation to deal with problems of erosion (Tewari, 2001). The 1972 Forest Act introduced the Afforestation Permit System of 1972 (APS) to curb uncontrolled plantings (Tewari, 2001; Scott, 2013). The 1930s policy recommending for 20 metres of the riparian reserve not be planted was to be continued (Scott, 2013). An interdepartmental Permit Committee managed the determination of afforestation permits (Bennett & Kruger, 2015). Important to note is that even present-day programmes, such as the Department of Environment Affairs' Working for Water Programme, are informed by the results of the Jonkershoek experiment. Other outputs such as Gush Tables, CSIR Flow Reduction Curves and Handy Reference Manual regarding stream flow reduction are all used for allocating permissible plantation areas to catchment areas today (Chapman, 2007). The CSIR's Flow Reduction Curves and Handy Reference Manual regarding stream flow are currently employed in South Africa in determining the clearing of alien invasive species that are colonising the environment and reducing stream flows (See Mander, 2017).

2.15.2 Nature of knowledge production and application

The success of the Jonkershoek experiment demonstrated the interactive nature of knowledge generation requiring interactions, linkages, and coordination. For a start, the research was funded by the Department of Agriculture and Forestry. Moral support to Wicht was provided through constant visits by the leaders in the Department of Agriculture and Forestry, such as Colonel Collins,[18] JJ Kotze, IJ Craib and JD Keet[19] (Bennett & Kruger, 2015). Wicht's partners from other disciplines, such as John Phillips and IB Pole Evans,[20] also visited him. TE W Schumann[21] also visited Wicht at Jonkershoek (Bennett & Kruger, 2015). Wicht also collaborated with botanists from the University of Cape Town such as RS Adamson and Margaret Levyns, who did a botanical survey of the valley (Bennett & Kruger, 2015. Mr Sandeberg, the Town Engineer from Stellenbosch, and experts from the Irrigation Department and engineers from Elsenburg Agriculture College provided advice on stream gauging (Bennett & Kruger, 2015). Professor Snape from the University of Cape Town's Civil Engineering Department assited Wicht on V-Notch calibration (Bennett & Kruger, 2015). Wicht also established international networks for exchanging knowledge and best practices in forest hydrology. He had correspondence with USA hydrologists and scientists, such as Walter C Lowdermilk, Andrew P Marurak, CE Ramser, and CF Brook (Bennett & Kruger, 2015). For the development of talent and future scientists, Wicht employed assistants. Thus, Settler EJ Borchardt was appointed the Clerical Foreman for Research to provide technical assistance, while HB Rycroft joined in 1943 as a graduate student but later went on to become the Director of Kirstenbosch National Botanical Garden (Bennett & Kruger, 2015). Mike de Villiers joined Wicht as his first assistant but later went on to establish his own afforestation experiment at Cathedral Peak under Wicht's supervision (Bennett & Kruger, 2015). The carrier of De Villiers demonstrates the importance of mentoring and the fact that knowledge may be acquired tacitly through doing in the process of work. However, knowledge is generated for the benefit of society, hence the importance of its dissemination. Wicht published in a number of journals and maintained a close relationship with the American WGW Musgrave who presented him with the opportunity to publish in the Transactions of the American Geophysical Union (Bennett & Kruger, 2015). As part of knowledge dissemination,

[18] Colonel Collins was the Minister of Agriculture and Forestry during the time of the Jonkershoek experiment.

[19] JJ Kotze and I Crain were Chief Forest Research Officers in the Department of Forestry based in Pretoria.

[20] John Phillips and IB Pole Evans were renowned botanists in South Africa during this time.

[21] TEW Schumann was a leading meteorologist.

Wicht also approved interviews with daily newspapers in the Cape and lectured at the Rotarian Club of Cape Town (Bennett & Kruger, 2015). Wicht's career demonstrates the importance of interactions, collaboration, and coordination in knowledge generation and transfers. The way in which Wicht directed the Jonkershoek research demonstrated that forestry R&D spans disciplines from social sciences to biodiversity, hydrology, geography, and this influenced the future evolution of the industry with regard to R&D approaches. In this regard, Wicht was ahead of his generation.

2.15.3 Silvicultural Studies by IJ Craib, AJ O'Connor, and John Phillips

The studies by IJ Craib and AJ O'Connor revolutionised the growing and management of wattle in the state of Natal and that of other commercial trees in South Africa. IJ Craib had obtained a BA and MSc from the University of Cape Town and an MSc and PhD in forestry science from Yale University (Bennett & Kruger, 2015), while AJ O'Connor was a graduate from the Tokai School of Forestry. The wattle silvicultural studies by Craib and O'Conner were a result of the fact that the wattle plantations had become run-down from the 1920s, emanating from the regressive cultural practices by growers in Natal (Sherry, 1973, 2010). The growers had not followed the advice for thinning early in life to between 450 to 500 trees per acre and for a final thinning to not more than 600 trees per acre before the plantation reached five years (Sherry, 1973, 2010). Plantations were thinned very lightly and carried 1000 or more trees per acre at maturity (Sherry, 1973, 2010). This practice negatively affected the quality of the tanbark and timber, hence returns on investments. For professional advice, the Natal Wattle Bark Union, formed in 1925, approached the State Department of Forest for technical advice (Sherry, 1972, 2010). The Department of Forestry appointed Dr IJ Craib in 1928 as the first forest researcher delegated to conduct silvicultural research on behalf of the Wattle industry (Sherry 1973, 2010). Craib was able to cooperate with other researchers, such as O'Connor, in a number of studies. He was able to gain the cooperation of many growers who applied his recommendations to their plantations. This was important for researchers have to work with the end-users, who are responsible for knowledge application. The effect was phenomenal. As noted by Sherry (2010),

> The resulting enhanced growth of these better-managed plantations served as an example to neighboring growers, so the general standard of wattle culture in Natal improved rapidly. The realisation that yields of bark and timber could be materially improved, simply by the application of correct thinning methods, helped to dispel the natural pessimism engendered by the reduced bark prices resulting from the economic depression of the early nineteen thirties. In consequence, when the Second World War broke out, the industry was in a much better condition to meet the demands, which were to be made upon it than would otherwise have been the case (p. 43).

Box 1

Mr. AJ O'Connor and Dr IJ Craib advise to Wattle Growers, December 1929

O'Conner and Crab advised growers on, soil preparation; treatment of seed, sowing, spacing, grass control, thinning, fertilizers, and escapement. On soil preparation they advised for land to be thoroughly ploughed and harrowed to control grass. The seeds were to be boiled for five to ten minutes and then washed in clean water to remove mucilage. They advised for sowing to be done when rains were expected between November and March. They advised growers to desist from bunching the seeds in spots to prevent them from suffering suppression. The seeds were to be spaced at 1 to 2 feet as soon as they are large enough to be handled. O'Conner and Crain also advised the growers to keep down grass, and to remove weeds until the growing stock was able to control competing vegetation. Further, they advised that the neglect of early spacing and subsequent thinning was fatal especially when combined with failure to eliminate grass growth. They encouraged growers to frequently maintain thinning to prolong the vigour of the trees. They also advised to fertilise with 200-350 1 b of superphosphate per acre with the fertiliser being broadcast by hand. They encouraged for thorough grass control and efficient distribution of the stock.

Source: Farming in South Africa. Forestry Department: South Africa (1929).

However, worthy of note is that, in the absence of scientific knowledge, it was always difficult for growers to determine the most appropriate time for thinning. With regard to this problem, AJ O'Connor designed an innovative tool in the 1930s, the Correlated Curve Trend (CCT) (Bennett & Kruger, 2015). The tool employed a quantification system for estimating the growth of a given species in relation to 'site conditions, current densities, and growth rates', as the basis for timing thinning practices (Bennett & Kruger, 2015). The tool allowed the farmers to determine scientifically the most appropriate time for thinning.

O'Connor collaborated with Craib in his work with the wattle growers in Natal. Collaboration between AJ O'Connor and foreign educated professionals, such as IJ Craib, was important in fusing the different types of knowledge at the disposal of South Africa. O'Connor had a fertile understanding of the local performance of exotic timber gained from experimental tests in South

Africa, while foreign-educated professionals brought in universally grounded theories and scientific principles. The fusion of the two types of knowledge generated a hybrid knowledge system that revolutionised forestry knowledge and management systems in South Africa.

Another researcher who contributed immensely to innovative forestry conservation and silvicultural procedures was John Phillips. Phillips was educated at the University of Edinburgh where he obtained a BA in botany and forestry and a PhD in botany (Bennett & Kruger, 2015). Phillips' ideas developed in contradistinction to those of O'Connor and Craib. While Craib and O'Conner's studies were focused on the acclimatisation of exotic germplasm for improved yields, John Phillips was concerned with the harmony of species, both in nature and on plantation stands (Bennett & Kruger, 2015). Phillips was highly interested in ecology and his thinking had been influenced by Fredrick Clements, a Nebraskan ecologist's scholarly work on plant succession (Bennett & Kruger, 2015). In his work Plant Succession, Clements had posited that plants in nature develop from simple communities to highly complex communities, arriving at a climax in equilibrium with their environment (Pooley, 2012). Phillips was also influenced by Jan Smuts' ideas on Holism and Evolution *(1926)* which were in line with plant-succession ideas of Fredrick Clements (Bennett & Kruger, 2015). Holism was about interdependence in nature's evolution towards wholes. However, Phillips' orientation and focus on plant communities (both indigenous and exotic) was bound to clash with foresters in South Africa, who had spent their lives working on the acclimatisation of exotic species in Natal and in the Cape Colony. While John Phillips regarded Fredrick Clements' book Plant Succession as a 'wonderful book', the Cape forester, Henry Fourcade regarded it as ''seriously marred by his mania for coining new words'' (Bennett & Kruger 2015, p.139). The ideas of John Phillips on the interdependence of plants in nature are being employed currently in South Africa in the management of exotic species to prevent ecological colonisation with the effect of replacing indigenous vegetation and of reducing stream flows. Thus, the current Working for Water Programme by DEA is partly informed by these ideas.

Phillips worked for the Forestry Department conducting experiments on the effects of moisture, dryness, and light on forestry regeneration to determine appropriate silvicultural practices for different areas (Bennett & Kruger, 2015). From this work, Phillips developed the idea of the 'biotic community' whereby forests were considered to be 'more than the sum of their parts'

(Bennett & Kruger 2015, p. 140). This confirms the entrenchment of the systems' approach to forestry management in South Africa. His ideas were disseminated through publications in the Journal of Ecology (Bennett & Kruger, 2015). From his investigations in the Knysna forests, Phillips noted that exotic germplasm was disturbing the wellbeing of biotic communities of indigenous species (Bennett & Kruger, 2015). He also blamed eucalyptus for reducing the bee populations and emphasised the growing and protection of native trees and forests. He criticised Australian Acacia (wattle) for affecting the reproduction of indigenous species by decreasing soil moisture and soil fertility (Bennett & Kruger, 2015). His conclusion was that all species of trees that are not natural to an environment strongly drew moisture from the soil (Bennett & Kruger, 2015). This was also one of the conclusions arrived at by Wicht's forestry hydrological research at Jonkershoek, as noted earlier. Phillips argues for natural tree communities to provide indicators with regards to the selection of sites for plantations. These ideas were very fundamental in relation to conservation, biodiversity and the growth of plantation forests in South Africa. They were crucial in balancing the interests of stakeholders, such as farmers, foresters, tourists, nature conservationists, and woodcutters.

The experiments by O'Connor, Craib and Phillips, together with the rationality of JDM Keet as the head of research in the Forestry Department in the late 1940s (Bennett, 2010), in infusing and harmonising their ideas were crucial in formulating a coherent forestry policy with regards to the management of indigenous forests, plantations, catchment management and in facilitating forest settlements after World War II. O'Connor and Craib generated knowledge that improved wattle growing in the Natal Colony. Both the government and the private sector supported O'Connor and Craib's work. Phillips generated knowledge that harmonised conservation and plantation forestry. The government funded Phillips' work. This demonstrates that, for the effective employment of R&D, there is a need for the cooperation of professionals and the other components of a system of innovation. Further, worthy of noting is that Craib and Phillips had received their education outside South Africa, while O'Connor had been educated at the Tokai School of Forestry. Thus, for R&D to be employed effectively, there is a need to broaden the country's knowledge base by tapping both into local and internationally generated knowledge in addressing local challenges.

2.15.4 The Fynbos Research Project

The fynbos research project, just like the Jonkershoek hydrology research, started in the context of conflicts between different stakeholders on the nature of exploitation and management of forestry resources. The forestry plantation economy was very unpopular in the 1920s among the local black South Africans, whom it displaced from land (Brown, 2010). It was for this reason that David Hutchins, based on his experience with Indian forestry management practices, wanted a policy that accommodated the access rights of indigenous people (Roche, 2010). The farmers believed that plantations were drying streams while nature lovers accused foresters of destroying the aesthetic values of nature and the botanists criticised plantations for loss of indigenous trees (Pooley, 2013). The foresters, on the other hand, perceived fire as a threat to both natural and exotic plantations and blamed the farmers' burning practices for causing erosion and for contributing towards water loss (Bennett & Kruger, 2015). However, during this time (the 1920s and 1930s), there existed no scientific explanation as to which practice was bad with regard to forestry resource management. Prof John William Bews, a lecturer at the University of Natal, had applied the Clementsian model of plant succession to all types of vegetation when he wrote the first ecological vegetation survey of South Africa in 1916 (Pooley, 2013). Bews regarded fire as a tool that destroys complex climax communities of vegetation reducing them to simple communities of primitive plants. As such, he argued for the exclusion of fire in the management of forestry resources (Pooley, 2013). Also believing that the burning practices by farmers were a danger to conservation and water supplies, the Department of Forestry took over the management and protection of catchment areas in 1930 and implemented the Soil Conservation Act of 1946, providing for the prevention of fire on private mountain catchment land (Bennett & Kruger, 2015). Even though the results of Wicht's 1935 Jonkershoek experiment had tentatively confirmed that burning improves stream flows, the Department of Agriculture did not recommend fire in the management practices of the forestry resources, until the 1970s.

Nonetheless, the scientific understanding of the role of fire in conservation was incidental, a by-product of the unintended consequences of the exclusion of fire in conservation policies, which had resulted in the disappearance and near extinction of fynbos species. As argued by Brian van Wilgen (cited in Pooley, 2012), the realisation of the necessity of fire management in fynbos, ''was brought home by the spectacular failure of fire protection policies to prevent the decline to the apparent virtual extinction of two rare and charismatic plants - the Marsh Rose *Orothamnus* *zeyheri* and the Blushing Bride *Serruria Florida*''. The Blushing Bride was not recorded from the 18th century until the accidental discovery of a population in the Franschhoek Mountains in 1881 (Pooley, 2012). The exclusion of fire resulted in the disappearance of the population between the 1930s and 1960s (Pooley, 2012). Then in 1962, there was a chance discovery of a few Blushing Pride at Assegaaiboskloof (Pooley, 2012). As a conservation measure, the site was cleared of litter that might prevent germination or lead to consumption by fire (Pooley, 2016). This, however, failed to stimulate reproduction. An accidental fire outbreak in the 1960s stimulated the underground seeds and the plants reappeared (Pooley, 2012). Similarly, protection from the fire had resulted in the disappearance of the Marsh rose in the Kogelberg Mountains (Pooley, 2012). Again, six plants were discovered in 1967 (Pooley, 2012). An experimental burning resulted in the reappearance of the Marsh rose (Pooley, 2012). These two incidences provided evidence of the importance of fire in maintaining complex communities of plants. It was as a result of these and partly the discoveries of Jonkershoek experiment that in the 1970s the Department of Forestry recommended burning in some humid catchment as an important farming practice and also essential in the prevention of large-scale accidental fires (Ross 1961, cited in Pooley, 2013).

The need to provide an explanation of the behaviour of fynbos in relation to fire regimes resulted in South African researchers setting up the Fynbos Biome Project in the 1920s, whereby plant communities were treated to different fire regimes and the results recorded. The project confirmed the importance of variable fire regimes in maintaining equilibrium and complexity in plant communities by preventing the dominance of a single species (Pooley, 2012). As a result, the fynbos project recommended fire regimes in conservation to be determined by non-sprouting plants, as sprouting plants can survive fires even before maturity (Pooley, 2012). The project discovered that some vegetation, such as fynbos, were dependent on fire for their regeneration. The research project also noted that in their natural state fynbos were treeless but well suited to tree growth (Pooley, 2012).

Further, the research also discovered that exotic invasive trees were responsible for the extinction of about 26 fynbos species and that 750 species were at risk (Pooley, 2012). This is because the fynbos species are focused on surviving fire but have no capacity to develop into dense stands while exotic invasive trees have the capacity to exploit the space provided by fires that kill non-sprouting species, enabling them to invade fynbos environments (Pooley, 2012). Thus, the invasive trees had a shorter return rate after fires than fynbos (Pooley, 2012). The behaviour of the invasive trees destroyed the non-equilibrium maintained by fires in fynbos communities. It was recognised that the state of non-equilibrium could be maintained by removing invasive trees mechanically. Frederick Kruger, who was the department's linchpin in the Fynbos Research Project in the 1980s, noted that with fynbos the richness in species increases in the first five years after the fire with a gradual loss thereafter, resulting from the suppression of the understory (Pooley, 2012). In addition, frequent burning to grow pastures was recognised as a danger to the survival of fynbos. These discoveries with regard to the relationship between fire and fynbos were an antithesis to the Clementsian model of a linear progression from simple to complex vegetation communities, which had been employed in conservation in South Africa (Pooley, 2012). Thus, ''rather than developing from simple to complex species-rich climax communities following fires, in fynbos species diversity decreased with age after fires'' (Pooley, 2012, p. 72). Further, the discoveries contradicted the views of early Cape botanists and ecologists. The project discovered that it was not fire that disrupted the equilibrium of the fynbos that destroys it, as assumed by earlier foresters at Cape, but it was the disequilibrium maintained by a fire that sustains fynbos (Pooley, 2012).

The Fynbos Project recommended burning in the late summer-early autumn and fire frequencies of 10 to 25 years depending on the complexity of vegetation communities (Pooley 2012:71). However, this period was the most delicate with limited suitable fire weather days because of the winds. It would be difficult to prevent incidences of runaway fires during this period. Nonetheless, in collaboration with researchers at the Northern Forest Fire Laboratory (USA), Brian van Wilgen, a forest researcher at Jonkershoek, employed the National Fire Danger Rating method from the USA in his work on fynbos. However, this had proved to be a failure by the 1990s (Pooley, 2012).

The fynbos research project provides a number of insights with regard to the process of knowledge generation. First, established hypotheses and theories are always imported and tested to prove or refute their applicability or explanatory power. The fynbos project refuted the Clementsian linear progression from simple to complex communities with regard to fynbos vegetation. Second, it proved that ideas developed somewhere are always brought in to advance knowledge generation within local spheres. The project used the 'vital attributes scheme' of IR Noble and RO Slatyer in developing generalisations on responses of plant communities to fire intensity and frequency (Pooley, 2012). Further, Frederick Kruger's (the Department's point person in the project) arguments on the relationship between fire regimes and Mediterranean type regions were informed by the work of Malcom Gill and Richard Grooves from Australia (Pooley, 2012). In addition, Brian van Wilgen, a forest researcher at Jonkershoek, adapted the highly technical National Fire Danger Rating method for fynbos from the USA. The project shows that international networks are important in informing and advancing local knowledge generation processes. The fynbos project emanated from the ideas that were discussed at international fora, such as the MEDECOS (Mediterranean Ecosystems), British Commonwealth networks and the International Council of Scientific Unions, which were also working on Mediterranean vegetation (Kruger & Bennett, 2015; Pooley, 2012). South African researchers, such as Frederick Kruger, were active in these fora.

Third, the fynbos project shows that integration and coordination at the national level are important for the success of knowledge generation and application processes. The Cooperative Scientific Programs of the Centre for Scientific and Industrial Research (CSIR) did the coordination of the fynbos project (Pooley, 2012). The state played a role through Frederick Kruger and other state researchers who coordinated the research and fynbos catchment management through the Management, Research, and Planning (MAREP) meetings. The project brought together stakeholders including researchers, forestry and land managers and planning officials and revolutionised research and management practices. With all this in mind, it becomes difficult to say that South African forestry knowledge systems were not influenced by external ideas, nor would it be possible to say that it was completely foreign. South Africa rather developed a hybrid knowledge system that took into consideration foreign ideas in advancing local knowledge-generating processes.

2.16 Political, social, economic and scientific influences and the plantation economy

The developments in forestry R&D were embedded in developments that were taking place in the wider South African environment but also connected to international phenomena. These included political, social, economic and scientific influences. The political influences included competing interest groups, the nature of the state, social dynamics, the Anglo-Boer war of 1889 to 1902, the Union of 1910, World War I, and World War II. The social influences included poverty and unemployment among the white communities in South Africa, especially after 1902. The economic influences included the development of the mining industry, the development of the insurance industry, the growth of rail systems in South Africa and the existence of markets for forestry products. The scientific influences included breakthroughs in forestry science in dealing with pests and diseases, fires, successes achieved in the adapting and growing of exotic wattle, pines and eucalyptus and advanced management practices of plantations with profitable returns.

Afred Milner's[22] reconstruction programme following the conclusion of the Anglo-Boer War in 1902 involved the extension of Cape forestry practices through the employment of professional Cape foresters in Natal, Orange River Colony and in the Transvaal (Bennett & Kruger, 2015). In the words of Lister, the employment of professional foresters marked the beginning of the department's first efforts ''to supply experienced and competent forest officers for these posts, for it … meant a uniform system of sound forestry throughout South Africa'' (Brown 2001, p. 36). The employment of professional foresters improved the success rate of plantings throughout South Africa. Milner's reconstruction programme anchored on afforestation, together with the 1910 Union of South Africa, brought about the unification of the forestry services of the former colonies into one forestry department with Joseph Storr Lister as the first Conservator of the forests of the Union (Van der Merwe, 2011). Soon after the Union of 1910, the Forest Act no. 16 of 1913 was passed to replace the Cape Forests Act of 1888 to give a new direction to forestry development (Burgess & Wingfield, 2001). The 1913 Forest Act was aimed at encouraging exotic timber plantations in the Union of South Africa, as well as conservation by reigning in the activities of the remaining woodcutters, especially in the Knysna Forests (Van der Merwe, 2011). This 1913 Act was amended in 1941 to allow for effective government monitoring and protection of indigenous forests and the growth of afforestation in demarcated areas (Burgess & Wingfield, 2001). As such, after 1910 South Africa's forest research system became more integrated and coordinated than it had been before. The integration was a result of the collaboration of the foresters, the private sector, the government and also an incidental outcome

[22] Alfred Milner was a colonial administrator who became the Governor of the Cape and High Commisioner of South Africa in 1897. Milner pushed the British Empire to war against the two Boer states, the South African Republic (Republic of Transvaal) and the Orange Free State (Anglo-Boer war 1899-1902) and organised the reconstruction after the war.

of the Anglo-Boer War that culminated in the 1910 Union of South Africa. As a result of the cooperation of the private sector with the foresters and the government, the size of plantation forests had reached 175 000 hectares by 1914 (Chamshama & Nwonwu, 2004). System scholars regard cooperation, collaboration, partnerships and networks as the basis for success in the employment of R&D in a system of innovation. This collaboration was the basis of the South African system of innovation which was formalised later in 1996.

However, worthy of noting is that Milner's reconstruction programme also faced resistance. The major challenge in the period after the Anglo-Boer War was the lack of trust between Milner (of Transvaal) and the government of Natal. The Dutch in Natal regarded plantations and the settlement of British farmers as an Anglicisation process meant to constrain Afrikaner influence (Brown 2001). This led to limited budget apportionment for forestry and finally the abolition of the post of the Conservator in Natal in 1906 (McCracken, 2010, 1984). In the Transvaal, there was also continued conflict between the need to conserve natural forests and to boost the mining economy, hence the continued destructive exploitation of indigenous timber to support the mining economy (Bennett & Kruger, 2016). This created a conflict between mining houses and conservators. Moreover, white farmers also resisted the growth of plantations, which they thought increased the incidence of ticks for their cattle (Bennett & Kruger, 2016). Furthermore, successful plantings during this period led to conflicts between white farmers and foresters in the colonies, conflicts that became more pronounced during the droughts of the 1920s when farmers argued, even though without scientific evidence, that plantations were drying up streams (Pooley, 2010).

The developments in the forestry economy were also determined by the nature of the white supremacist state that supported the various capital accumulation activities, through the law which symbolised the dominant culture of the time. The white supremacist state imposed conservation laws to protect natural forests for their own development needs. However, the African communities claimed ownership of the land to which plantations were established. As such the conservation laws disrupted the agrarian peasant economies of the African communities. In some cases, the African communities were compelled to leave their lands, as they were demarcated for conservation purposes. A good case of this was the Makiwane family in the Eastern Cape, which had claimed legal rights dating back to 1863 to land in the Lenye

Forest (Brown, 2001). However, a court ruling in 1906 recognised the Lenye Forest to be within the ambits of the Forest Department and the family had to move to another land (Brown, 2001). The conservators who enforced the colonial laws were thus seen by Africans as agents of the colonial states, hence their efforts to conserve natural forests and to afforest the land were resisted. In the Eastern Cape and in Transkei, the Xhosa communities resisted the Cape colonial government's attempts to restrict hunting, collection of fruits, harvesting of building materials and medicinal herbs and for the pasturage of their animals (Brown, 2001). Some forms of resistance included the disregard of rules and the mutilation of trees, which made it difficult for the conservators to realise their objectives (Brown, 2001).

The Makiwane family case alluded to above is important in demonstrating the interplay between institutions and development. The 1906 court ruling represented colonial institutions and the dominant culture at the time. Colonial institutions were much more concerned about the advancement of the colonial economy and not the welfare of the African communities. Thus, legal instruments and, not war, were by 1906 employed to dispossess and disempower Africans and this symbolised the entrenchment of colonial rule. These conflicts show that development progresses in contradictions. The disempowerment of the Africans by the colonial regimes is one of the challenges that the current system of innovation in South Africa has to grapple with in trying to empower those who were disempowered and implies the interaction of people in development.

The period marking the end of the 19th century and the beginning of the 20th century was marked by the growth of railways and the mining economy. This increased the demand for timber as sleepers on rail lines and props in mines. For example, the Paarl-Franschhoek rail link came into being in 1904 (Malan, 2018). Moreover, the government also encouraged the private sector to set up plantations to satisfy growing demand during this period (Malan, 2018). However, it seems that private investors were more encouraged by the positive market dynamics during this period, since they were mainly concerned about positive returns on investments. An example of early private investment was the 1902 Transvaal Gold Mining Estate's investment in afforestation which, according to Bennett and Kruger (2015), ‘’marked the beginning of serious corporate investment in plantation forestry’’ (p. 58). Moreover, the need to reduce the costs of transport and logistics resulted in some plantations being set up near the mines. This was the case with the

Maccauvlei plantation which was established near coal deposits in the Orange Free State, where plantations started in 1893 with the planting of 100 000 oak trees and were later on extended to 2000 hectares of *Pinus radiate* and *Pinus pinaster* (Bennett & Kruger, 2015). The involvement of private investors in the plantation economy was a result of their interaction with the government and the market. This points to the need for systems of innovation to consider the market dynamics, if positive returns on investments are to be realised.

Moreover, World War I and World War II also stimulated the plantation economy in South Africa. Timber supplies from exogenous sources were heavily affected by the disruptions in sea transport caused by World War I of 1914-18 (Britton, 2006). This together with the need to create employment for the demobilised soldiers from the war led to the acceleration of the afforestation programme. According to Van der Zel (1989),

> The timber famine occurring during the (first world) war years was a strong motivation after the war for the Republic of South Africa government to establish timber plantations with the object of attaining self-sufficiency within 50 years. The economic depressions in the post-war period and the unemployment (thereafter) provided the incentive for the RSA government to embark upon large afforestation schemes to provide a living to poor whites and returned soldiers (cited in Tewari, 2002, p. 4).

In a bid to achieve economic self-sufficiency the then government adopted an inward-looking industrialisation approach to protecting the nascent timber industry from international competition (Chamshama & Nwonwu, 2001). This was important in giving the emerging firms time to grow in a protected environment before being exposed to international competition. This points to the importance of policy (institutions) in economic development.

The government took the lead in the afforestation process, as the private sector was still concerned about the cost, risk, and the length of investments (Bethlehem, 2001). The government's concern about addressing the unemployment situation of the poor whites after the 1914 war resulted in the initiation of a job creation policy. In Franschhoek (Western Cape), the job creation policy resulted in a forestry industry in the La Motte and Wemmershoek region, at Robertsvlei and later in Maarsdorp in the 1960s (Malan, 2018). The interaction between the government and the poor white community was important in the growth of the plantation economy. Plantations are labour intensive; hence the availability of poor whites was important in the provision of such labour, for more hectares to be afforested. Since the process of segregation was already underway, ensuring a steady flow of black labour to the capitalist economy, the use of white labour in afforestation activities must have been largely political, to deal with the scourge of poverty and the resultant discontent among the white people in South Africa. The failure to reduce poverty among the white sections of society must have been one of the reasons behind the defeat of Jan Smuts and the South African Party in the 1924 election, by the Nationalist-Labour Pact led by JBM Hertzog.

It is important to understand the interaction of the plantation economy with other economic sectors and the politics at the time. Following the Rand Miners Strike of 1922, the leaders of the strike were rounded up by the authorities and some were sent to forestry labour camps. One such worker, John Gower arrived at the Karatara forestry plantation settlement (Western Cape) on 21 July 1922 (Caveney, 2015). Thus, the shortage of labour to advance the plantations was partly eased during this period by workers who were punished with plantation labour for having instigated the 1922 Rand Miners Strike. The reason to send the striking labourers to plantations must have been a political move to protect the mining economy from further strikes. The mining economy, which had become the backbone of the country's economy, was to be protected if it was survive, as it was already under pressure from declining gold prices in the 1920s.

The participation of the private sector in the plantation economy increased after World War I. In the 1940s, downstream private processing firms were also established. For example, in 1944, the South African All Bound Box Company opened a factory in the Stellenbosch region. Because of growing interest, the company was soon bought by Anglo-America in 1945 and operated as the General Box Company (Malan, 2018). The government's desire to provide a solution to timber shortages emanating from disruptions because of global circumstances, such as World War I, is a clear demonstration that the industry's establishment was partly a response to global circumstances.

National development strategies are thus concerns partly influenced by both domestic and international politics. Policy strategies are a result of the interaction of economies by themselves and with exogenous factors. The period up to 1914 was a great success, as a result of a convergence of factors all underpinned by the importance of interactions between the various stakeholders in the forestry SSI. The existence of strong demand for forest products coupled with the existence of a protective policy regime enabled the growth of the industry as a whole. Further, the investments by the state were crucial in the provision of the resources needed in downstream processing activities. The availability of labour from poor whites enabled much land to be put under plantations. Moreover, the growth of scientific knowledge during this period managed to clarify some of the challenges that had bedevilled the plantation economy previously. This was the case with the bioclimatic modelling that had been developed by the Cape foresters at the turn of the 20th century. As a result of these factors, South Africa's plantation forestry had reached almost 600 000 ha by 1945 (Chamshama & Nwonwu, 2001).

The 1945 World War II period and soon after was marked by continued state activity in establishing plantations and setting up processing facilities. The period witnessed massive participation by the private sector. After World War II, the private sector set up processors at sawmills using material from State-owned plantations (Chamshama & Nwonwu, 2004; Mayers et al, 2001). Also, investments were made by the private sector in plantations. By 1955, plantation forests had reached 693 000 hectares with 73 % of this owned by the private sector (Mayers et al, 2001). Private sector involvement was encouraged by government incentives and guaranteed prices (Chamshama & Nwonwu, 2004). The saw millers benefited from the cheap raw materials from state plantations and of low-cost raw material provided by state-run plantations and ‘'guaranteed minimum prices for their products through a government timber-pricing mechanism'' (Bethelhem & Dlomo, 2003). Previously, private investors had been hindered by the lack of scientific knowledge and of the insurance market. According to Bethlehem (2003), private-sector participation in the period after World War II was encouraged by three main developments. These factors were, the private sector realised the possibility of running plantations profitably on a rotation basis; the growth of insurance market had minimised some risks of the earlier period; and forestry research and innovation had addressed many of the earlier challenges (Bethlehem, 2003). During this period, production orientation was much more focused on the pulp and paper industry than had been the case previously, when much focus was on sawn timber and mining supports (Wicht, 1958). Bethlehem and Dlomo (2003) noted that, during this period, ‘'the private sector companies became more experienced and developed tremendous expertise in the manufacture of pulp, paper, and packaging, as well as certain solid wood applications'' (p. 4). Mayers et al (2001:12) are of the view that international dynamics with regard to high prices offered on pulp and paper were an incentive in stimulating private-sector participation. The 1940s to 1972 was the period when major private players Mondi and SAPPI established themselves (Bennett & Kruger, 2015). Despite increased participation by the private sector, the state continued to play a pivotal role in the industry. The government, through its various arms, provided incentives for investments in processing facilities in the form of subsidised and guaranteed loans (Mayers et al, 2001).

The government's efforts during this period were boosted by the recommendations of the 1956 Government Commission into Socio-Economic Development (Mayers et al, 2001:9, Dlomo 2003:7). The commission encourgaged regional economic development through afforestation in the homelands (Mayers et al 2001:10). Following the recommendations, large scale plantations were established in the Transkei, Ciskei, KwaZulu, Kangwane, Lebowa, and Venda during this time (Mayers et al 2001:10). These plantations were to serve for the timber needs of the people in the homelands (Mayers et al, 2001). The plantations were an attempt to rectify the destruction of the environment resulting from pressure on forestry resources emanating from overcrowding in the Bantustans. All in all, about 150 000 hectares of forest were planrted as a result (Grundy & Wynberg, 2001). However, it is worth noting that the Bantustans were not fully supported through the provision of extension services and this led to poor outcomes in terms of timber quality (Grundy & Wynberg, 2001). The 'development of underdevelopment' of the former homelands in South Africa with regard to forestry productivity can thus be partially attributed to the lack of forestry R&D emanating from limited state support during the apartheid era.

The concerted effort by the government and private-sector participation in the preceding years resulted in the forestry plantation area reaching 1.025 million hectares by 1972, with two thirds (684 000) of this in the hands of the private sector and the balance of it (341 000 hectares) in public ownership (Mayers et al, 2001). Rapid afforestation was achieved during and after this period such that, by 1994, the plantation estate had risen to 1.4 million hectares (Mayers et al, 2001). This was much a result of the government's incentive schemes to encourage private-sector participation and to stimulate export-oriented industrialisation. This period marked a change in government policy from inward-looking forest industrialisation to export-oriented industrialisation. Government incentives, including tax incentives and the General Export

Incentive Scheme under which payments of up to 5% of export values was advanced to exporters were critical in stimulating private sector participation (Mayers et al, 2001). The latter scheme provided exporters with a 5% cost advantage. To protect the young nascent industry from international competition, import tariffs ranging from 10% to 30% were imposed on pulp, paper, and board products (Mayers et al, 2001). This was important, as South Africa was still far from the technological frontier, hence the need for institutions to protect rents generated for innovative purposes until such time these private concerns could compete on their own terms internationally. This also demonstrates the importance of policy in stimulating innovation, as emphasised by the system of innovation approach.

As a result of these measures, the private sector emerged as a dominant and dynamic force with a focus mainly on paper and pulp production in the 1970s and 1980s (Mayers et al, 2001). The period was, however, marked by increasing concentration and vertical integration in the industry (Mayers et al, 2001). This was more pronounced in the paper and pulp subsector, due to the huge amount of capital requirements of the new pulp and paper investments (Tewari, 2001). Vertical integration points to a concern by investors to ensure adequate throughput in the newly established processing facilities to realise returns on investments. The concentrated drive by the government and the heightened participation of the private sector resulted in the industry emerging as an international player during this period. This was further accentuated by the acquisition of overseas assets by South African companies, such as Mondi and Sappi, which committed massive investments in forestry resources and processing capacity in the late 1980s (Mayers et al, 2001). International acquisitions, especially in Europe and Asia, were important in facilitating knowledge and skills transfers from the developed economies of Europe to South Africa. As a result of a combination of all these factors, plantation forestry extended over 1.5 million hectares in 1999 (Mayers et al, 2001).

2.17 Conclusion

Innovation occurs in the process of learning to resolve societal contradictions manifesting themselves in various forms of conflicts (Engeström, 2011). Learning is a process emanating from history and human experiences. It is cumulative such that present-day models of innovation represent the development and perfection of old learning models. Important to note is that the developments in the South African forestry sector from the 18th century were based on research, knowledge production and application. In this, the interaction of the NSI with exogenous factors was important in the acquisition of knowledge produced internationally and its adaptability to the South African environment. The triple helix of the state, the private sector and research institutions ensured the necessary collaboration required in funding the production of knowledge and its application within the forest sector. Collaboration and partnerships between the industry, the government and research organisations were paramount in capacity building and development. Thus, by the 1960s, South Africa had managed to create an integrated forestry research system (Bennett & Kruger, 2015). As a result of these developments, South Africa which did not have any natural forests, and had a few valuable stinkwoods and yellowwoods when Van Riebeeck arrived in 1652, had managed to set up plantation forests extending over 1.4 million hectares by 1994. Policies that emerged during the colonial and apartheid periods were influenced by research activities but, in turn, these policies also gave the research direction in forestry production. However, this research system began to collapse in the late 1970s as a result of the diversion of resources towards military innovation to support the war effort. The migration of senior researchers in search of greener pastures in the early 1990s and the failure to replace ageing researchers worsened the situation. Despite many measures taken by the democratic governments and the adoption of the National System of Innovation in 1996, the system is still not integrated, as there are too many projects, activities, policy fluidity, and changes without much interdepartmental coordination mechanisms in place. As noted in 2000 by the Chief Director of Forestry in the Department of Water, Agriculture, and Forestry, Leal Bethlehem, ‘’there is no collective national level in planning policy or process’’ (cited in Grundy & Wynber, 2001, p. 5).

Chapter 3: Innovation, innovation models and the systems of innovation

3.1. Introduction

This study employs the Sectoral Systems of Innovation (SSI) (Malerba, 2005) as the guiding conceptual framework. The conceptual framework is an element of the Systems of Innovation (SI) approach (Freeman, 1987; Lundvall, 1992; Nelson, 1993; Edquist, 1997) to understanding the processes of innovation and creative destruction. The central features of a system of innovation are the interactions and coordination between its various components (institutions, organisations, and knowledge systems) in the generation and application of knowledge and technologies[23] for improved processes, methods, and products in a way that boosts a firm's productivity and market entrenchment. This will automatically have a positive impact on the economy as a whole (Edquist, 2006). The emphasis on interactions between the components of a system of innovation shifts the focus away from actions at the level of individuals and isolated units within the economy (firms or consumers) towards the collective actions underpinning innovation (Chaminade & Edquist, 2010; Edquist, 2005). The approach realises that innovation by firms is not solely a result of the choices made at the level of the firm (Bergek, Jacobsson, Hekkert, & Smith, 2010). The innovation activities of a firm are determined and limited by contextual, regulatory and interactional patterns which ''persist in systemic ways and which influence how innovation may occur'' (Bergek, Jacobsson, Hekkert, & Smith, 2010, p. 115).

The importance of the SSI for this study lies in that the approach incorporates aspects of the other systems of innovation, such as the regional, the national, and the global systems of innovation. This is important for the forestry sector in South Africa, which is made up of SMEs and big firms located in regions. These firms also are forced to operate within the context of national rules, regulations and organisations, and some participate in international markets. The SSI emanates from the realisation that firms are always located in geographical settings at regional levels which are themselves influenced by the national systems and policy frameworks. In addition, regional systems interact with national frameworks and global systems. Individual actions exert an influence on these systems but are also constrained and influenced in the process (Myrdal, 1957, cited in Bergek et al, 2010). The systems approach has a focus on systems-level

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[23] This thesis adopts DU Pre's 2010 definition of technology to imply, 'the effective and efficient application of the accumulated know-how, knowledge, skills, and expertise that, when applied will result in the input of value-added products, processes and services' (DU Pre 2010, p. 9).

factors, such as system failures and blocking mechanisms, rather than on the internal blocking mechanisms within individual components, such as the firm. The problems within what could be labelled the South African System of Innovation are firstly the lack of integration (OECD, 2007), followed by ‘weak coordination, weak linkages and limited resources and capacity’ (Greenberg 2010, p. ix). These, are system-level problems that cannot be addressed by the neoclassical linear models of innovation with their focus on the firm. This highlights the importance of the SSI approach for this study.

The chapter defines innovation and systems of innovation and analyses how the SSI that is the guiding framework for this study is embedded in the NSI and the impact of that on sectoral knowledge production and application. This is important in that SSIs do not exist in isolation. A comprehension of knowledge production and application in sectors cannot be fully appreciated without an exegesis of the links to and influences from other systems.

3.2 Defining innovation

According to Smits, Kuhlmann, and Shapira, (2010), innovation is, ‘’the development and adoption of new and improved ways of addressing social and economic needs and wants’’ (p. 2). Schumpeter (1934, cited in Smits, Kuhlmann, & Shapira, 2010) defined innovation as creative destruction. Creative destruction is a revolutionising process whereby new skills, new technologies, new products or new methods and forms of production improve or displace the old, with the effect of improving efficiency and effectiveness in an organisation (Elliot 1987). The process involves ‘’new combinations of hitherto disconnected ideas, knowledge domains, technologies, or markets’’ (Smits, Kuhlmann, & Shapira, 2010, p. 2). With regards to the government, creative destruction may include the abolishment of obsolete institutions, rules and regulations, and organisations (Smits, Kuhlmann, & Teuball, 2010). This is important in South Africa, especially in redressing apartheid legacies and in determining the effects of change, continuities, and discontinuities from apartheid to democratic institutions on forestry production.

Stoneman (1995, cited in Mahdjoubi, 1997) noted that R&D (which he equated with innovation) is commonly referred to as Schumpeter’s trilogy of ‘’invention-innovation-diffusion’’ (Mahdjoubi, 1997, p. 1). According to Stoneman (1995, cited in Mahdjoubi, 1997), the process of technological change progresses in that order with the first stage of invention encompassing the development of new ideas; to the second stage of innovation involving the development new ideas into marketable products and processes; and lastly the third stage involving the diffusion of the new products and processes in the market (Stoneman, 1995, cited in Mahdjoubi, 1997). Stoneman's definition assumes linearity in innovation processes.

The process of innovation improves the efficiency and effectiveness of firms in resources usage through the introduction of new skills, methods, processes and products, thereby creating 'economic rents' giving advantages to the firms involved over non-innovating firms. Innovation may result in the emergence of new firms or the displacement of old firms whose methods would have become obsolete (Kaplinsky & Morris, 2000). Innovation is an essential feature of modern economies, as noted by Marx when he said that, ''capitalism cannot exist without constantly revolutionising the instruments of production … thereby the relations of production and with them the whole relations of society'' (Marx, as cited in Elliot, 1987). Overall, since innovation improves the performance of firms in an economy, it also improves the performance of an economy, hence an understanding of the processes of innovation may facilitate in unblocking the 'blocking mechanisms' that hinder the processes in the South African forestry sector.

3.2.1 Types of innovation

Innovation is explained at two levels, that is, evolutionary innovation (incremental innovation) and radical innovation, also referred to as revolutionary innovation or creative destruction (Stoneman 1995, cited in Mahdjoubi, 1997). Evolutionary innovations are incremental, characterised by gradual changes in products, processes, or organisations (Blind, 2010). This type of innovation mainly employs tacit knowledge that is accumulated by firms and individuals in the process of doing (Lundvall, 1992). Evolutionary innovation is embedded in the concept of learning by *doing*, *using and interacting* (DUI) developed by Lundvall to capture the incremental mode of innovation driven by experience-based learning (Chaminade, Lundvall, & Haneef, 2018:8-9, 23). Most of the technical intermediate skills acquired from agricultural and forestry colleges (NQ4 level) in South Africa and those facilitated by the SETAs are geared for this type of innovation. Most SMEs in developing countries are amicable to this type of innovation, for most of their innovation activities involve the adoption and adaptation of existing technologies (Teuball, 2010). In contrast to incremental innovation, radical innovation (creative destruction) is mainly dependent on codified knowledge generated at universities, research organisations, and science councils (Lundvall, 1992). It is the type of innovation that results in fundamental paradigm shifts in development practices. Chaminade and Edquist (2010) noted that, while firms can embark on incremental innovation on their own, radical technological innovation in most cases takes place with the support of the government. Distinguishing between these two types of innovation is important for the South African forestry sector is made up of both small firms which depend mostly on incremental innovations and big firms which depend on both incremental and radical innovations.

3.3 The linear model of innovation

The trilogy of 'invention-innovation-diffusion' (Mahdjoubi, 1997) assumes a sequential approach to innovation equitable to the linear model of innovation. The linear model implies that innovation occurs towards the end of a process that begins with research, development, and commercilisation in a sequential manner (Shapira, 2010). The model sees research, development and commercialisation processes as ''subsequent activities of institutionally and organisationally distinct units'' (Smits, Kuhlmann, & Shapira, 2010). This model considers innovation as a matter of market dynamics. It wrongly assumes the existence of perfect markets without information asymmetries and distortions that are liable to increase transactions costs in ways that may hinder investments in innovation (Graham, 2010). The linear model places much focus on the firm in innovation and ignores the importance of feedback loops, and the iterative and interactive nature of knowledge generation, product and process development, and commercialisation.

The linear model of innovation is akin to Gibbons' Mode 1 thesis of knowledge production. Mode 1 thesis argues that, before the 1980s, knowledge production was done in silos with universities, government laboratories and firms working in isolation and focusing on the production of different types of knowledge (Gibbons, 2000). In Mode 1, there is a clear distinction between basic research concerned with seeking new understanding about the world (knowledge for its own sake) and applied research (knowledge produced with a specific application in mind) (Gibbons, 2000). According to Martin (2010), Gibbons' Mode 1 was a culmination of the establishment of the Humboldtian University model in the 19th century. With the development of the Humboldtian University, research and teaching (separated from product development) came to be seen as an 'essential unity of science' with trained scientists becoming professionals in university departments (Martin, 2010). Over time, university departments fragmented on the basis of emerging disciplines, such as geography, biology, and chemistry, and university research became more academic, de-linked from applied research (Martin, 2010). In the universities, scientists did not collaborate across scientific disciplines (Martin, 2010). Thus, the university was predominantly discipline-based in terms of teaching and research with professional career researchers more dependent on their contributions to their discipline and judged by peers within their discipline (Martin, 2010). This compartimentalisation of knowledge production was augmented at the end of the 19th century with some high-tech firms in Europe establishing their own laboratories for applied research (Chandler, 1992). Firms such as AT&T, IBM, Philips, and Siemens in electronics; Lockheed, and Rolls Royce in aerospace; BASF, Dupont, Hoechst and ICI in chemicals and pharmaceuticals and British Petroleum and Shell in oil, created 'technological' knowledge and development in their industrial laboratories to produce 'inventions' which, if introduced commercially became 'innovations' (Martin, 2010). In the forestry sector of South Africa, Bethlehem and Dlomo (2003) noted that, through experimenting, ''the private sector companies became more experienced and developed tremendous expertise in the manufacture of pulp, paper, and packaging, as well as certain solid wood applications'' in the 1960s (p. 4). With these developments, the university was de-linked from the industry.

The compartmentalisation of knowledge production, application, and development was further accentuated as governments established their own laboratories in the late 19th century to conduct their own R&D in areas that were not covered by industry research, such as health, agriculture, defence, space, and energy (Martin, 2010). The Mode 1 linear approach implies a clear-cut division of labour between the university, industry and the government and that university knowledge was disciplinary. Earlier scholars of innovation were partly influenced by this understanding of knowledge production. Even early evolutionary and political economists also emphasised the role of the firm in innovation, leading Schumpeter to emphasise the role of the entrepreneur in innovation while Marx emphasised the role of the capitalist in innovation (Elliot, 1987). Nonetheless, Schumpeter and Marx differed from the neo-classical linear model in that they partly acknowledged the role of complex interactions in evolutionary systems (Nelson et al, 2018). As such, in Mode 1, innovation is defined as an isolated and fragmented activity achieved without cooperation between the government, academia, and the industry. Further, Mode 1 does not consider the non-disciplinary (i.e. trans-, inter-, and multi-disciplinary activities) nature of knowledge production.

3.4 Mode 2/Multi actor approach to innovation

According to Gibbons (2001), Mode 1 of knowledge production became diluted with the growth of Mode 2 thesis of knowledge production and innovation in the late 20th century.[24] Mode 2 is characterised by heterogeneous sets of organisations and types of researchers involved in specific contexts in problem-solving (De Besselaar & Heimeriks, 2014). Different organisational forms exist in Mode 2 and research is not exclusively based in universities (De Besselaar & Heimeriks, 2014). The researchers involved in Mode 2 are concerned with both basic research and the generation of knowledge, that can be applied in developing new technologies (Gibbons 2001:160). In relation to this, Ranga (2013, cited in Bergman, 2014) brings in the concept of an *entrepreneurial scientist* interested in advancing the frontiers of knowledge but at the same time attentive to the ‘’practical and commercial application’’ of knowledge for financial gain. This development is important as it removes barriers to innovation occurring when different people in the different components of a system of innovation carry out basic and applied research separately. One of the characteristics of the entrepreneurial scientist is the zeal to cooperate with other scientists within and across disciplines and with the end users of knowledge and technologies in the generation and application of knowledge. Under Mode 2, knowledge production is done with little regard to disciplinary boundaries (De Besselaar & Heimeriks, 2014).

Knowledge production in Mode 2 may involve multi-disciplinary, inter-disciplinary or trans-disciplinary research, bringing ‘’together researchers from different disciplinary or technological backgrounds with ‘different theoretical and conceptual approaches, techniques, methodologies, and instrumentation, and perhaps even different goals and motivations’’ (Martin, 2010, p. 26). Despite the subtle differences in the meaning of these terms (*inter, multi, trans*), De Besselaar and Heimeriks (2014) defined them as non-disciplinary, by which they mean the combination of elements from various disciplines involving the interaction of researchers across disciplines in solving problems. As a result of these developments, innovation is increasingly being seen as

[24] Gibbon’s concept of Mode 2 is not a replacement of Mode 1, but a phenomenon that has emerged and sits alongside Mode 1. It requires Mode 1 to be in existence so that it can take Mode 1 disciplines into the field of practice and generate inter-disciplinary Mode 2 knowledge.

negotiated at multi-levels. The consideration of innovation as a multi-actor, multi-level, and multi-system activity has implications for understanding the challenges with regard to innovation. It removes the focus from the firm to challenges in the interaction between actors and among the components of a system. This is important for this study meant at understanding the lack of integration (OECD, 2007) and the existence of 'weak coordination, weak linkages, and limited resources and capacity' (Greenberg, 2010) in the South African forestry SSI, which cannot be addressed by a focus on individual components in a system.

However, to regard Mode 2 or the multi-actor activity to R&D as a new approach to innovation emerging in the 1980s, as done by Gibbons (2000), would be ahistorical and amounts to a distortion of reality. For example, Freeman (1997) noted that, the superiority of Britain's system of innovation during the first industrial revolution was a result of the strong links between the science, industry and the political systems (Kuhlmann, Shapira, & Smits 2010). In addition, Martin (2010) noted that, during the British Industrial Revolution, networks of industrialists, inventors, engineers, and natural philosophers were central in the acquisition and sharing of the knowledge required to develop important innovations. Further, Thomas Edison's design and development of an innovative electric lighting system in New York at the end of the 19th century was influenced by ‘’a series of mediating economic, social and political institutions and organisations’’ (Shapira, Smits, & Kuhlmann 2010, p. 450). The example of the British Industrial Revolution and that of Thomas Edison's electric lighting points to the fact that knowledge production and application have generally been intertwined. Gibbons' (2001) Mode 2 should be considered a resurgence of an approach that existed before the rise of the Humboldtian University in the 19th century rather than a new approach to knowledge production, application, and development.

3.4.1 Factors in the resurgence of Mode 2

The resurgence of the multi-actor approach to knowledge production starting from the 1980s was mainly a result of the global economic crises of the late 1970s (Martin, 2010). The crises of the 1970s made it difficult for governments to cope with problems of inflation, unemployment, and stagnation (Martin, 2010). The crises changed the institutional environment in which research and knowledge production take place. Due to hardships accompanying the crises, many corporations previously active in research and innovation were forced to cut back on investments in R&D or outsource their research to universities or to specialised organisations (Martin, 2010). Outsourcing led to increased interaction between corporates and research organisations. Further, globalisation during this period opened up economies to market capitalism, leading to increased economic competition (Held & McGrew, 2005). This had two important effects on companies' strategies. The first was for firms to embark on innovation to counter competition from low-cost economies (Martin, 2010). The second was to expand across borders by buying foreign companies, especially in countries where skills were developed and where the cost of labour was cheap, like China (Martin, 2010). The second option had major implications for STI policy and practice, as governments had to ensure that the local knowledge base is strong enough to attract foreign investment (Shapira, Smits, & Kuhlmann, 2010). These developments account for the rise of Southeast Asian countries, such as China and India, as competitive producers of new knowledge and as centres of innovation at the dawn of the 21^{st} century (Lundvall et al, 2006). Further, the period starting from the 1970s witnessed a growth of multi-national companies. For example, the leading forestry companies in South Africa, such as SAPPI and Mondi, made some acquisitions in Europe and Asia (Mayers et al, 2001). International acquisitions, especially in Europe and Asia, were important in facilitating knowledge and skills transfers from the developed economies of Europe as South Africa was still far from the technological frontier.

The emphasis on scientific and technological knowledge and skills as the basis for developing competitive economies pushed nations towards more knowledge-intensive societies or the 'knowledge economy'. The World Bank (2014) defined the knowledge-based economy (KBE) as an economy, ''where organisations and people acquire, create, disseminate, and use knowledge more effectively for greater economic and social development'' (p. 45). The knowledge economy is thus defined by the development of critical skills and the production and application of knowledge to improve functions and processes through innovation (CHE, 2016). Moreover, another feature of this period was the growth in the scale of higher education and the increase in the number of academics in need of research funding in addition to their teaching activities (Martin, 2010). All of this occurred at a time when research costs were rising and when governments were cutting back on public spending. For example, the Thatcher government in the United Kingdom downsized the government and its spending during this time. Pressure on public resources led to demands for transparency and accountability in areas of government spending, including research. This factor led to the ''growth of evaluations and the use of performance indicators'' in research activities (Martin, 2010). According to Martin (2010), these developments led to a tight social contract between the government and the university, with expectations that public funding of research should yield benefits to the economy and society.

As a result of the developments, the earlier 'loose' social contract between science and society in Mode 1 characterising the decades soon after World War II was replaced under Mode 2 by a tighter social contract with more direct expectations that public funding of research should yield benefits to the economy and society (Martin, 2010). In addition, this period witnessed a growing public concern over the risks associated with some scientific and technological activities, such as nuclear energy and genetically modified crops. This concern increased public interest in research, making society an important component in the research activities of the scientists.

These developments led to the emergence of Mode 2. Moreover, globalisation, outshoring and international acquisitions starting from the late 1970s, led MNCs to interact and to exploit knowledge from sources far away from their home countries (Chandler, 1992). Despite the pressures on public spending during this time, some governments were compelled to invest in their knowledge systems in order to make their economies more competitive and to attract foreign investments (Martin, 2010). However, the need to see to it that research yields benefits to the economy and the society at large led to the growth in interactions between the government and universities and research institutes (Bergman, 2014). The government had to institute legal frameworks governing research activities in areas such as genetically modified organisms (GMOs) and nuclear energy (Kuhlmann, Shapira, & Smits, 2010). As such, research becomes a multi-actor interactional activity based on collaboration and partnerships, leading to networks in knowledge production, application, and development. These developments led to the growth in popularity of the Systems of Innovation approach, starting from the 1980s as the performance of R&D was increasingly defined in terms of interactions between the components involved in knowledge production, application, and development in a country. Countries that were able to build bridges between the components of their systems of innovation and to integrate and coordinate their R&D activities, such as China, India and Brazil, experienced rapid economic growth, starting from the decade ending the 20th century and the beginning of the 21st century (Shapira, Smits, & Kuhlmann, 2010). These countries' integrated systems of innovation managed to provide for bodies, facilitating interactions, and transactions between individuals and other actors (Shapira, Smits, & Kuhlmann, 2010:454). Smits, Kuhlmann, and Shapira (2010) noted that ‘’leading innovation systems are based on well-established exchange relationships among the institutions of science and technology, industry and the political system’’ (p. 3). Freeman (1997) also noted the importance of an integrated system of innovation in relation to developments in Britain and Germany during the first and the second industrial revolutions. Freeman (1997) noted that, during the first industrial revolution, Britain experienced rapid economic development because its system of innovation was more integrated because of the strong links between the industry, knowledge producing organisations and the political system (Shapira, Smits, & Kuhlmann, 2010). Freeman (1997) further noted that Germany experienced rapid growth during the second industrial revolution because the establishment of strong connections between the economic, political, and social-cultural components had enhanced the German system of innovation (Shapira, Smits, & Kuhlmann, 2010). Freeman (1997) explained Britain’s dismal economic performance during the second industrial revolution in terms of the erosion of its system due to the growing disconnection between the economic, political, cultural and scientific components of its system of innovation (Shapira, Smits, & Kuhlmann, 2010).

3.5 The System of Innovation approach

The system of innovation concept emerged in the 1990s from the works of Freeman (1987), Lundvall (1992), Nelson (1993), Edquist (1997) and others. According to Chaminade and Edquist (2010:99), the approach has its foundation in evolutionary theory (Nelson & Winter, 1982). The approach was also influenced by institutional economics (North, 1990) and sociology (Granovetter, 1985). The SI approach emerged as a response to the growing understanding of the importance of interaction in knowledge production, application, and development, as espoused by Mode 2, or the multi-actor approach to knowledge production. The Mode 2 thesis of knowledge production exposed the inadequacy of the neoclassical linear theory in explaining innovation processes (Lundvall, 1992). The building blocks of the SI (theory, policy, and practice) highlight the limitations of neoclassical theory and provide alternatives.

The SI approach emphasises the fact that firms do not innovate in isolation but in continuous interactions with other organisations in the system at regional, sectoral, national, and supranational levels (Edquist, 1997, 2005; Lundvall, 1992). As such, innovation cannot be purely understood in terms of independent decision making at the firm level, as the firm’s options are determined by environmental factors and collaborative patterns, regulatory systems and customary practices that influence how innovations occur. According to Bergek et al (2010), the premise of systems theories is that ‘’system conditions have a decisive impact on the extent to which firms make innovation decisions, on the modes of innovation which are undertaken and, on the success, or failure of these’’ (p. 115). The system approach, therefore, implies that the lack/failure of innovation in an economy can be explained in terms of system failures (Smith, 2010) or blocking mechanisms (Bergek, 2010) that hinder interaction between the components of a system and the individuals making up these components. The blocking mechanisms are to be found in the interaction of the cultural, political, and economic subsystems of a society. The systems approach is very useful for this study as it allows us to focus on and analyse the lack of integration in the South African forestry sector (OECD, 2007). It allows us to assess how ‘weak coordination and linkages and limited resources and capacity’ (Greenberg 2010), which are systemic failures, are limiting the performance of forestry R&D in terms of realisable benefits to the economy.

The systems approach hinges on the fact that innovation can no longer be the privilege of a mastermind discoverer operating alone in isolation, but is a multi-actor activity in a system of innovation (Smits, Kuhlmann, & Teuball, 2010). The systems’ approach rejects linearity in innovation as it acknowledges that, ‘’firms do not innovate in isolation but in complex relations characterised by reciprocity and feedback mechanisms’’ (Edquist, 2006). Innovation is thus considered a complex interactive process by which a number of actors working together produce an innovation in the process of interaction. These complex activities also define Gibbons’s (2001) Mode 2 of knowledge production. However, for the interactions between various actors to be beneficial, there is a need for coordination for the system to be integrated (Goedhuys et al, 2015).

The implications of this approach are that it is vital to establish forums or intermediary bodies to facilitate debate and the exchange of ideas among the heterogeneous actors on innovation needs and potential (Dalziel, 2010). An economy has to provide for mechanisms to enable the flow of information among the players in the system. Intermediary organisations should be constituted to enable exchanges between the producers and the end-users of innovations.

Kuhlmann and Shapira (2010) noted of the co-evolution and interdependence of innovation theory, policy, and practice as emanating from the interactions between the various actors in a system of innovation. These various actors interact with each other with the aim of influencing technological developments, directions and goals. Firms are more interested in the production and commercialisation of technologies to improve their competitiveness and to generate financial returns. The NGOs may pursue health improvement or environmental protection. The national governments and their agencies may have a focus on issues pertaining to inclusivity, resource sustainability, economic regulations, and their implementation. Interactions and coordination are therefore crucial for information flows, in building consensus and in reconciling the conflicting goals of the different players in a system.

Most of South Africa’s policy frameworks, such as the White Paper on Science and Technology (DCAST, 1996, strongly influenced by Mode 2 thesis), the Human Resource Development Strategy (2001), the National Research and Development Strategy (2002), the Department of Science and Technology’s 10 Year Innovation Plan (2008), the National Development Plan (2011), recognise that innovation is a multi-actor activity requiring systems integration and coordination to enable the exchange of knowledge among the various players involved. These frameworks also emphasise the importance of mediating organisations to enable interactions between the various players. This is important for Freeman (1997) noted that the British system was superior during the first industrial revolution because of the links in the triple helix of the state, industry, and knowledge producing organisations (Kuhlmann, Shapira, & Smits, 2010). However, despite its innovation policy frameworks’ consideration of most of the important issues raised by the system approach, South Africa’s system of innovation continues to be marked by a lack of integration, with weak coordination and linkages.

When thinking about tackling these ongoing challenges, it is important to consider Kuhlmann, and Shapira’s (2010) observation that successful systems of innovation develop their special competitiveness and strength gradually over decades or centuries. South Africa experienced institutional ruptures of creative destruction in its transition to democracy in 1994. Taking this into consideration, it is possible that South Africa’s system has not yet matured. Further, Kuhlmann and Shapira (2010) noted that national, regional, and sectoral systems and technological specialisation and transimission are rooted in the long history of interactions between the industrial, political, scientific, and socio-cultural institutions of a society. These interactive relationships affect the capabilities of the actors in knowledge production and the capacity of the state to invest and to regulate.

The historical dimension is therefore crucial in South Africa, especially as the legacies of apartheid remain with us despite the profound institutional changes that occurred at the end of Apartheid. We also have to acknowledge that, at the dawn of democracy, South Africa was faced with an extreme shortage of skilled labour (Natrass, 2014). This would obviously have affected its ability to generate and diffuse the knowledge required to spur innovation for the benefit of the economy and society. Some of the building blocks of the South African system of innovation are not yet strong, as the process of capacitation and stabilisation may take decades or centuries.

3.6 Building blocks of innovation systems

Chaminade and Edquist (2010) noted that the building blocks of a system of innovation are Institutions (Policy); Learning and knowledge generation (Theory) and Organisations and capabilities (Practice). This section considers each of these building blocks and how they relate to the South African challenge of building a more effective innovation system in the forestry sector.

3.7 What are institutions and how do they work?

In defining *institutions*, the system of innovation scholars borrowed much from the work of institutional economists, such as North (1990), and from the work of sociologists, such as Granovetter (1985). According to North (1990) ‘’institutions are the rules of the game in a society or … humanly devised constraints that shape human interactions’’ (p. 3). North (1990) went on to emphasise that institutions ‘’structure incentives in human exchange, whether political, social or economic’’ (p. 3). Systems of Innovation scholars’ understanding of institutions is more aligned with North’s (1990) definition. For example, Edquist and Johnson (1997) defined institutions as, ‘’sets of habits, norms, routines, established practices, rules or laws that regulate relations and interactions between individuals, groups, and organisations’’ (Edquist, 2006, p. 187). Also, Scott (1995) conceptualises institutions as ‘’sets of rules’’, regulating the behaviour of actors for the stability of a system. The above definitions differ from Nelson and Rosenberg (1993), who conceptualise institutions to mean different kinds of organisations. Nonetheless, Nelson and Rosenberg's (2006) definition fails to distinguish the players from the rules that govern their behaviour. North (1990)'s definition is more apt for this study for it differentiates the players of the game from the rules that govern them. North (1990) and his followers thus create a clear distinction between institutions and organisations. This study employs the definition of North (1990) in trying to understand how the 'rules of the game', as in policies and regulations at national and sectoral and international levels, encourage or hinder certain behaviours by forestry firms in innovation processes.

Institutions have three main functions in a system, which are (a) reducing uncertainty by providing information; (b) managing conflicts and collaboration; and (c) providing stimuli (Edquist, 1997). The system scholars believe that innovation can only be spurred if information and knowledge are diffused in a system. They also believe that institutions assist in building trust between collaborating partners by formalising agreements (or contracts) as a way of managing conflicts that may arise between partners in the process of innovation, especially with regard to the sharing of intellectual property (IP).

All of this is relevant to the South African situation. For example, the laws and accepted practices that have emerged out of the pursuit of broad-based black economic empowerment have created a complex set of incentives, one of which is the participation of SMEs and of formally disadvantaged groups in the economy. In South Africa, many institutions and policy frameworks have an impact on forestry productivity. These include the Constitution of the Republic of South Africa (1996), the Reconstruction and Development Programme (RDP) (1994) which aims to alleviate poverty; the Rural Development Strategy (RDS 2000) which hopes to provide an enabling environment for the expansion of rural livelihoods, and the Integrated Programme for Land Redistribution and Agricultural Development (2009).

Economic behaviour should therefore be primarily understood as a function of institutions. Certainty is important for investment-related decisions. Policy interventions are also necessary to unblock the blocking mechanisms as exclusion from participation, as is the case in South Africa with its history of apartheid. This is important, especially when taking into consideration that the South African forestry sector has big and vertically-integrated firms. This vertical integration could have the effect of clogging the space for small businesses, especially in relation to the sourcing of timber required for their operations. If this is the case, it may be necessary to create regulatory institutions to ensure that small businesses are not unfairly disadvantaged.

In South Africa, the most important institution is the constitution, with its focus on the transformation of apartheid structures for inclusive and equitable development. Apart from the constitution, innovation policies affecting all sectors are the domain of the Department of Science and Technology (DST), with its policies that encourage collaboration between universities, the industry, and other agencies in the national system of innovation. Such policy frameworks include the White Paper on Science and Technology (1996), The Innovation Fund (1999), and the Ten-Year Innovation Plan (2008-2018). The White Paper (1996) encourages collaboration between universities and other agencies in the national system of innovation (Peterson & Rumbelow, 2008). The Innovation Fund (1999) promotes ‘’technological innovation and transdisciplinary collaboration within the research community by encouraging and supporting longer-term, large-scale, collaborative innovation projects in the higher education sector, government science councils, civil society, and the private sector’’ (Peterson & Rumbelow, 2008, p. 4). The Ten-Year Innovation Plan (2008-2018) provides a strategy for the promotion of innovation for socio-economic development by ‘’improving access to finance, creating an innovation-friendly regulatory environment and strengthening the NSI’’ (p.v). Further, the Department of Trade and Industry’s (DTI) policies encourage innovation for economic development. The DTI’s Technology and Human Resources for Industry Programme (THRIP), launched in 1991, promotes collaboration between higher education and industry in the development of human-resource skills for understanding, adapting and using new knowledge and technologies (Peterson & Rumbelow, 2008). The National Research Fund (NRF) manages THRIP on behalf of the DTI (Peterson & Rumbelow, 2008).

Forestry production is mainly a rural economic activity and, for this reason, it is influenced by policies from the Department of Agriculture, Forestry and Fisheries (DAFF), and the Department Rural Development and Land Reform (DRDLR). As a land-use activity that relies on rainfall and that transforms the landscape and, in the process, affects water resources, the environment, and bio-diversity, forestry activities are also governed by policies emanating from the Department of Water and Sanitation (DWS), and the Department of Environmental Affairs (DEA). With regard to South Africa, it would also be important to understand how the new institutions following the transition to democracy in 1994 affected the economy. Some of the institutions with an impact on forestry production include the water policy as governed by the National Water Act 36 of 1998; the Environmental policy as enunciated by the National Environmental Management Act (NEMA) 107 of 1998 and the Labour policy as enunciated by the Labour Relations Act (LRA) of 1996, the Basic Conditions of Employment Act (BCEA) 75 of 1997, the Employment Equity Act 55 of 1998, and the Extension of Security of Tenure Act (ESTA) 62 of 1997. Strategies aimed at encouraging small businesses, such as the Integrated Small Enterprise Development Strategy (ISEDS *for 2005-2014*), Broad-Based Black Economic Empowerment (Act 53 of 2003) and strategies aimed at increasing participation in education, such as the National Plan for Higher Education (2001), also impact on forestry production. As with all sectors in need of transforming the apartheid patterns of production and accumulation, the forestry sector has seen a number of policies aimed at promoting economic inclusion through broad-based black economic empowerment. There also exist sectoral policies, such as the Forestry Transformation Charter (2007), aimed at achieving economic inclusion through the development of small businesses. All of these have had an impact on the dynamic capabilities of forestry-sector-based firms in South Africa.

However, in relation to innovation, one would ask whether these policies have created an environment that is conducive, allowing for collaboration and the exchange of knowledge and information important in innovation. The policies governing forestry innovation emanate from different departments, hence the need for cross-departmental collaboration and coordination. As cautioned by Goedhuys et al (2015), the cross-departmental and cross-sectoral nature of innovation require policy to be “multi-faceted and complex, involving aspects of education policy, industrial policy, international trade policy, and various other institutional reforms, good coordination between ministries and between the private and the government sectors is therefore essential” (p. 85).

Bergek et al (2010) noted that contextual factors such as the nature of networks, collaboration, legal systems, and cultural practices constrain the strategic options of a firm. Bennett and Kruger (2015) noted the lack of collaboration in the forestry system of South Africa, which is affecting production. Thus, systems theorists are of the view that systemic conditions impact firms’ innovation decisions to innovate and on the nature of innovations and the failure or achievement of these innovations.

3.7.1 Property rights

Property rights institutions have also become paramount in forestry resource development in South Africa, especially in relation to the ongoing land and agrarian reform programme and its impact on forestry investments. The importance of property rights institutions in economic efficiency has been emphasised throughout history. It had been acknowledged since the time of Greek city-states, when Aristotle noted that communal property rights regimes were inefficient when compared to individualised property rights regimes. Aristotle despised communal tenure institutions, arguing that:

> for that which is common to the greatest has the least care bestowed upon…everyone thinks chiefly of his own, hardly at all of the common interest and only when himself is concerned as an individual … For besides other contradictions, everyone is more inclined to neglect the duty that he expects another to fulfill (cited in Ostrom, 1990, p. 2).

The conclusion by Aristotle with regard to inefficiencies of communal tenure was also arrived at by Garret Hardin in the Tragedy of the Commons (1968) and by Von Mises (1949) who noted that, if property is commonly owned,

> Although legal formalism may call it public property, it is used without any regard to the disadvantages resulting. Those who are in a position to appropriate returns … do not bother about the later effects of the mode of exploitation. For the erosion, depletion of soil, and depletion of the exhaustible resources and other impairments of the future utilisation are external costs not entering into their calculation of input and output. They cut trees down without regard for fresh shoots or reforestation (p. 639).

An understanding of property rights regimes is therefore important in South Africa in discerning the reasons behind the degradation of communally owned forestry plantations (AgriSETA, 2016) in areas under traditional authorities while those owned by corporates, such as Mondi, SAPPI and Merensky, are well maintained. Different types of institutions determine people's behaviour differently in terms of innovation, in resources exploitation and with different economic outcomes. Some institutions incentivise innovation and economic efficiency while others unintentionally discourage resource efficiency and innovation. Generally, it is believed that individualised property rights are more secure and economically efficient for people are more incentivised to take care of and to improve their own properties than those that are communally owned (World Bank 1998; De Soto, 1989, 2000; Acemoglu et al, 2004).

More so, and with regard to SMEs, De Soto (1989, 2000) basing on his study of Peru, has argued that formalised (registered) property is more efficient than informalised (unregistered) property. According to De Soto (2002), in poor countries, capitalism can be made to work through institutional reforms. De Soto argues that in these countries the poor hold assets worth trillions of dollars in the form of houses, buildings, land, and small businesses. The lack of development in these countries, according to De Soto (1989), is a result of the cumbersome and undemocratic bureaucratic institutions that do not incentivise the formalisation of the poor people's assets. These institutions compel the poor to operate in the 'extra-legal' or the informal sphere where they could not link up with financial and skills development organisations important in building their capabilities. Moreover, by operating in the informal sector, the poor's unregistered properties cannot be used as collateral to secure loans from banks to capitalise their businesses. Institutions may, therefore, limit the innovative potential of many poor entrepreneurs by denying them the opportunities existing in the formal sector, hence impacting negatively on their potential to upgrade their businesses. As such, De Soto noted that:

> Because they (poor entrepreneurs) have no secure property rights, they cannot issue shares. Because they have no patents or royalties, they cannot protect innovations. Because they do not have access to contracts and justice organised on a wide scale, they cannot develop long-term projects. Because they cannot legally burden their assets, they are unable to use their homes and businesses to guarantee credit (De Soto, 1989, p. 5).

As a result of this, the poor's assets, according to De Soto (1989), constitute ''dead capital'' as they cannot be easily converted into liquid capital for the generation of more capital. Acemoglu, Johnson, and Robinson (2004) emphasised that ''economic institutions influence investments in physical and human capital and technology and the organisation of production'' (p. 2). The land

and agrarian reforms and their impact on property rights are some of the factors discouraging investments in the sector at the moment in South Africa. The land and agrarian reforms, together with the bureaucratic hurdles discouraging the formalisation of SMEs, are issues impacting negatively on building the capabilities of forestry-based firms.

3.7.2 Intellectual property rights

Further, institutions may influence the level of innovation in an economy. For example, intellectual property rights (IPR) regulations may incentivise innovation by protecting the rights of innovators, making it possible for firms to appropriate the benefits of their innovations (Chaminade & Edquist, 2010). Since innovation is regarded as a collaborative enterprise, this has brought in a number of new challenges, particularly in relation to trust and the protection of IPR in networks of collaborating companies. Dankbaar and Vissers (2010) are of the view that, to solve issues pertaining to trust where innovation is a result of collaborative work, formal agreements have to be made to prevent undue benefits accruing to individuals. Different countries have introduced IPR laws in order to deal with problems pertaining to IP ownership. In South Africa, the nature of interaction and transfer of knowledge between public research institutes and organisations are governed by the Intellectual Property Rights of Publicly Funded Research and Development Act (5) of 2008. Policies such as this may incentivise innovation by allowing firms and individuals to consider the results of their own R&D and those of others as products that can be bought and sold. IPR laws may provide guidelines on how firms can buy IP from others, if they can use it or may sell their own IP if they have no use of it. This greatly incentivises innovation for in the past many unused IP had to stay on shelves but now companies may profit from the sale of their IP (Dankbaar & Vissers, 2010). However, though IPRs may solve the problem of appropriability, they may lead to systems failures by introducing barriers to knowledge and information flows (Chaminade & Edquist, 2010).

The disadvantage of this development is that IPRs may limit the diffusion of knowledge to particular segments of a community. When knowledge production is linked to the profit motive and the ability to consume, knowledge ceases to be a public good (David, 2006). Only established firms with the financial capabilities to consume may end up having access to new and important knowledge generated by researchers and innovators (David, 2006; Mushangai, 2015). SMEs and those in the informal sector with fewer financial resources may end up being disadvantaged with regard to accessing advanced knowledge, hence limiting their innovative potential to contribute to the economy as a whole. The profit motive may also affect the quality of the knowledge produced, for it makes knowledge production more secretive in nature which limits research being exposed to standard protocols, such as peer review mechanisms (David, 2006). There is, therefore, a need for political institutions to ensure that knowledge production does not completely become secretive for all players in an economy to benefit from new knowledge coming from universities and other knowledge-producing organisations.

2.7.3 The burden of regulation

De Soto (1989) noted the burdens of institutions with regard to formalised SMEs. Once formalised, the SMEs are compelled to pay a variety of taxes, levies, and fees. They have also to adhere to strict legal regimes in terms of labour laws, environmental laws, and a plethora of other regulations. Thus, the immense bureaucracies and legal strictures, mostly in developing countries, are behind the growth of market distortions and high transaction costs, which make it difficult for most SMEs to operate successfully within the legal sphere (De Soto, 1989). The solution to these challenges, according to De Soto (2000), lies in the deregulation, debureaucratisation and simplification of the legal strictures to allow the SMEs to formalise their businesses and to operate unfettered in an open-market environment.

South Africa has attempted to incentivise small business formalisation and to lessen the burden of operating in the formal sector by the SMEs, through a number of acts and policy frameworks. Despite the measures formulated to lessen the burden of regulation and ensure the ease of doing business, both big and small firms in the forestry sector of South Africa are still burdened by a number of regulations, such as the water licences, environmental laws, and labour laws. These regulations are necessary to protect labour and the environment, in line with the International Standards Organisation (ISO) and the Forest Stewardship Council (FSC) standards, but they make it difficult, especially for small businesses trying to stand on their own feet, to operate profitably.

System failures or blocking mechanisms (Bergek et al, 2010) may therefore be a result of an institutional set-up that does not provide the right stimuli for innovation processes. Policies may incentivise or hinder innovation processes. Policies should therefore, strive to achieve a balance on conflicting matters pertaining to innovation.

3.7.4 Globalisation and international institutions

Smith (2010) noted the argument that globalisation and the resultant integration of capital and product markets is affecting the capacity of the state in playing its regulatory functions. Accompanying globalisation processes has been a growth in the number of institutions in trans-national bargaining and regulation, such as the Trade-Related Intellectual Property agreement (TRIPS) and General Agreement on Trade in Services (GATS), and Trade-Related Investment Measures (TRIMS), all negotiated inside the World Trade Organisation (WTO). South Africa became a member of the WTO in 1996, following the demise of apartheid and, with it, the end of international isolation (Webster & Sikwebu, 2010). In line with the dictates of the WTO, South Africa opened its economy to international competition through the removal of tariff barriers and entered into trade agreements with other regions of the world (Webster & Sikwebu, 2010). The reintegration of South Africa into the international community, starting from the 1990s, exposed the once-protected South African economy to the vagaries of international competition, placing a huge demand on South African forestry firms to adopt world-class operations to compete successfully in a globalised world (White Paper, 1996). Innovations may thus be a matter of exogenous pressures. Moreover, in the forestry sector, the ISO and the FSC regulations compel local forestry-sector-based firms to comply with international standards and protocols with regard to environmental protection and labour rights, if they are to access the lucrative markets in Europe and America (Mayers et al, 2001). Further, in global value chains, governance issues are mainly the prerogative of the big firms (Mitsuhashi, 2006). South Africa has big firms, such as Mondi and SAPPI that are leaders in forestry value chains globally but interact within their national environments with other firms and SMEs. Some of these networks are quite hierarchical and the leading companies may impose some rules that may limit innovation by small firms while other networks are more horizontal, allowing firms to learn from each other (Mitsuhashi, 2006). This factor will be analysed in Chapters 6 and 7 in relation to partnerships in the South African forestry sector between the big firms and SMEs. All of these issues have to be taken into consideration in understanding the processes of and challenges to innovation in the South

African forestry sector. To resolve some these challenges, the systems approach emphasises the management of innovation in networks.

3.7.5 The need for reflexive governance

The institutional and policymaking processes should be reflective of innovation system dynamics and strive to achieve a balance between conflicting interests. This calls for reflexive governance, aiming at continuous interactions and interventions in ongoing changing environments. In areas pertaining to water management and environmental protection, the actors involved are the government, companies, and sometimes consumers. For the development of regulatory frameworks encouraging innovation and sustainability, a balance has to be found between the economic interests of the forestry-sector-based companies, some of which would have ‘’already started to change from short-term interests to sustainable paths and the long-term…requirement for the protection of the environment and natural resources’’ (Blind, 2010, p. 236). This should also take into consideration the capabilities of SMEs to meet the requirements. As such, a policy should provide for intermediaries allowing for negotiations and renegotiations, for negotiated compromises to be achieved for the benefit of the economy as a whole. If possible, policy should be tiered, considering the differences in capabilities between the big established firms and small firms still struggling to stand on their own in the sector. The success of a system of innovation is partly based on interactions to generate broad understanding, hence consensus building and the avoidance of conflicts. This requires ‘embeddedness’ as articulated by the sociologist Granovetter (1985) in relation to the need for close interrelationships between individuals and organisations in society, as defined by both formal and informal ‘rules of the game’ existing at different scales of a system (Lam, 2004). The systems of innovation approach is therefore important for this study because it takes into consideration the importance of evolution and of designing a mix of policy instruments to solve the problems once identified in ongoing interactions.

Public policy can act as a catalyst by organising multi-actor foresight processes (for example, Sector Education and Training Authorities, SETAs, and the Labour Market Intelligence Partnership, LMIP, in South Africa) or providing support for intermediary organisations enabling interaction between government, firms, and users of innovative achievements. Kuhlmann and Shapira (2010) defined *policy* as any policy undertaken to address issues of public concern.

Public policies are therefore those developed by governmental bodies and officials in dealing with matters of public concern (Kuhlmann & Shapira, 2010). Chaminade and Edquist (2010) defined innovation policy as ‘’the public actions that influence innovation processes, i.e. the development and diffusion of product and process innovation’’ (p. 97). For consensus building, policymaking demands consultation and the participation of a number of stakeholders. Here, the political notion of governance provides an important heuristic for understanding interactions in relationship building between members across the components of a system of innovation. Governance relates to the ‘’dynamic interrelation of involved actors, their resources, their interests and power, for a debate and arenas for negotiation between actors, rules of the game and policy instruments applied’’ (Kuhlmann & Shapira, 2010, p.11). The governance heuristic assist in comprehending public policy constrains in relation to contexts and the available options especially in the forestry sector of South Africa, which is composed of unequal participants, such as informal SMEs, formalised SMEs and big firms operating at a global scale.

However, systems and their institutions develop over decades and centuries and are slow to change (Dankbaar & Vissers, 2010). Moreover, the structural elements of a system, such as the educational system, the universities, the industrial structure, industrial relations, and the role of the state, culture, social legislation, and traditions of entrepreneurship are wholly national in character (Dankbaar & Vissers, 2010). They are built up largely using national resources in national contexts. An understanding of innovation processes would thus require an understanding of the nature of the interaction between endogenous institutions and exogenous institutions and how they influence each other and this should be done through historical and evolutionary lenses. The issues relating to institutions are important in comprehending the challenges with regard to innovation in South Africa, hence the importance of the SSI, for it considers both the local and international dimensions and historical dimensions in innovation processes. The importance of institutions in economic activity differentiates the SI approach from neo-classicism, which regards markets as supreme despite the existence of market imperfections and their negative impact on economic undertaking related to information asymmetries, market distortions and high transaction costs that hinder the application of R&D by economic agents. In line with the SSI, this study is centric to the notion that capabilities are interactive and determined by the social context in which market relations are embedded, rather than taking innovations as ‘’manna from heaven’’ to be appropriated ‘’off the shelf’’ (Lall, 2004) by firms as implied by the neo-classical. Moreover, innovation is not wholly dependent on endogenous capabilities, as the evolutionary economists would like to believe, but is a matter of both endogenous and exogenous dynamics, as rightly posited by the SI approach. The SI scholars have taken note of the fact that firms 'rarely innovate' based on their internal knowledge (Bergek, et al, 2010), though such capabilities are essential, especially for technological absorption and adaptation.

3.8 Organisations and capabilities

Organisations constitute another important building block of a system of innovation (Malerba, 2004). Organisations are consciously created formal structures with clear purposes (Helfat et al, 2007). Firms are one of the most important organisations in an SI. Other organisations in the SI are there in most cases to create an environment conducive for firms and communities to embark on innovative activities. The SI has to enhance entrepreneurship to create new firms and to diversify existing firms (Edquist, 2006). Once firms are created, they need to have capabilities to absorb new knowledge and technologies to innovate to create rents. Firms have to adapt to be able to exploit changes in their business environments. For this to happen they need to have capabilities to absorb, generate or to combine elements of existing knowledge in order to embark on new processes to generate new products or take on new functions. Helfat et al (2007) have argued that:

> Creating, adapting to, and exploiting change is inherently entrepreneurial, for large and small, for old and new … To survive and to prosper under conditions of change, firms must develop the dynamic capabilities to create, extend, and modify the ways in which they make their living (p.5).

A firm needs to assemble its resources, both tangible (such as land, machines and capital) and intangible (for example, knowledge bases and networks), which are part of its capabilities to enhance these competencies through technological, organisational and strategic innovation. *Capabilities* refer to the capacity to accomplish certain tasks and activities (Helfat et al 2007). Teece, Pisano, and Shuen (1997, cited in Helfat et al, 2007) have taken dynamic capabilities to mean a ''firm's ability to integrate, build, and reconfigure its internal and external competencies to address rapidly changing environments''. The ability of a firm to employ or change its tangible and intangible resources in opening strategic options is a critical capability in mapping new ways to improve competitiveness (Helfat et al, 2007).

Other definitions of dynamic capabilities include that of Eisenhardt and Martin (2000) who defined dynamic capabilities as the ‘’firm’s processes that use resources…to match and…create market change’’ (p. 1107). Eisenhardt and Martin (2000) identified such things as the ability to change the market, ability to respond to external pressures, ‘’product development routines’’, alliances and ‘’acquisition capabilities, resource allocation routines, and knowledge transfer and replication routines as examples of a firm’s dynamic capabilities’’. Zollo and Winter (2002) emphasised the importance of organisational learning as a source of dynamic capabilities. This they defined as ‘’a learned and stable pattern of collective *action* through which the organisation systematically generates and modifies its operating routines in pursuit of improved effectiveness’’ (Zollo & Winter, 2002, p. 340). Since capabilities involve collective action, this means that they are partly social and interactive processes, implying social capacity. Important to note is that capabilities, whether organisational, managerial, or operational, are said to consist of patterned organisational behaviour that companies can invoke on a repeated basis. Lazonick (2009:198-203) noted that these capabilities are part of an innovative organisation. To build these capabilities, an organisation has to invest in ‘’specialised research and development skills and facilities’’ to generate new technologies (Lazonick, 2002, p. 340). The firm has to invest in ‘specialised marketing skills and facilities’ to determine the needs of buyers (Lazonick, 2002). The firm has to invest in ‘’managerial skills and bureaucracy’’ to plan and coordinate development, production, and marketing and to develop the productive potential for shaping and controlling the economic environment for its strategic success (Lazonick, 2002). Chandler (1999) noted that multi-national corporations (MNCs) build their capabilities by exploiting different knowledge types from different geographical markets. As such, firms have to interact with other organisations and markets to acquire new knowledge and technologies to transform production. The big firms in the South African forestry sector, such as Mondi and SAPPI, possess these capabilities while most of the SMEs in the sector lack these capabilities. This consideration is critical and defines the choice of the SI but most importantly the SSI approach as the framework for this study. The SI therefore offers a critique to both the neo-classical and evolutionary economics approaches for dynamic capabilities within the SI framework are regarded as interactive and both endogenous and exogenous. The neo-classicists put emphasis on technology as an exogenous variable to be appropriated freely 'off the shelf' by firms (Lall 2004:95). On the other hand, evolutionary economists emphasise the endogenous nature of technological capabilities as largely determined by a firm's internal capabilities. What differentiates the systems approach, especially the SSI from these two approaches is that it locates the firm's technological capabilities in networks at national, sectoral, and international levels. The SI approach therefore regards technological capabilities to be a result of interactions between the endogenous factors in networks or between endogenous and exogenous variables in networks.

3.9 Learning and knowledge acquisition

According to Edquist (2006), the SI places innovation and learning processes at the centre of development. This is because learning may enhance product differentiation allowing a firm's access to knowledge, making it possible to ''constantly adapt the configuration of products and processes so as to anticipate the competition'' (Bergek et al, 2010). The emphasis on learning acknowledges that innovation is a matter of producing new knowledge or combining existing elements of knowledge. Storper (2002), however, noted that the importance of learning and knowledge production in an SI demands an understanding as to what constitutes knowledge and how firms can use this knowledge. This calls for an understanding of the different types of knowledge, as to how they are produced and how firms can tap into them in order to promote innovation as a differentiation strategy.

3.9.1 Types of knowledge

A firm's knowledge can be analysed in terms of the epistemological and ontological dimensions. The epistemological dimension of knowledge pertains to the mode of expression of knowledge, namely, Michael Polanyi's (1962, 1966) distinction between explicit and implicit (tacit) knowledge. The ontological dimension relates to the locus of the knowledge, which can either be the individual or the collective level (Lam, 2004). Knowledge that resides at the level of the individual can be applied by the individual in solving the specific problems of a firm. This knowledge is transferable with movement of the possessor of such knowledge in departments or from one firm to another, hence the problem of retention or accumulation of the knowledge in a firm or department (Lam, 2004). In contrast, knowledge that resides at the collective level is distributed and shared among the members of a firm. This knowledge is easy to retain and can be accumulated and stored by the firm in the form of rules, procedures, and routines and shared norms (Lam, 2004). The epistemological and ontomogical dimensions of a firm's knowledge are important in understanding the processes of innovation with regard to how knowledge is generated, transferred, and applied to improve production processes.

3.9.2 Knowledge for incremental innovations

Implicit knowledge is the tacit knowledge characterising mostly the operational skills, routines, and procedures acquired through practical experience. The knowledge has been referred to as *know-how* by Lundvall (Lundvall, 2004). Tacit knowledge is 'sticky' for it is context-specific and has a personal quality making it difficult to codify, formalise, or communicate. The transfer of this knowledge requires close interaction and trust among individuals and organisations alike. Maskell and Malmberg (2002) noted that tacit knowledge is transferred through observation, comparing and monitoring the activities of others. Lundvall (2004) believes this knowledge is crucial for incremental innovations by firms. Important to note is that, for incremental innovation to happen, firms have to develop 'operational capabilities' to use and operate given forms of technology in specific configurations. The growth of partnerships between big and small firms and the importance of mentorship programmes in the forestry sector of South Africa is a result of the understanding that this knowledge, which is important especially for SMEs concerned with the imitation, adoption and adaptation of existing technologies, is mostly transferred through close interaction between the 'haves' and the 'have nots' of such knowledge. Partnerships between the big firms and SMEs in the sector allow the 'newcomers' and other small firms to acquire the technologies of practice possessed by the big established firms. Through participation in partnerships, the SMEs embody the sectoral knowledge and skills that have been accumulated through time and ''learn to use it in encompassing ways'' (Guile, 2008, p. 113).

However, Smits et al (2010) noted that innovation scholars have been much more concerned with progress in knowledge-intensive and high-tech industries, hence a focus on radical innovation and high-tech activities in innovation theory, practice, and policy. This is despite the fact that many small and medium enterprises without laboratories of their own and with limited capabilities to acquire and absorb new technologies depend on imitations and incremental innovations (Smits et al, 2010). Incremental innovations are crucial, for 95% of firms in the Western economies are made up of small or medium-sized firms and these depend mostly on this type of innovation (Smits et al, 2010). South Africa has emerging farmers in the range of 50 000 to 120 000 in their number and these require various forms of support, ranging from development finance; managerial skills, and enterprise development to agricultural technical skills (AgriSETA 2016:8). In the forestry sector specifically, there are about 24 194 SMEs with an average woodlot of two hectares, overall adding up to 45 000 hectares (XIV World Forestry Congress, Financial Mail, 10 Sept, 2015). The AgriSETA and the FPM SETA have been working closely to enable the interaction between firms and between forestry colleges, such as Fort Cox College and other intermediaries, to facilitate the diffusion of non-R&D DEEM skills required by small businesses to improve their operational capabilities. The challenge in the sector with regard to SME productivity mostly pertains to the fact that most universities in South Africa focus more on the production of generalised conceptual and propositional knowledge than on the technical skills required by SMEs in incremental innovations.

3.9.3 Knowledge for radical innovations

Explicit knowledge[25] includes knowledge produced in universities, research institutes, science councils, and company laboratories. This knowledge is conceptual and factual. Explicit knowledge can be formulated, abstracted, and transferred easily across time and space (Lundvall, 2004). This type of knowledge is mainly generated through logical deduction and acquired through formal studies (Lundvall, 2004). It is important in both basic and applied research and in the systematic development of products and processes. In-house R&D and university research outputs rely mostly on this type of knowledge. It is the knowledge that is more prone to bringing about radical and disruptive innovations. The established firms collaborate with universities, government laboratories, standard-setting organisations, and research institutes to acquire and use this knowledge to produce new products and to embark on new processes (Bergek et al, 2010). Important to note is that, from propositional and conceptual knowledge, we derive other forms of specialised knowledge generalities which focus on occupational practices in providing technical solutions to technical problems (Hordern, 2016). An example of this may be engineering in pulp and paper production in the forestry sector. Engineering relies on general conceptual knowledge from the physical sciences. At the firm level, specialised engineering knowledge is blended with tacit knowledge accumulated by senior employees in operating the

[25] The *know that* which includes all the knowledge types such as the know why, know when, know where.

specialised pulp and paper production machines and passed down to new employees through job induction.

Big firms may produce scientific knowledge in their own laboratories but, as SI scholars Bergek et al (2010) observed, firms in most of the cases do not innovate basing on their internal knowledge because of technological complexity and technological dynamics. Technological complexity makes it difficult for firms to command all the relevant knowledge internally while technological dynamics make it hard for firms to command all the knowledge, which keeps evolving (Bergek et al, 2010). Technological knowledge is complex and cannot be transferred in its entirety. The purchaser always receives a reduced amount of information than what is possessed by the seller (Nelson & Winter, 1977, cited in Joseph, 2009). As such, relationships and interactions become important and therefore networks as repositories of both tacit and codified knowledge. It is because of this that the SI scholars put emphasis on technological cooperation or collaboration, as technological knowledge is by nature collective. As noted by Bergek et al (2010), ‘’technological knowledge is generated by interactive learning, and technological knowledge … takes the form of ‘distributed’ knowledge bases among different types of economic agents who must interact in some way if technological knowledge is to be applied’’ (p. 117). The policy documents and strategies in South Africa, such as the National Research and Development Strategy (NRDS 2002), the 10 Year Innovation Plan (2008), and the National Development Plan (NDP) (2011), recognise innovation as an interactive activity and emphasise collaboration for the generation and application of knowledge. As such, policies and institutions should support the components of the knowlwdge system such as standards-setting organisations, universities, government science councils, and research institutes, as sites of collaboration. Also institutions that limit interaction in an SI should be reformed to enable the SMEs to acquire knowledge important for upgrading, as recommended by De Soto (2000).

The differentiation of the types of knowledge does not mean that tacit knowledge and incremental innovations are the preserve of SMEs; neither does it mean that R&D and radical innovations are the preserve of big firms. As noted by Shapira (2010), innovation systems in western countries have been concerned with linking both small and big firms with universities to facilitate the diffusion and application of knowledge. In South Africa, most universities have technology transfer offices to facilitate interactions and the diffusion of propositional knowledge to big and small firms (Higher Education South Africa, 2013). The strength of the SI approach is that, rather than seeing the different types of knowledge in terms of opposites, they see innovation as emanating from a combination of conceptual knowledge applied to production and the tacit knowledge accumulated by workers in working with specific technologies in specific contexts. For this study, the importance of the SSI approach partly lies in its realisation that situated learning at the micro level cannot be explained outside wider societal influences, hence the emphasis on institutions, knowledge infrastructure and partnerships, networks, and collaboration between firms in and across sectors to allow for spillovers. All of these forms of knowledge, their nature, and how they are acquired are important in comprehending R&D dynamics and the systemic blocking mechanisms in the South African forestry sector.

3.10 Functions of a system of innovation

The SI functions to support the growth of an industry (Johnson & Jacobson 2003:1093). Edquist (2006) noted that the SI functions to pursue innovation processes, that is, to facilitate innovation processes in relation to product development, diffusion, and the use of innovations. These functions, according to Edquist (2006), are achieved through:

- The provision of research and development – creation of new knowledge
- Competence building – provision of education, training, human capital, production and reproduction skills, individual learning
- Formation of new products
- Articulation of the quality requirements
- Creating and changing organisations
- Networking through markets and other mechanisms
- Creating and changing institutions, for example, IPR laws, tax laws, environment and safety, R&D investments
- Incubation activities
- Financing innovation processes
- Provision of consultancy services – technology transfer, commercial information and its adoption

The strength of the SI approach, as identified by Edquist (2006), is that it places interactive learning at the centre of innovation. This is in opposition to other approaches to technological change (Dahlman, 1984, Fransman, 1986) that regard innovation as exogenous. Further, the SI approach is holistic for its emphasis is on interactions. The holistic nature considers the inter-linkages of organisational, political, social, and economic factors through the integration of perspectives from different disciplines. This is line with the dictates of the critical paradigm within which this study was framed.

Nevertheless, the SI has its own weaknesses as well. These include conceptual diffuseness. For example, the definition of *institutions* is not agreed upon by the protagonists of the SI approach. While others would say institutions are organisations (Nelson & Rosenberg, 1993), others see them as rules and regulations (Lundvall, 1992). However, this study differentiates organisations from institutions, which it considers as the rules and regulations governing the behaviour of individuals, and organisations in innovation. The other weakness of the systems approach has been a tendency to perceive the system as stable despite the fact that creative destruction brings about radical and discontinuous changes, which in most cases are stabilised by the emergence of new institutions in a system. This study considers a system as a structure made up of components in a state of continuous adjustment. It is amenable to both incremental and radical changes and to processes of stabilisation.

The importance of the SI approach is that it directly addresses the demands of this study in relation to the lack of integration (OECD, 2007) and of ‘weak coordination and linkages and limited resources and capacity’ (Greenberg, 2010) which affects knowledge generation, application, and innovation in the South African forestry sector. Woolthuis et al (2005) observed that the systems theory addresses four types of interactional challenges related to structural components and these are ‘’infrastructural failures’’, ‘’institutional failures’’, ‘’interaction failures’’, and ‘’capabilities’ failures’’. An analysis of these structural failures will provide answers to interactional challenges as to why South Africa’s SI lacks integration (OECD, 2007) and has ‘weak coordination and linkages and limited resources and capacity’ (Greenberg, 2010), limiting the benefits of R&D to the economy.

It is crucial to note that the SI approach applies at different levels and scales. As such, there is the national, the regional and the sectoral SIs. Edquist (2006) noted that the national, sectoral, and regional SIs are all variants of a single generic SI. These variants coexist and complement each other (Edquist, 2006). The choice of which is more suitable depends on the questions one wants to answer. Mehrizi and Pakneiat (2008) consider choosing among different models of the generic SI as determined by the intention of the investigation, the structure of the industry and the environmental context of the industry. This study employs the Sectoral System of Innovation (SSI), as the study is specifically focused on a particular sector of the economy: the South African forestry sector. The SSI caters for factors in both the national and international dimensions in knowledge generation and application, which is important for the South African forestry sector has nationally based firms and other firms, such as Mondi and SAPPI with an international presence.

3.11 The Sectoral System of Innovation

The SSI is a variant of the SI approach. The goal of the SSI is to explain the formation, adoption, distribution, and employment of knowledge and innovation in a sector (Mehrizi & Pakneiat 2008:80). Malerba (2005) defined a sector as, ‘’a set of activities which are unified by some related product groups for a given or emerging demand and which share some basic knowledge’’ (p. 65). Further, Malerba (2005, cited in McGrath, 2015) defined the SSI as a ‘’sets of actors organised around specific types of productive activities and technologies…and institutional settings’’. The forestry sector would, therefore, be defined in terms of interactions by forestry stakeholders (enterprise domain, education and research domain, intermediary domain, support structures, demand domain) in the generation, transfer, application of knowledge and the marketing of products. The forestry sectoral players represent different perspectives and have different skills, such as logistics, genetics, metrology, land rights, chemistry, safety standards, intellectual property, resource economics and slash and burn farming (World Bank, 2011). In addition to Malerba’s definition of an SSI, it is important to note that, in a globalised world, regions are not containers but interact as hubs of international networks and flows of knowledge. As noted by Held (2003), globalisation is related to the speed in communication, the growing scale, and the deepening impact of inter-regional interactions. The process transforms the scale of human organisation by linking distant communities, thereby expanding the influence of power relations across the globe (Held, 2003). Globalisation thus entails time-space compression, and global integration and interdependence (Held, 2003). However, the nature of international networks differs with fields of technology involved, which define the communities of practice. The nature of international networks is also defined by the structure of the global market and the standards ‘’enabling, limiting and shaping the activities of the sector’’ (Koschatzky, 2008, p. 8). Following, Malerba’s definition of a sector and the international dimensions of interactions related to globalisation, three issues stand out:

a) SSIs are characterised by organisations and actors whose knowledge and technologies span national boundaries.

b) Since the activities may span national boundaries, there is a greater need for coordination. Multi-national enterprises play a role in the coordination of processes between sectoral and national systems of innovation. The coordination process takes into consideration the international norms and standards that guide interaction in knowledge generation, transfers, application, and commercialisation.

c) The national and sectoral systems of innovation are embedded in each other and the comprehension of the processes of innovation demands an understanding of the relationship between these variants of an SI.

The SSI emerged from the realisation of extensive differences between sectors in terms of knowledge bases, actors and processes (Malerba, 2004). Mehrizi and Pakneiat (2008) consider the rationale for the emergence of sectoral studies to be the ‘lost ring’ which links factors at the firms to structural level factors. The SSI exists at a multi-scalar level and connects the different SIs, but with a strong sectoral focus. The approach caters for both the top-down organisational approaches, such as the triple, quadruple, and quintuple helix approaches, and the bottom-up voluntary decentralised participatory models, which are much more grassroots, whereby innovations can start with those in the informal sector and be appropriated by much more formalised organisations. The SSI, like any other SI, is made up of building blocks, which are institutions; organisations, and knowledge and learning processes.

3.11.1 Sectoral institutions

In addition to national laws and regulations, international treaties and norms govern the firms in specific sectors. International institutions governing firms in sectoral systems would include regulations emanating from international treaties, norming and standardisation bodies and international IPR administration associations (Koschatzky, 2008). In the forestry sector, some of the important international norms and standards pertain to internationally recognised best practices aligned to the tenets of sustainable forestry production, as articulated by the ISO and the FSC. These standards require the certification of forestry sectoral activities to be aligned with international best practices in connection to labour and environmental practices. Potential buyers often link forestry products and product markets to such certification. Without this certification, firms cannot access the lucrative European and American markets (Tehergeen, 2011). All of the major forestry operators in South Africa (Mondi, SAPPI, Merensky Timbers, and SAFCOL, among others) have received certification from the Forest Stewardship Council (FSC) (Wilgen & Richardson, 2012). This certification requires firms to adhere to certain principles, such as the control of exotic species to avoid adverse ecological impact and the requirement for Environmental Impact Assessments (EIA) before large-scale plantings. Wilgen and Richardson, (2012) noted that international forestry standards, as governed by the FSC, are customised to national conditions and regulations. In the South African context, the FSC certification takes into account the forestry permits requiring the payment of streamflow reduction in terms of the National Water Act of 1998 (Wilgen & Richardson, 2012). The FSC also takes into account national regulations requiring firms in South Africa to control the spread of plants from the demarcated areas in terms of the Conservation of Agricultural Resources Act (CARA) no 47 of 1983 (Wilgen & Richardson, 2012). All of these regulations show that the SSI is always in interaction with the NSI and international systems. Other nationally determined policies which impact on the forestry sector in South Africa include land reform policies, the education policy, innovation policy, labour policy, national IPR laws, anti-trust legislation, and bankruptcy legislation. All these, entail multi-level interactions and imply the need for coordination and integration if interactional blockages and system failures are to be countered for the efficiency of a sectoral system. The sector-specific nature of this study allows for an understanding of the nature of the forestry sector interactional challenges to be discerned as the basis for finding ways to resolve them.

3.11.2 Sectoral organisations and players

The players in an SSI range from individuals to organisations, such as firms (customers, producers, and suppliers) universities, government agencies and financial organisations (Mehrizi, 2008). The international organisations include multi-national corporations (MNC), international norming, and standadisation bodies, international IPR administration associations (Koschatzky 2008:8). The World Bank (2008:4) identified the agroforestry sector as comprising:

a) The Enterprise sphere. This sphere is made up of the producers of tacit knowledge and the users of codified knowledge (Growers, commodity traders, input supply agents, companies and industries related to agriculture- agro-processing, transporters). In South Africa, the enterprises include the big firms and MNCs such as Mondi Forests, SAPPI, Merensky Timbers, 24 190 small growers (Financial Times, Sep 10, 2015) and other small firms in downstream processing and manufacturing activities, such DEA's eco-furniture industries and others in the informal sector. Tacit knowledge will be the know-how mainly produced by interactions of firms and individuals in process and product innovation.

b) The Education and knowledge-producing sphere. The organisations in this sphere mainly produce codified knowledge (national, international, and local agricultural research organisations, universities and technical colleges, private research foundations sometimes producing codified knowledge, private companies, and NGOs). In South Africa, these include forestry and environmental faculties at the University of Stellenbosch, the University of the Witwatersrand, the University of Venda, the University of KwaZulu-Natal, Rhodes University, the University of Cape Town, and ICFR, CSIR, agricultural and forestry colleges, such as Fort Cox, and vocational education and training colleges, such as the Johannesburg College.

c) The link-making or Intermediary sphere (Consultants, NGOs, extension services, private companies and other entrepreneurs, farmer and trade associations, and donors). In the South African forestry sector, some such organisations are the Rural Action Committee, 4Sight Futures, FSA, government (DAFF), the FPM SETA and AgriSETA and organisations offering extension services to small growers.

d) The support sphere (transport and marketing infrastructure, financial organisations, networks- trade and farmer associations, and education system). Examples of these in South Africa include the IDC, the Land Bank, and road and rail agencies.

e) The Demand sphere (consumers of forestry products in rural and urban areas, consumers of industrial raw materials, international commodity markets, policy-making process, and agencies). In South Africa, these include the big firms providing market to SMEs, DAFF, DEA, DTI, and forestry product consumers.

According to Malerba (2004), the actors in a sectoral system are connected and interact through different kinds of relationships, such as ‘’communication, exchange, cooperation, competition, and command’’. In these relationships, multinational enterprises mainly fulfil an important role by connecting sectoral and territorial networks. The MNCs direct the interregional flow of knowlwledge in specific sectors and fields of technology into regional and national systems in a way that territorialises the international systems of innovation (Koschatzky, 2008).

Networks, collaboration, and interactions are the non-negotiable aspects of an effective SI (World Bank, 2011). Accordingly, there is a need for policies, organisations, and agencies, such as brokers and intermediaries, to assist in organising the often-differentiated groups with different capabilities, knowledge, and understanding to participate in innovation processes. In the agroforestry sector, these actors represent the varying perceptions and have different skills. Some of the skills would include resource economics, metrological skills, quantitative genetics, standards, transport and logistics, property, land and intellectual property rights (World Bank, 2011). For innovation to occur there is a need for coordination of the diverse stakeholders to tap into and absord the latest knowledge available. Though interactions may be stimulated through policy, long-lasting relationships are a result of conscious engagements to build trust and confidence in each other. It is on the basis of ‘talk’ (Storper, 2002) that trust as the most valuable aspect of a systems interaction is built, facilitating the sharing and transmission of codified and tacit knowledge between different organisations and individuals in innovation processes. In most cases, interactions designed from above require incentives to sustain them. However, once the incentives are removed the whole structure crumbles, hence the importance of decentralised bottom-up voluntary participatory interactions based on mutual trust. The recognition by the SSI that a sector is made up of various players, some operating at national, regional and international levels make the SSI relevant for this study. The forestry sector of South Africa is made up of various players: informal SMEs, government departments and agencies, NGOs, and knowledge organisations rooted in different geographical locations and MNEs with a global presence, such as Mondi and SAPPI.

3.11.3 Sectoral knowledge and learning

The knowledge base of a sector includes tacit and codified knowledge in intra-regional networks and communities of practice (Koschatzky, 2008). The learning and knowledge base of the forestry sector of South Africa involves public and private education and training organisations (McGrath, 2015). These include universities (for example, university forestry and environmental faculties at the University of Stellenbosch, the University of the Witwatersrand, the University of Venda, the University of KwaZulu-Natal, Rhodes University and the University of Cape Town), research organisations and councils (for example, ARC, CSIR, ICFR, and FABI), agricultural colleges (for example, Fort Cox), vocational education and training colleges (for example, Johannesburg College), the SETAS (FPM SETA and AgriSETA), and training centres run by industry associations.

The effective functioning of the forestry SSI depends on interactions and human capacity development. Agricultural and forestry training organisations should thus, be capacitated as the basis of knowledge for capacity development. The World Bank (2011) noted that development could not occur without knowledge. This knowledge in most cases is generated and applied nationally and locally. In most countries, organisations have not been able to provide for the rapidly changing skills environment and the demand for agri-business, programme, and project management skills and problem-solving and interpersonal skills (World Bank, 2011). There is a need for the integration of the skills systems for the production of scientists and people with technical capabilities in the field of forestry. Important to note is that no country is an island, therefore the need for collaboration at national and international scales in facilitating the diffusion of knowledge and technologies and in opening new markets. Most of the countries in the global south are still far away from the technological frontier and most of their innovations are a result of imitation, adoption, and adaptation of technologies developed somewhere (Aghion, 2009). However, Rajalahti, Janssen, and Pehu (2008) noted that the major issue for successful innovation is not about the creation of new knowledge and technologies but the adoption and adaptation of existing ones. As such, global networks linking domestic R&D organisations to global innovative research organisations facilitate the adoption and adaptation technologies, hence lessening the technological gap. In the forestry sector, for effective production, knowledge and technologies have to reach the growers and those in downstream processing and manufacturing activities. This requires investment in forestry extension advisory and mentoring services. Nonetheless, the public services that dominate forestry extension in South Africa are beset by the lack of funding, lack of qualified staff, lack of farmer involvement, and the existence of weak linkages (Ngomane, 2003).

Forestry science, innovation, and development thrive on interaction and collaboration by stakeholders. Interactions between the producer and user of technologies are important for the absorption of new knowledge and technologies. Other than focusing only on public service extension networks, other means of facilitating knowledge transfers, adoption, and adaptation have to be fostered to encourage the stakeholders to connect, interact and cooperate innovatively (World Bank, 2014). Technology generation has to go hand in hand with the assimilation of new technologies by growers and those in downstream activities. Extension services are critical in providing feedback loops in the development and application of user-friendly technologies, especially taking into consideration the diverse capabilities and cultural backgrounds of the growers and the SMEs in forestry growing, processing, and manufacturing activities. Important to consider is that the development and maintenance of partnerships is highly dependent on contextual factors which evolve over time in relation to the changing needs of the actors. Intangible factors (networks, knowledge, trust etc) are crucial in the formation and continuation of innovation networks among organisations. This very factor calls for the need to develop interactive capabilities to enable network management (Marques, De Carvalho Alves & Saur, 2005).

From the above discussion of the SSI, it can be seen that, while some forms of competition, organisation, and activities can be clearly demarcated as characteristics of an SSI, they are also the result of the national systems. It can, therefore, be seen that the NSI is always in interaction with the SSI and, as such, a study employing the SSI as a conceptual framework should take cognisance of these interactions if the interactional dynamics hindering the application of R&D in the South African forestry sector are to be comprehended.

3.12 Conclusion

The chapter defined innovation and the various models of innovation. It traced the evolution of innovation approaches from the neo-classical linear models linked to Gibbons's Mode 1 thesis of knowledge generation to the emergence of systems of innovation approaches in the 1980s/1990s linked to Gibbons's Mode 2 thesis of knowledge production. The Chapter discussed the SI approach, its pillars, and functions as the backdrop to understanding the SSI which informs this study. The SSI was outlined and discussed in relation to the NSI for the systems are interwoven and influence each other in varying degrees. The superiority of the SSI is hinged on its ability to incorporate aspects of the NSI and international systems in innovation. The SSI demonstrates evolution in thinking about innovation. It emerged in recognition that national policy frameworks that are influenced by global production systems define local production regimes in regions and at national levels. The SSI also acknowledges the role of MNCs and their participation in global sectoral systems and the importance of this in the localisation of knowledge gained in international markets. Thus, innovation is recognised at multi-scalar levels. This will be a result of the interaction of the various components of an SSI. The focus of this study is on the South African forestry sector. The importance of the SSI in the study lies in the recognition that the sector is made up of diverse players of different capabilities. The players are embedded in regional and national economies, with some of the players, such as Mondi and SAPPI, actively involved in global value chains. The smaller players in the sector are linked up in varying degrees to the major players, hence indirectly influenced by global dynamics partly determining the productive activities of the MNCs in the sector. For the comprehension of the challenges in the employment of R&D in the sector, the SSI was considered appropriate for its linkages with the NSI and international systems provides a nuanced and holistic understanding of the dynamics at play in sectoral economies and their evolution.

Chapter 4: Philosophical orientation and Research Methodology

4.1 Introduction

South Africa as one of the most unequal countries in the World, demands a developmental paradigm that incorporates an emancipatory agenda to ensure that the benefits of growth and development are fairly distributed (Callaghan, 2016). It was on the basis of this understanding that the study decided to situate itself within the critical paradigm for its emancipatory focus. The realisation within the critical paradigm that the economic, political, social, and the cultural realms interact and determine each other and that these dimensions of a system are connected to global dynamics with an influence on local systems (Kellner, undated, p.12) allows for a multi-level and multi-scale analysis of the subject matter. This aligns well with the SSI as the conceptual framework of the study, for systems of innovation focus on the interaction of components and how the system itself is also connected supranational systems in the generation and application of knowledge. The emancipatory agenda of the critical paradigm informed the choice of a qualitative research design as the most flexible design with flexible techniques in giving the stakeholders the agency to articulate their views with regard to epistemological access, innovation, economic inclusion etc. and the understsnding of development in South Africa.

4.2 Philosophical orientations and the nature of social reality

The critical paradigm is linked to the Frankfurt Institute of Social Research founded in 1923 (Friesen, 2008). The paradigm has its foundations in the work of Herbert Marcuse (1898-1979); Theodore Adorno (1903-1969); Max Horkheimer (1895-1973); Walter Benjamin (1892-1940); and Jürgen Habermas (1929-) (Barker-Ruchti, 2012). The ontological premise of the critical paradigm is that realities are social constructs and are always redefined in interactional processes. The nature of these interactional processes is determined by the economic, political, social, cultural, and psychic realms which are interconnected and the relationships of which are defined in terms of mediations and contradictions (Kellner, undated, p.12). The interconnectedness of the components brings in the idea of a system, whose components' interaction is mediated by human processes. The systemic interactions generate formal and informal rules of the game that governs the human mediation processes. This dialectical nature of reality with regard to systemic interactions and mediation processes and rules governing these processes as understood within the critical paradigm reflect the influence of Marxism (Larrain, 2007). However, the paradigm differs from the Marxist ontology in its rejection of the economic material deterministic of a system. Within the critical paradigm, the economic, political, social, cultural, and psychic realms interact and influence each other. The critical theorists regard the economic, political, social, cultural, and psychic realms as social constructs but also defining human interactions and their outcomes (Larrain, 2007). These economic, political, social, cultural, and psychic realms are connected to global dynamics with an influence on local systems (Kellner, undated p.12). The effect of these interactions at different scales and levels (individual, local and global) brings in the multi-scalar, multi-level analysis to understanding reality; hence the possibility of multiple realities in a scientific study.Within these interactions at different level are issues of power relations pertaining to justice and what can be done to achieve justice in production. The issues of power relations and of justice in production regimes are mainly linked to regulations, as to who makes regulations, who enforces regulations, and who benefit?

It is the interactive nature of the economic, political, social, cultural realms that determines the object of understanding such as meanings, beliefs, and motives. With regard to this assumption, the critical paradigm is much more aligned to the critical realism. Sayer (1992) a critical realist noted of the objects of interpretive understanding such as meanings, beliefs, motives, and material and cultural resources enabling individuals to make sense of their situations. Further, critical theory emphasises the importance of power relations in the construction of reality. This is important for this study in understanding the power dynamics in the formulation of colonial and apartheid ideologies. This is also critical in understanding the post apartheid transformation ideologies in South Africa and the extent to which they have failed to enable the emancipation of the people and in some ways resulted in the encroachment of ‘crony capitalism’ under democratic governments. Thus, within the critical paradigm, both knowledge and reality are regarded as socially constructed but influenced by power relations in society. However, these dynamics are not regarded static and are analysed within a historicist and evolutionary perspective whereby the current realities are seen in light of the past developments (Kellner, undated, p.12). The historical and evolutionary aspects link to the concept of irreversibility but with an underststanding that the wisdom of the past informs the present and the future.

4.3 Research methodology

The realisation that local dynamics interact with international dynamics and influence each other calls for a multi-scalar level analysis in understanding how production regimes in South Africa are influenced by global production regimes and vice-versa. This is critical in understanding how interactions by individuals in the SSI determines its shape and how the SSI is connected to the NSI and to supra-national systems of innovation and the impact of this on both local and global production regimes. The emphasis placed on the importance of history and the evolutionary dynamics of a system in understanding systems and the nature of reality within the critical paradigm enables for an analysis bringing about an understanding into how the present South African reality is influenced by colonial and apartheid ideologies and the effect of path dependence on current development trajectories. According to Watson & Watson (2013) the critical paradigm is flexible and allows ‘’researchers (to) employ a creative design of methods by appreciating all methods and using multiple methods, grounded in appropriate theory’’ (p.117). This study employed multiple research methods and techniques, ranging from semi-structured interviews, case studies, and observations to document analysis in trying to unravel as to why the South African SI is not integrated and the interactional challenges thereof as the backdrop to understanding what could be done to resolve the defects for the effective employment of R&D.

4.4 The qualitative research design

Churchman (1970, cited in Watson & Watson, 2013) noted that qualitative methods do enable an interpretive understanding of the human components of the systems approach, ‘’particularly the messy nature of social systems and the anxieties of such social issues as political power, poverty, crime, or pollution’’. As a result of the nexus of issues in a social system, Churchman (1970) argues that there cannot be one judgement or solution to a system problem (cited in Watson & Watson, 2013). Thus, system problems are defined in term of multiple realities. Systems of innovation are determined by the connectedness of the components, connections as realtionships defined in terms of harmony, concensus, conflict, and contradictions etc, informing the nexus of issues within a system. The nexus of issues in a system of innovation informed the choice of a qualitative methodology as more flexible allowing for indepth inderstanding of relationships which may be difficult to comprehend using quantitative stastical techniques.

According to Babbie and Mouton (2010), a qualitative study endeavours to obtain in-depth descriptions and enhanced understanding of individual and organisational actions and activities. The study employed a qualitative methodology to comprehend the challenges in interactions which bring about the lack of integration in the South Africa forestry SSI. The SSI is made up of partnerships, collaboration, and networks emerging in the processes of interaction. Partnerships, collaboration, and networks entail human relationships whose qualitative aspects are difficult ascertain quantitatively. Wyse (2011) has argued that a qualitative approach is fundamental to understanding opinions and motivations. At stake in this study were the relationships as determined by institutions and interactions between individuals and organisations in R&D. Relationships are emergent and socially constructed based on motives and opinions which maybe difficult to quantifiy statistically, therefore, the importance of a qualitative approach in understanding them and challenges thereof, through qualitative techniques, such as interviews, case studies and observations.

Further, institutions governing interactions in an SI such as regulations, culture and group habits are socially constructed and can be understood in depth by talking to those involved. The study considered a qualitative research design for its wider applicability and flexibility enabling the interrogation of the various issues affecting interactions and human relationships in production processes. The study employed methods, such as semi-structured interviews, case studies, and observations as the most flexible techniques in gathering data to explain the motives and nature of relationships. Secondary sources were analysed and desktop research conducted as the basis for contextualising the study. Purposive sampling was employed in the identification of interviewees and participants. Purposive sampling was considered the most appropriate sampling technique for the components of the SSI as the guiding framework for this study were known by the researcher.

4.5 Macro level study

The macro level study involved analysing principal government strategy and policy documents and secondary sources such as published books and journal articles from the Cullen Africana library at the University of the Witwatersrand or downloaded from the internet, to bring about an understanding of the interaction between innovation policy, theory, and practice. This was important in comprehending the approaches to innovation, their merits, and demerits and how the variants of the SI interact with each other in determining relationships and the nature of innovation. This provided the basis for an understanding as to why the SSI emerged and how it transformed understanding linked to sectoral innovations and economic development. Sources allowing for the identification of multiple perspectives on interactions in relation to the employment of R&D were selected. Also, relevant texts with citations that enabled location, clarification, and connections among different works were selected. The sources selected were evaluated for bias and to assess the authors' lines of argument. Further, at this level, desktop research was employed extensively in tracing the historical trajectories and the connectedness of various issues that determined the development of forestry research in South Africa in relation to funding, the role of government policies, the role of the private sector, the development of research capabilities, and the interaction between national and international dynamics. As for the online material, a number of things were considered in the selection of sources. Among these were authorship, sponsorship of the website, the purpose and the target audience, and, lastly, currency in relation to the date of publication.

Furthermore, documents from research organisations, industrial bodies like Forestry South Africa (FSA) and from government organisations, such as annual research reviews, annual reports, SETA's skills plans, and the CSIR Science scope series publications, were analysed to determine these organisations' approaches to R&D; linkages to other organisations; and the nature of challenges involved in knowledge generation and application in the forestry sector. Newspaper articles and forestry magazines such as the SA Forestry series were analysed to capture the current R&D trends, especially on the interaction between the democratic governments, small-scale businesses and big firms linked to the land reform, environmental regulations, firm capabilities, and broad-based black economic empowerment (BBBEE) processes. This was important in understanding how the various policies, some of which are considered a hindrance to innovation by the industry, came into play and their impact on forestry resource development.

At the macro level, the research banked on deliberations at workshops and conferences on forestry sector development, such as the Forestry Industrialisation Conference (FIC, Esselen Park, Kempton Park: South Africa, October 4, 2017). This conference provided a platform whereby stakeholders representing the various components of the South African forestry SSI and international delegates representing the forestry sectors of Finland, Germany and other countries were able to deliberate on the challenges in forestry resource development and the importance of R&D in forestry sectoral industrialisation.

4.6 Micro level study

At the micro level, the study relied on semi-structured interviews with the personnel from research institutes linked to forest resource production. These include organisations, such as the University of Stellenbosch, University of Pretoria, Nelson Mandela University, University of the Witwatersrand, the Institute of Commercial Forestry Research, the Council for Scientific and Industrial Research, Fort Cox College and intermediary organs within the skills system, such as the AgriSETA and the FPM SETA. The focus was on comprehending the challenges related to the production of skills, knowledge and technologies at research organisations and the linkages in the transfer of skills and knowledge to the industry and the public sector. This was important to enable an understanding of the nature of interactions between research organisations, the government, and the industry in facilitating knowledge production, innovation, and the diffusion of new methods, skills, and technologies and the impact on production capabilities. Interviews were important in ascertaining relationships, the motives behind them, and the challenges in maintaining them in forestry R&D. Some of the areas around which the interviews revolved are R&D in genomics, pests and diseases, business skills and sustainable development. These areas have been crucial in the sustainability of the plantation forestry economy in a bid to improve growth, quality, and quantity without undermining other ecological values. The interviews were also crucial in ascertaining challenges in R&D in the downstream processing and manufacturing activities of the forestry sector.

The interviews were also conducted with personnel from firms in the forestry sector. Here, research managers and strategists from the firms were interviewed. Further, interviews were conducted with the personnel from industry associations and government departments (Department of Environmental Affairs - DEA; Department of Agriculture, Water, Forestry, and Fisheries - DAFF; Department of Higher Education and Training - DHET). The other informants were the forestry researchers at universities and research institutes. Furthermore, the owners of SMEs and personnel from forestry cooperatives were interviewed in relation to business operations, skills development, innovation, and linkages to other components of the SSI. All of the interviews were recorded to allow the data to be examined repeatedly, as a way of preventing premature inferences and conclusions (Erickson, 1992). Overall, 44 interviews were conducted- See appendix 2.

4.6.1 Case studies

Case studies were employed at the micro-level. As noted by Zainal (2007), though ‘’case study methods remain a controversial approach to data collection; they are widely recognised in many social science studies especially when in-depth explanations of social behaviour are sought after’’ (p. 1). The case study method is mostly employed under the constructivist paradigm but this study, though framed within the critical paradigm, decided on case studies to improve the robustness of the data and to allow for triangulation.

The study included six detailed case studies. These case studies are the Genomics research project, the Sirex research project, the Cryphonectria Cubensis research project, the DEA Eco-furniture industry at Heidelberg (Mpumalanga), the Fire Research and the Small Timber Winch project. These were conducted through documentary analysis, interviews and, in the case of the eco-furniture industry, through a combination of documentary analysis, interviews, and observations. The cases were important for three main reasons, which are:

a) They were important in illustrating points and supporting positions.

b) They were important in understanding the interaction between a unique case and the context so as to demonstrate how forestry projects are intentionally or unintentionally influenced by the context in which they occur. According to Sayer (2001), ‘’much of what happens does not depend on or correspond to actors’ understanding: there are unintended consequences and unacknowledged conditions and things can happen to people regardless of their understanding’’ (p. 20). Much of what happens in a specific case may be the result of broader interactions in an SSI.

c) The cases were also important to corroborate the data from interviews and documentary analysis so as to determine patterns, as in the process of discovery, in this case, patterns related to the importance of collaboration and factors undermining collaboration, partnerships, and networking. Bassey (1999) argues that it is possible to make tentative generalisations from cases, especially if patterns begin to emerge in relatively similar cases. Again, this research considered the cases as a part of the wider research project within the broader context of interactions in the forestry SSI. This explains the importance of linking and corroborating data from the cases with data collected from interviews and desktop and documentary analysis. A combination of these data provides deep and penetrating explanations while allowing for tentative generalisations to be made with regard to interactional challenges pertaining to the lack of integration which hinder the employment of R&D in the forestry sector.

4.7 Sampling design

Sampling is important in the identification and selection of those to take part in the study from the population. According to Welman, Kruger, and Mitchell (2005), a population consists of objects that may be individuals, groups, and organisations. The population for this study included organisations and individuals forming part of the forestry SSI, such as universities, firms, government agencies, and individuals within them. The target population consisted of government departments responsible for forestry and enterprise development; major forestry research organisations and forestry/environmental faculties and departments at universities/colleges in South Africa, and the big and small-scale firms in the forestry sector of South Africa.

The study employed purposive sampling. Purposive sampling is a non-probability sampling technique based on the population's characteristics and the aim of the investigation (Crossman, 2017). This type of sampling is feasible when you need to reach a targeted sample quickly and where sampling proportionality is not the main concern, as was the case in this study. Purposive sampling is employed when the population of the study is clearly discernible. In this study, the major players in the agriculture and forestry SSI were known by the researcher. Purposive sampling was imperative in this study because of limited resources. However, important to note is that, with qualitative methods, there are no rules pertaining to the size of the sample (Polit & Beck, 2008). The sample size is determined by 'the point to be raised, the purpose of the research, useful things, and things to do with time and resources available' (Shaari, Jamil, & Razak, 2012). Smith (2004) is of the view that qualitative research samples must be small to allow for detailed investigation.

4.7.1 Micro-level

The research organisations and firms included in the study were selected for their forestry-focused studies and collaboration with industry and government in achieving forest resource development. At this level, the study focused on major firms, such as Mondi, Sappi, and Merensky; small and medium businesses, such as NTC Forest Cooperative; Transvaal Wattle Growers Association (TWK); and other small firms, such as the Department of Environmental Affairs' Eco-Furniture factory in Heidelberg, Mpumalanga. These firms were also selected for their own R&D activities and linkages with other firms, universities, and research institutes in South Africa. The big firms have been the linchpin upon which the plantation economy of South Africa revolves. Major innovations in the sector have been a result of their R&D initiatives.

The study included research organisations with forestry-focused research departments and these are the Forestry and Agricultural Biotechnology Institute (University of Pretoria); the Agriculture and Forestry Department at the Council for Scientific and Industrial Research; the Institute of Commercial Forestry Research; Forestry and Environmental Departments at the University of Stellenbosch; the University of the Witwatersrand; Nelson Mandela University; the University of Pretoria; the University of Venda and Fort Cox College. These organisations have been identified by the National Research and Development Strategy (2002) as the core institutes in forestry R&D in South Africa.

Interviews were conducted with officials from DEA, DAFF and with personnel from the FPM SETA and the AgriSETA. The AgriSETA and the FPM SETA are responsible for coordination of stakeholders in skills development and knowledge application in the forestry sector of South Africa. The SETAs are in a position to understand some of the challenges involved in their role as intermediaries, and coordinators and on how these challenges may be addressed.

4.8 Positionality

The choice of the field of study was determined by the contract which had been signed between Wits-Real and the FPM SETA. The FPM SETA and Wits Real have had an agreement where by the SETA provided study bursaries aimed at developing an understanding of forestry innovation and industrialisation in South Africa. Wits-Real as part of the agreement was to supervise the Masters and Doctoral students awarded these bursaries in their research degrees. The doctoral programme was a highly structured programme, prescribing the methods to be employed (Burawoy participant observation) and the conceptual framework to be used. Formerly the researcher was interested in small business development and innovation in propelling Township economies. The researcher had to change and focus his study on forestry businesses in order to align with the dictates of the bursary. The structured nature of the programme hindered early progress as a lot of negotiations and compromises have to be made. From the beginning of the study, the researcher had been interested in employing the concept of creative destruction and systems of innovation concept as the framework of the study in understanding systemic failures and blocking mechanisms that hinder the employment of R&D by firms in the forestry sector of South Africa. The firm was important in all this, but the focus on systemic level factors directed the researcher towards an analysis of interactions in partnerships, collaboration, and networks rather than the internal dynamics of a firm. This immediately contradicted the programme's focus on the employment of Michael Burawoy's participant observation method as the prescribed method. The employment of Burawoy's participant observation method would mean that one has to negotiate entry and to stay at an entiy of study for a long time. This method was not feasible in gathering information that would enable a critical understanding of the points of linkage within a system of innovation. The researcher's focus was on interactions in networks, collaboration, and partnerships made it impossible to employ Michael Burawoy's participant observation for a researcher could not understand a point of linkage such as a 'network', 'collaboration' or a 'partnership' by studying the production processes within a firm. The thesis process was therefore a negotiated process with compromises having to be made pertaining to the feasibility and appropriateness of some research methods. It was as result of these negotiated compromises that the programme changed completely from being prescriptive to allowing the researcher the latitude to determine his/her own study methods and frameworks. Those who became part of the programme at a later stage are not aware of these academic processes that determined the evolution of my study and that of the PhD programme – the Sectors, Skills, and Economic Evolution of South Africa programme.

Further, FPM SETA (the funder) was more interested in international comparability studies in understanding the international dynamics that allowed for forestry industrialisation in some countries for their monograph. The international comparability study was also to define the PhD thesis's literature review chapter. The international comparability study was important in broadening one's understanding of the global production systems. However, this was less important to the researcher who was more interested in tracing the history and evolution of the forestry research system in South Africa linked to the introduction of capitalism (colonialism, dispossession, apartheid, race, class, violence, and accumulation) up to the democratic era. This was to allow the researcher to develop a deep understanding into how interactional challenges were defined and resolved in the South African forestry sector throughout history. This schism delayed the completion of the thesis as much time was spend on interanational comparability studies which in the end did not form part of this thesis. The researcher ended up having to produce chapters for the FMP SETA for their monograph to meet the bursary requirements and unrelated chapters for his own PhD project. It was only through this, that the researcher took ownership of the PhD project. These schisms ended up worsening relations as FPM SETA officials were nolonger attending some of the meetings and workshops at which the PhD researchers were supposed to share their studies and progress. These schisms must have been one of the the reason why the FPM SETA failed to assist the reseacher with the payment of his fees for the years 2018 and 2019 as he was completing the study.

This study involved a number of case studies. The case studies required the researcher to visit a number firms and sites, to observe production systems and to conduct individual and group interviews. Two issues were critical in this undertaking in relation to the position of the researcher. First, was the issue of the researcher's position as a foreign nationale who did not understand local South African languages. This proved to be a challenge when the researcher was interviewing some workers who did not understand the English language which he employed as the medium of communication. In one of the cases at Heidelburg in Mpumalanga, the researcher had to invite a workmate to interpret. This to some extent limited the freedom of the interviewees to express themselves because of the presence of their workmate.

Second, the researcher as foreign black Zimbabwean studying firms in the forestry sector of South Africa had its own silent burdens. The sector is considered highly concentrated and white dominated. Because of the failure to achieve the 2015 targets of the land reform, the current owners of the land who are in most of the cases of white descent are under threat because of the motions of expropriation without compansation which are gaining momentum in South Africa. As a Zimbabwean you carry the burden of being associated with a 'failed' land reform process which disrupted many people's lives. There are therefore always some questions which the researcher had to carry at the back of head in the research process: What would people think if they know that I am a Zimbabwean? Would people be able express themselves freely? And what are the implications for the study? Worse still, the study was done at a time when the land reform is hotting in South Africa with many corporates feeling threatened. On the 27th of February 2018, the National Assembly had made a landmark decision to review Section 25 of the Constitution of the Republic of South Africa to expedite the principle of land expropriation without compensation. With all this happenstance was a feeling that the researcher might not be granted the permission to interview the high-level personnel with the information which he wanted from the firms in the sector. These issues partly determined the negotiation into field and the techniques to use especially with regard to interviews. Thus in some instances telephonic interviews were considered while in other cases face to face conversations were considered. However, this fear though it affected the researcher entry position was in most of the cases unfounded as many informants were earger to talk and even to refer the researcher to some of the key informants in the sector. The only hurdle was in setting up an interview with a research manager from one of the leading firms in the sector. The manager kept on postponing the date of the interview until the researcher gave up.

The other challenge which the researcher faced was in dealing with politically connected leaders, leaders who had been appointed to direct government project firms in the forestry sector. In one case, the researcher had been granted permission to interview the management and the workers at a government funded processing and manaufacturing forestry firm. Arrangements were made as to when the researcher was going to interview the General Manager and workers. All were notified and the dates and times were agreed on. However, on the day of the researcher's visit to the firm, the General Manager decided to absent himself from work for reasons which could not be communicated. He was a central figure with a lot of information crucial in unravelling the interaction between the political and the economic in government projects. Attempts to arrange for another meeting with him were unsuccessful. Also on the day of the interviews with the workers at this firm, upon arrival the researcher found that workers have placed into groups for focus group discusions. In each group was their supervisor. The arrangement deprived the workers of the freedom express themselves without fear of repercussions. In this case, the researcher made it clear that he was not interested in focus group discussions but in one on one interviews. The researcher therefore resorted to interviewing the supervisor and two workers from each group taking into consideration the gender and age dynamics. The position of the researcher therefore influences the research processes in a big way.

4.9 Method of data analysis/interpretation

In analysing the data, the study employed documentary analysis and thematic analysis. The literature was analysed in relation to various themes on research, innovation, and development. Documentary analysis allowed the researcher to understand the importance of the interactions in collaboration between research organisations, the state, and industry in R&D in building the capabilities of firms in the forestry sector based on what has already been investigated and written by others in the field of forestry R&D in South Africa and other countries.

Thematic analysis was employed in the analysis of data from observations and interviews. The technique employed a thematic reconstruction of responses to semi-structured questions, as well as other questions which arose in probing the answers provided. Interviews were transcribed and analysed using a framework technique developed by the researcher. This technique involved: 1). familiarisation, 2). identification of the recurring themes in relation to identified themes in the literature review upon which the research questions were framed; 3). rearrangement of data according to thematic content, allowing for cross-examination of interview data and within-case analysis, 4). the mapping and interpretation of the data. Thematic analysis is a common qualitative method appropriate when analysing interview transcripts. The final thesis product is a synthetic exegesis of comparative analysis, documentary analysis and thematic analysis.

4.10 Ethics consideration

Responsible research is dependent on the principles and values of the researcher. This research considered the following: respect and courtesy, acceptance and understanding, integrity, individualism, honesty, sincerity, confidentiality, and anonymity. In relation to these values, participants were informed of the purpose of the study, namely, to investigate the challenges in the interaction of institutions in the forestry SSI in the employment of R&D. The participats were informed that they were to be referred to by psuedonmys in the thesis. Each participant gave his or her informed consent by signature to participate in the study. All personal information collected had been kept confidential and study participants were referred to by pseudonyms.

Ethics clearance for the study was obtained from the University of the Witwatersrand Ethics Committee.

4.11 Limitations of the study

The study took into consideration the various debates around the systems of innovation, their merits, and demerits in knowledge generation, development, transfer, and application. The factors accounting for the success of an SI in the application of R&D are varied and determined by history and contextual considerations. Due to limited time and financial resources and the multi-faceted nature of the components of a forestry SSI and individuals making these components, was difficult to explore all of these factors thoroughly in relation to the nature of interactional challenges bringing about the lack of integration, weak linkages, weak coordination, limited resources and capacity hindering the application of R&D in the sector. The SMEs in the informal sector were difficult to contact because they do not have fixed addresses and are highly mobile. These factors made it difficult for compact generalisations to be made pertaining to the subject matter.

The other limitations are methodological. The qualitative methods, such as interviews, involve personal involvement, partiality, and empathetic understanding as opposed to detachment, impartiality, and objective portrayal. Human beings are rational, historical, and normative beings. Human beings are unique individuals with their own sets of value orientation, preferences, wishes, desires, convictions, and ideals. Human behaviour is not static or predetermined and patterns of behaviour tend to vary over time. All of these issues have an implication when human beings participate in a scientific investigation. These issues impact on the reliability of data collected from interviews. However, to counter some of these challenges, the study employed a number of sources and methods to allow for triangulation in order to improve the trustworthiness of the data.

Chapter 5: Formal forestry R&D and the processes of innovation in South Africa

5.1 Introduction

This chapter focuses on the interaction of big established firms with the government and high science research organisations in knowledge generation, transfers, and application. The interaction between firms, the government and high science organisations in a system of innovation usually leads to radical innovations in the form of new processes, new technologies, and new products (Berge et al, 2010; Smits et al, 2010). Radical innovations emanating from these interactions are different from the non-R&D incremental innovations that are mainly a result of imitation, adoption, and adaptation of existing technologies, especially by small-scale enterprises (Chaminade, Lundvall, & Haneef, 2018; Chaminade & Edquist, 2010).

System's scholars (Edquist 2010, Shapira, Smits, & Kuhlmann 2010) emphasise the removal of system failures or blocking mechanisms as the basis for improving the efficiency of systems of innovation in knowledge generation, transfer, and application. Systems scholars focus mainly on four system failures or blocking mechanisms, which prevent innovation systems from performing their functions efficiently and effectively. These systemic failures are discussed in terms of ''infrastructural failures'', ''institutional failures'', ''interaction failures'', and ''capabilities' failures'' (Woolthuis et al, 2005). This study broadly defines these failures in terms of interactional challenges, for they emanate mainly from the lack of linkages, or coordination weaknesses in a system. An understanding of these failures would enlighten us as to why the South African NSI and forestry SSI are less integrated (OECD, 2007) and suffering from 'weak coordination and linkages and limited resources and capacity' (Greenberg, 2010, p. ix). The lack of integration according to the OECD (2007) has made it difficult for the South African economy to realise the benefits of its SI.

The chapter provides a thematic analysis of interactional challenges in forestry innovation. Moreover, the chapter analyses four case studies: the Fire research project (Appendix 1, Box 2); the Cryphonectria Cubensis Research Project (Appendix 1, Box 3); the Cirex Research Project (Appendix 1, Box 4); and the Genomics Research Project (Appendix 1, Box 5), as a way of illustrating the importance of collaboration and in highlighting areas of interactional challenges in collaboration. The case studies provide the evidentiary basis as to how innovation knowledge is collectively generated and transferred in the process of research. The case studies also provide the fundamental axioms in the identification of the system failures and understanding as to what happens to innovation performance when systemic blockages are resolved or when they are not resolved.

The chapter strives to answer the following questions: *What have been the challenges affecting effective interaction in R&D by universities, research institutes, government agencies, and firms in the forestry sector of South Africa? What are the key challenges affecting effective interaction in R&D by universities, research institutes, government agencies, and (big) firms in the forestry sector of South Africa?* The second question is informed by the first question. The chapter is based on 23 interviews with research personnel from universities, firms, and government agencies. Written documents, such as annual research reviews, annual reports and other strategic documents by firms, research organisations, and government agencies were also employed as a way of contextualising and corroborating the interview data. In addition, the chapter depended on four presentations pertaining to forestry R&D by forestry stakeholders at the Forest Industrialisation Conference (FIC, Transnet Esselen Park, Kempton Park, South Africa, 4 October, 2017). The presentations were important in confirming or disconfirming the evidence from the interviews and case studies.

5.2 Failure by firms to apply new knowledge and technologies resulting from the work of researchers

The study identified the failure of firms to consider scientific research as one of the blocking mechanisms in knowledge application, hence the realisation of the benefits of scientific research in the South African forestry economy. Researchers complained about the failure by firms to consider and apply their research findings as one of the reasons behind the lack of innovation in the forest sector. As noted by Ms B39, the Knowledge Manager at the Institute of Commercial Forestry Research (ICFR),

> The biggest challenge is to change people's perceptions around the fact that research is showing that we should start doing things differently. The forestry industry is not quick to respond to innovation and to change. Over the past fifteen years that I have been doing this job, that has probably been one of the biggest challenges. They will come to you and say that we have always done it this way. When you tell them that

> research is now showing that we need to change and do it differently, that is when they dig in their heels and it is hard for you to show them.[26]

The above observation was buttressed by Prof B44, a retired professor at the University of Pretoria, who complained about the failure of some forestry firms to consider his fire-pathways research. According to Prof B44, the failure to implement the results of his fire pathways research resulted in whole plantations being burnt in the southern Cape during accidental fire outbreaks in the years 2015, 2016, and 2017. Prof B44 reflected on one of the cases involving a company known as Mountain to Ocean (MTO),

> I have been involved in a court case with one semi-government company, Mountain to Oceans in the Southern Cape. I have got my concept of the fire flow patterns. I showed them what happens with fire in their landscape. Then I showed them some of the places they are putting fire breaks that have got no value and they spend a lot of money. I showed them a fire-flow pattern and the fire pathways on their land that they are not managing. Then they had this big fire and I had to go through a court case to tell them what the problems were, which they did not follow when I advised them.[27]

When one has to take firms to court in order to compel them to implement the results of R&D, it shows that not all research is taken seriously by firms, despite the value it may have in relation to resource sustainability. Firms are mainly interested in taking up research findings which they are sure would improve the efficiency of their productive capabilities by reducing costs (Whitley 2008). For example, most of the big firms in South Africa, such as Mondi and SAPPI, have been able to reduce the cost of labour through mechanisation and other production methods, such as the contracting system (Pons-Vignon 2014).

The importance of fire research in forestry production is demonstrated by the fire Research project by Prof B44 (Appendix 1, Box 2). The fire research project discovered that fire flows follow particular pathways determined by the long history of interaction between fire and plants in the veld. It discovered that both plantations and indigenous forests were burnt down when they were located in fire pathways. The fire research project led to a radical interpretation of fire

[26] Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[27] Prof B44. Forest Ecologist, UP, interviewed by Mushangai, UP, 29/05/2017

behaviour, which, if implemented, would provide radical innovations with the effect of protecting plantations from the fire menace. The findings of the fire research project (Appendix 1, Box 2) show that research can lead to a radical reinterpretation of existing phenomena.

What is important to consider are the reasons why some firms fail to consider and apply such scientific research findings. First, it is necessary to consider the differences in studies that are conducted with the participation of the end-users and those without the participation of the end-users. As noted by Ngomane (2003), interaction with the end users of technologies is important in facilitating the understanding of how particular technologies and knowledge can be employed practically by those involved with the production processes. As a result of the challenges involved in the transfer of knowledge when research is conducted without the participation of the end-users, the Small Business Manager at Forestry South Africa (FSA), Mr B15, stressed that he 'would not commission or financially support any research that is not supported by the end user'.[28] Important to note is that research studies that are conducted with the participation of the end-users provide fertile grounds for interaction, enabling the personnel from the firms to learn, assimilate, and resolve misunderstandings in applying the findings. This is less likely to happen when research is conducted by researchers alone and then communicated to the end users. The participation of end users in research is an important way of bridging the research-practice gap. Prof B44's fire research fits in the second category, as the end-users were not involved in the fire pathways research. When research is conducted without the participation of the end users, the challenge becomes to communicate the results for assimilation and application by the end users. This may require lobbying or the setting up of intermediary organs/bodies for that purpose (Chaminade & Edquist, 2010). Communicating competently becomes more crucial, especially when there are contending explanations of phenomena, as was the case with fire in 2007 in South Africa.

In 2007, Peter Briscoe and Prof B44 were providing contending explanations with regard to fire behaviour on the landscape, based on observations of the scars left after fire outbreaks (Geldenhuys, 2007). Peter Briscoe, based on observations that indigenous natural forests remain after fires while plantation forests in the same regions were burnt and erased, concluded that natural forest was resistant to fire, hence the need to plant indigenous trees as fire guards around

[28] Mr B15. Small Business Manager-FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

plantations (Geldenhuys, 2007). Prof B44's explanation of the fire behaviour (Appendix 1, Box 2) started from a position of understanding the history of fire and the spatial clusters of natural forests on the landscape before the introduction of plantation forestry. The spatial patterns of natural forest were, according to Prof B44, a result of a long history of interaction between fire and natural forests, whereby natural forests, as a result of the frequency of fires, had been driven out of fire pathways (Geldenhuys, 2007). From this understanding, Prof B44 concluded that plantation forests were being burnt down while natural forests in the same regions were not because most of the plantations were located in fire pathways. His explanation countered Briscoe's explanation and provided evidence to the effect that indigenous forests were not fire-resistant, as assumed by Peter Briscoe. Indigenous trees located in fire pathways were also burnt down along with plantations during fire outbreaks. Prof B44 explanations of fire behaviour in relation to plantations and natural forests are more plausible and based on systematic and direct observable evidence, as opposed to general accounts by Peter Briscoe.

The plausibility of Prof B44's findings should have been an incentive for firms to consider and apply his research findings in practice but, on the contrary, some firms have not been receptive to his findings and advice. This is despite the fact that fires ‘'cause more damage to plantations in South Africa than any other factor'' (FSA Annual Report, 2013, p.13). The failure by firms to consider research findings by researchers may thus be a problem in communication, which points to interactional challenges. In communicating the results of research for their uptake by firms, researchers have to provide evidence that supports effectiveness predictions. With reference to the Genomics case study (Appendix 1, Box 5), Dr B, mentioned that, ‘The Genomics project was set up as an industrial program, one that would be based on cutting edge technology development. There was, therefore, a need to demonstrate industrial applicability soon enough to gain the trust and support of the industry'. Effectiveness predictions may be supported by general effectiveness claims or more directly by relevant evidence. If communication is not done effectively, firms would not risk embarking on new processes the results of which cannot be clearly predicted in terms of improving efficiency in production, in guaranteeing profits or sustainable forestry management. It is for these reasons that in some countries and economic sectors, intermediary organisations have been created to facilitate communication between firms and universities (Dankbaar & Vissers, 2010). Firms usually fear disrupting their old ways of doing things (the problem of technological lock-in) for new ones, which they are not sure of

(Whitley 2008). Some researchers complained that the failure by firms to apply R&D findings meant that their work is not being taken seriously.[29] There is thus the need for building interactive capabilities on both the supply and demand side of research. Interactive capabilities, according to Malerba (2005), involve the capacity to form effective linkages with other organisations. The failure to have the findings of the fire research adopted by some firms may be a reflection of the failure on the part of the researchers to articulate their findings clearly in a manner that is not confusing especially in situations when there are contending explanations of a phenomenon, as was the case with fire flows in 2007.

As indicated above, the failure to apply research findings by firms may be a result of the lack of competency on the part of researchers in communicating their findings (interaction failures, Woolthuis, 2005), but in some cases, this may be a result of a convergence of factors. Institutions may hinder or incentivise the application of research finding by firms. The behaviour of firms in most cases is influenced by institutions, especially when there is a contradiction between policy and science. As noted by Prof B44, plantation forestry firms in South Africa have been struggling with regard to plantation boundaries and where to put the firebreaks.[30] This has been the case because the boundaries are always shifting in relation to what the regulation says instead of shifting based on scientific principles/evidence.[31] This contradiction is well expressed by Prof B44 when he noted that,

> Today the boundary is here and next time after 30-years you find forest has moved into this space. They have to move the boundary there because the regulations say they have to do that. But I tell them that we have to keep the boundary where it was in relation to what science and ecology requires us to do.[32]

The contradiction points to the lack of alignment within the forestry SSI that reflects the lack of interaction between the policy makers and forest scientists.[33] This misalignment makes it difficult to keep the plantations out of fire pathways.

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[29] Prof B44. Forest Ecologist, UP, interviewed by Mushangai, UP, 29/05/2017

[30] Ibid

[31] Ibid

[32] Ibid

[33] Ibid

Prof B48, the SAPPI Research Chair in Systems Analysis at the University of the Witwatersrand is of the view that the big challenge is the 'dysfunctionality of the system'.[34] This stems from the lack of an integrated strategic forestry plan for the country.[35] The plan was produced by DAFF after extensive amounts of investigation and revision, but was never disseminated.[36] As a result, the ICFR, the research institutes, universities, the industry, and the government have been working with different ideas as to what each one of them feels is their contribution to both research and the economy of the country.[37] As was shown in Chapter 2 in relation to the integration of the apartheid forestry system, alignment between policy and science was brought through interactions in committees that involved all the stakeholders, government, foresters, and researchers included.

Moreover, the failure to employ new technologies by firms in the forestry sector, especially the state-owned enterprises, such as SACOL, partly emanates from the need by government firms to retain workers by limiting the effect of machines on human labour.[38] The need by the government to create employment dissuades state-owned enterprises from adopting new technologies emanating from research activities and with the effect of improving productivity. Ms B32, the Transformation Manager at SAFCOL, noted that they had not moved much in terms of mechanising production for fear of the negative impact of machines on human labour.[39] This is in contradistinction to what is happening in the private sector, where the big firms in South Africa, such as Mondi and SAPPI, have been able to reduce the cost of labour through mechanisation and other production methods, such as the contracting system (Pons-Vignon 2014). The interest of the government in retaining labour in state-owned enterprises has a discouraging effect on the employment of new technologies for efficiency improvement by reducing labour costs. The Technical Manager of the Department of Environmental Affairs's Eco-Furniture Industries, Mr B49, noted that the government had unnecessarily employed many

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[34] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[35] Ibid

[36] Ibid

[37] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[38] Ms B32. Senior Manager- Transformation, SAFCOL, interviewed by Mushangai, Nelspruit, Mpumalanga, 26/10/2017

[39] Ibid

people in their eco-furniture industries, which had negatively affected the efficiency of these factories.[40]

International organisations, such as the International Finance Corporation (IFC), compel the forestry firms to mechanise to reduce incidents that endanger the workers in forestry operations (ISO 160). There is a need for a common vision between the private firms aiming at reducing labour costs and government enterprises aiming at guaranteeing employment. In Sweden, a common vision with regard to mechanisation was instilled by the government's ''No worker on the ground, no hand at the log'' policy (Wang, 2013), which compelled both the private and state-owned enterprises to mechanise their production systems. The ''No worker on the ground, no hand at the log'' is a policy adopted by the Swedish government in a bid to reduce incidences that result in workers being injured at work. The policy resulted in the mechanisation of most of the manual labour activities in the forestry sector. As noted in Chapter 1, history casts a long shadow over current development policies and practices. Some of the challenges in relation to success in the employment of R&D in the forestry sector are historically determined. The historical circumstances of South Africa and the need for black economic empowerment prevent the development of a common forestry vision, as the relations between the government and the private sector are defined by dissimilar interests. Parastatals, such as SAFCOL and other government enterprises, are not prepared to mechanise all of their production processes, as a way of preserving employment. This is despite the international drive for mechanisation to improve efficiency and to reduce injuries to workers in forestry production activities. Overall, the failure to apply research findings and innovations, as noted above, may be related to the lack of a common vision in the sector, failures on the part of researchers in communicating the findings competently, the lack of involvement of end users in research activities (interaction failures, Woolthuis, 2005) or due to institutions or government policy orientation (institutional failures, Woolthuis, 2005). All of these issues imply interactional challenges. These partly explain weak linkages (Greenberg, 2010) and the lack of integration (OECD, 2007) in the forestry SSI of South Africa. The failure by firms in the forestry sector to apply R&D is also partly explained by the disjunction in the research needs and the focus of the industry *vis-à-vis* the research organisations.

[40] Mr B49. Technical Manager- DEA Eco-Furniture Industries, interviewed by Mushangai, 27/06/2017

5.3 The disjuncture in the research needs and focus of the industry and research organisations

The relationship between the collaborating partners in forestry R&D at times is characterised by disagreements (Storper, 2007), all of which affect the generation, transfer, and application of knowledge within the forestry sector. Some of the challenges and disagreements are a result of differences in objectives between the collaborating partners. Unlike most firms, universities and research institutes are not only interested in applied knowledge, but also in blue skies research (basic research) which may inform applied research (Kotecha, Walwyn, & Pinto, 2011). Further, universities and their successes are measured in terms of the number of graduates produced and the number of published research papers (HESA, 2011), while the success of firms is partly measured by the quantity and quality of their products that define their distictiveness. Some firms in the forestry sector complain that university R&D at times does not address their immediate production concerns, as most resources in terms of money and time are spent on basic research. As observed by Dr B3, the Research and Strategy Manager of Merensky Timbers,

> Universities have their own objectives and things they need to do that are important for their key stakeholders. We are only one of the stakeholders at the university. For us, the applied outcome would be extremely important. For example, if we have a new pest, we want that to be managed immediately at a level that it does not cause economic injury, but at the same time universities need to produce papers and to graduate students. They have challenges in terms of fees and all the other things that are playing out at the moment. We (industry) are not able to survive on papers. If a paper is published, that is great, it adds intellectual capital, but at the same time we cannot pay the bills based on papers, so there is a different objective in terms of that.[41]

Further, Mr B15 from SFA noted that,

[41] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

> The bigger problem is the reason for generating this knowledge. A lot of people generate knowledge to get a piece of paper called a Ph.D. I would not commission or financially support any research that is not supported by the end user. There should be demand. As somebody coming up from the business side of things, I would say let the demand drive the production.[42]

This was also voiced by Ms B39, at ICFR who observed that ‘in terms of universities the challenge for them is that their research is sometimes perceived as being kind of distant from the problems associated with production in firms’.[43] These sentiments were corroborated by Dr B5 from the Forestry and Agricultural Biotechnology Institute (FABI-University of Pretoria), who emphasised that,

> There is a bit of disjuncture between academia which is seen as the whole ivory tower mentality, and what are really the practical needs for the industry. Academia seeks to understand and to do basic research much of the time, whereas the application of that research is not always immediately clear. The industry often wants to do applied research which limits the potential for high impact application, because depending on what the topic is, applied work is of limited interest to most people as opposed to broad, or general findings in Biology which are attractive to the entire research community. The challenge is finding that critical balance when you deal with industry support of academic programmes to do the necessary applied research work, but also devote some funding towards small basic research where the return on investments to the industry is perhaps not as fruitful as with the applied research.[44]

The different objectives make it difficult for collaboration between research institutes and the industry, thus impacting negatively on the industry’s commitment to funding basic research or long-term projects. Things may even be more difficult if the research institution or a project is funded by the industry or firms in the industry. These differences in what to focus R&D funded by the industry led to the dismissal of Prof D as the Director of ICFR in 2017, as he was accused of failing to focus the institution’s research to address the immediate specific needs of the

[42] Mr B15. Small Business Manager-FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[43] Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[44] Dr B5. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

industry.[45] He was replaced by Dr AM from the industry (SAPPI).[46] With regard to this Prof B48 explains,

> The board of the ICFR during very angry negotiations in the whole of 2017, fired the director, Prof D and Dr AM had to take over from SAPPI. The board said you are no longer doing what we expect you to do, why are we paying for a product that we do not want? That was one of the reasons why their budget (ICFR) has been cut from R34 million to R8 million and had to retrench all their staff.[47]

The challenges, if not negotiated carefully, may end up limiting academic freedom. These challenges are well articulated in the research on fungal pests: the Cryphonectria cubensis project in (Appendix 1, Box 3). The Cryphonectria cubensis project is critical in demonstrating the importance of collaboration in knowledge generation, transfer and application and the benefits to be accrued by the industry when the industry and universities manage to resolve the challenges with regard to their focus on basic and applied research. The study showed that, because of ‘talk’ (Storper, 2006), the industry may be made to realise the benefits of long-term research in their production activities and therefore continued funding for academic research by the industry.

The Cryphonectria Cubensis (Appendix 1, Box 3) project demonstrates the importance of high science in the generation, transfer, and application of knowledge for improved productivity by firms. A number of technologies were generated in the process of research. The research provided evidence that tree breeding was also affected by pests and pathogens, whereas firms previously relied only on timber quality and growth in their selection and breeding processes. The Cryphonectria Cubensis project proved that the quality and growth functions were affected by pests and pathogens, hence the importance of funding for pests and pathogens research. The research resulted in the production of disease-resistant planting material for the industry and new technologies to screen the planting material.[48] Although no research has been conducted yet to quantify the benefits of this research to the industry in terms of financial gains, huge benefits are assumed in relation to upgrading and innovation. The FSA Annual Report (2013) noted that FSA is often asked by firms to quantify the extent of the loss avoided because of the research on pests

[45] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[46] Ibid

[47] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[48] Ibid

and diseases. This is difficult to do as it cannot be said with certainty, ‘’how widespread an outbreak would have been had there not been pests and disease research and the accompanying interventions’’ (FSA Annual Report, 2013, p. 6).

Nevertheless, the benefits that accrued to the industry from the Cryphonectria Cubensis research included the introduction of disease-resistant trees and of new screening technologies. The firms accumulated benefits from the research, especially in ‘having trees that do not die’.[49] Incremental innovations to the sector were realised in the adoption and adaptation of Polymerase Chain Reaction (PCR) technologies from America that were important in DNA multiplication and sequencing and permitted the scientists enhanced understanding of the genetic make-up of the fungal pests they were dealing with.[50] The application of knowledge from this research enabled upgrading by South African plantation firms from planting pure species to planting clones in the early 1990s. As noted by Prof B48, ‘We have changed our planting material dramatically from going just for pure species to clones and hybrids that are now much more tolerant to low rainfall and high temperatures and are resistant to most diseases’.[51] Following the achievements of this project, an interesting development has been witnessed in the sector with regard to pest and diseases research funding. Crane (2017) noted that, of the total FSA budget in 2016, ‘’the vast majority was spent on research and forest protection’’ (p. 5). However, the FSA noted that, while the returns on this investment have been diminishing in several cases, the benefits are still of greater magnitude than the investments (FSA Annual Report 2016, cited in Crane 2017:5). The report went on to note that benefits have been realised in higher growth and ‘’losses from pest and disease avoided’’ (FSA Annual Report, 2016, cited in Crane 2017). In terms of timber growing, the growers collectively are currently harvesting 85% more timber per hectare than they did in 1980 (FSA Annual Report 2016, cited in Crane 2017).

Despite these advances, South Africa has not yet adopted the new advances (exploited in Europe) in root technology that can modify the environment and make the right bacterial organisms in the soil to prevent pathogen infestation.[52] According to Prof B48, ‘We have not adopted any of the very advanced work in Europe on root technology’. The South African

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[49] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[50] Ibid

[51] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[52] Ibid

forestry SSI has to interact with the international SSI for the adoption and optimisation of root technologies in South Africa.

One of the most important impacts of the Cryphonectria cubensis project (Appendix 1, Box 3) was in making a complete mind shift on the part of the firms as to what they considered important when selecting for breeding purposes. As Prof B47 observed, there has been 'a revolution in forestry commercial production in South Africa as a result of the research'.[53] Among academics, knowledge was broadened, as Cryphonectria Cubensis, which they initially assumed wrongly to be a single species, was discovered to consist of 50 species of fungi. All of these species, which were unknown to science before, were described and explained during the research process.[54] Further, on the academic side, student training was facilitated by students' participation in the research.[55]

However, the major challenge at the beginning of the research project was the disagreement between the industry and the university researchers on what was to be researched. The firms concerned with cutting expenses were only interested in the solution, that is, applied research, but the scientists were of the view that this would not be possible without understanding the basic functions of research in relation to the origins of the fungi, its diversity, habitat, and biology.[56] As a result of 'talk' (Storper, 2006), the scientists were able to convince the industry and the government to provide funding for basic research which was important in informing the applied aspects of research, especially considering that the fungi were native to Africa. This was contrary to what was assumed at the beginning of the project. This finding was crucial in establishing the reasons why indigenous trees were not dying from the fungal infestation while exotic eucalyptus species were affected.

Another important dimension of this research was the participation of the industry and their researchers in the research process. This limited interactional challenges in communicating the findings of the research and their application. This is different from the case of fire research (Appendix 1, Box 2), whereby firms were not involved and had a challenge in taking up, and applying research findings. The participation of scientists from the industry in the research was

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[53] Ibid

[54] Ibid

[55] Ibid

[56] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

crucial in building the interactive and R&D operational capabilities of firms. These capabilities are normally developed through knowledge acquisition in the process of interacting with the collaborating partners (Maskell & Malmberg, 2002).

The benefits of R&D in a system of innovation can be optimised if the government and private firms are made to realise the importance of long-term research. In the conceptual framework, Chapter 3, Storper (2006) emphasised the importance of 'talk' for the efficiency of an innovation system. Prof B47 noted that, with pests and pathogens research, they have had disagreements with the industry throughout, since they started the Tree Protection and Cooperative Programme (TPCP) at the Free State University in the 1980s before transferring the Programme to the University of Pretoria in 1997.[57] However, it was as a result of 'talk' and negotiations that disagreements as blocking mechanisms (Bergek et al, 2010) within the forestry SSI were resolved amicably, allowing the industry to realise that 'with pests and pathogens it was not only important to design measures to eliminate but also broad research in terms of understanding the anatomy, genetic make-up, and habitats' in providing deep knowledge and deep understanding as the backdrop to successful tree breeding programmes.[58] In the process, both the industry and the university acquired interactive capabilities (Malerba, 2005), in resolving disagreements. As such, the industry has been funding the TPCP research on pests and pathogens that have been threatening plantation forestry for the past 27 years.[59] Nonetheless, 'talk' can only be possible if all the partners see the value of R&D and are eager to negotiate. This was not possible in the ICFR case alluded to above, which led to the dismissal of the director in 2017. The differences in research focus by firms and universities and research institutes are challenges defined by the system of innovation scholars as interaction failures (Woolthuis, 2005), which impose barriers to knowledge generation by researchers and in the optimisation of innovation by firms.

Nonetheless, Prof B47 noted that academics have been trying to find a balance between academic and applied research.[60] This implies a shift from teaching and basic research by academics to involvement in product development. It is an example of Gibbons' Mode 2 thesis in South Africa, according to which researchers are concerned with both basic research required in

[57] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[58] Ibid

[59] Ibid

[60] Ibid

generating useful knowledge and applied research important in the provision of solutions to identified problems, such as the development of new products and technologies. In relation to this, Ranga (2013, cited in Bergman 2014) brings in the concept of an *entrepreneurial scientist* interested in advancing the frontiers of knowledge but at the same time interested in the practical and commercial application of knowledge for industrial and financial returns. This development is important for it removes barriers to innovation that arise when different people in different components of an SI carry out basic research and applied research separately. As noted by Freeman (1997, cited in Shapira, Smits, & Kuhlmann, 2010), the rapid economic development of Britain during the first industrial revolution was because of the strong links between the scientific, industrial and political components of the system of innovation. Rapid economic development in Germany during the second industrial revolution was a result of improved connections between the components of the system of innovation (Shapira, Smits, & Kuhlmann 2010). Although there are still challenges in South Africa with regard to disagreements on research focus by the industry and the university, the Cryphonectria cubensis research (Appendix 1, Box 3) shows that there is a gradual shift in the perspective of the industry concerning the importance of basic research. The Cryphonectria cubensis project also demonstrated that, through communication and collaboration in research, differences could be addressed amicably. However, this has to be based on the ability of the university to demonstrate the effectiveness of research through the provision of relevant evidence. Despite the slight improvement in the relations between academics and the industry in knowledge generation, transfer, and application, as in the Cryphonectria cubensis project, interactions in the forestry SSI are still hindered by the lack of funding.

5.4 Funding Challenges and their impact on the employment of R&D

Funding challenges are a fundamental 'systemic problem' (Bergek et al, 2010), imposing limitations on knowledge generation, transfer and application in the forestry sector of South Africa. Collaboration in R&D in South Africa has been heavily affected by the lack of funding (HESA, 2014). The forestry sector stakeholders (industry, firms and government officials) alluded to a reduction in forestry R&D funding by the democratic governments of South Africa as an impediment to the employment of forestry R&D.[61] Much of the funding that the forestry

[61] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

sector used to receive under apartheid is now directed to agriculture by DAFF in order to ensure food self-sufficiency (FSA Annual Report, 2016)**.** The lack of funding makes it impossible for those involved in forestry production processes to enhance their research activities. As elaborated by Dr B3,

> In terms of the government structures, the lead department is DAFF and there is a clear focus on agriculture in terms of funding and attention. In many ways, the reason for that links back to food security. There is a lack of dedicated focus in terms of forestry by DAFF. Funding is definitely not committed to forestry and the focus is on agriculture. It is quite clear that the Minister is focused on agriculture and the Deputy Minister is focused on forestry. That immediately tells who the priority is. If you look at the expenses and the budgets, you will see there is an even greater divide in terms of what is spent on agriculture and forestry.[62]

This was also highlighted by Dr B5, from the University of Pretoria who indicated that,

> There is very little that we can do to enhance it (R&D). We are in need of research funding from the government. That is probably one of our biggest challenges that we need to improve on. If the government does come to the party then we will see a significant impact of the value of the research of the sector.[63]

The agricultural focus by DAFF was also emphasised by the former Deputy Minister of DAFF, General Bheki Cele.[64] In a speech at the Forestry Industrialisation Conference (FIC), Bheki Cele pronounced that DAFF does not have significant resources to commit to forestry R&D because of budget constraints.[65] He noted that in other countries, agriculture, forestry and fisheries are different departments with separate budgets but, in South Africa, they are considered as a single department.[66] This has implications for resource distribution such that resources are thinly spread across the three functional areas but with the major share allocated to agriculture in order to

[62] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[63] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

[64] Bheki Cele is the Deputy Minister of Agriculture, Forestry and Fisheries. This was a remark that he passed in his presentation at the Forestry Industrialisation Conference (FIC, October 4 2017, Kempton Park).

[65] Ibid

[66] Ibid

ensure food security. The arrangement leaves little in the way of resources being channelled to forestry R&D.[67] In such an arrangement, Prof B48 noted that,

> Because it is Agriculture, Forestry, and Fisheries (DAFF), agriculture was their first priority, fisheries were their second priority, and forestry was their third priority. For the total funding, we used to get nearly R800 million in the budget for research across those three sectors, and forestry used to get about R80 million a year. But in the last two years, that has gone to R800 000.[68]

Underfunding by the government was also considered a huge constraint in driving forestry innovation by Mr B12.[69] With regard to this problem, Mr B12 has this to say,

> We are in a chronically underfunded situation. The private sector contributes in the region of R200 million or so a year into forestry innovation and the government contributes about R5 million. There should be a proper partnership between the state and the private sector that actually drives the innovation for the country. In many countries that we have looked at, those with successful innovation systems have a sort of tri-party process with common goals being pursued by the state, the private sector, and the universities. We need the three; we need to use institutions we have in the country and not just the universities. If we can get all the three targeting the same goal and have appropriate resourcing, then we have a better chance of moving forward faster and more effectively.[70]

The triple helix relationship (Ye, Yu, & Leydesdorff, 2013) of the state, industry, and universities in forestry R&D is hindered by the government's lack of commitment. The above testimonies point to the lack of funding because of the lack of a common vision between firms and universities on one side and the government on the other side, as an impediment to R&D. The lack of alignment in terms of vision in forestry R&D between the firms and research institutes on the one hand and the government on the other hand limits the extent of research

[67] Bheki Cele, Forestry Industrialisation Conference (FIC, October 4 2017, Kempton Park)

[68] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[69] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[70] Ibid

benefits in the forestry SSI. Prof B46, a genomics professor at the University of Pretoria observed that,

> In most of our programs, the main problem is the stability of funding. Even if funding is there is, it is not guaranteed for longer than 3 years at a time. You can get funding for a 3- or 5-year period or if it is Foundation money maybe for a 10-year period. We cannot make permanent appointments of staff because we do not know whether the funding will be renewed. The university will not be able to do that.[71]

Long-term planning is therefore made difficult because of the unreliability of some funding models. The problem of funding is further accentuated by the unreliability of government funding schemes when funds are available. In relation to this, Dr B5 stressed that,

> We have had instances where we are expecting a million Rand from the government, but then it never materialises because government's budget has been cut or there is no money available. Government funding is unreliable.[72]

Unreliable funding models compel researchers to focus on short-term projects devoid of long-term R&D benefits to the industry. The importance of long-term financial commitment in capacity building and in the success of research enterprises is an issue which has been strongly emphasised (Burley et al, 1989; African Academy of Sciences, 1994; Walton, 1994). In some instances, short-termism with regard to funding models has had the effect of stalling the implementation of research projects. In some cases, projects are abandoned halfway, which limits impactful long-term production improvements. This was the case as noted in Chapter 2 with the dismissal of Tom Sim as a conservator of Natal in 1907. Long-term planning is therefore made difficult because of the unreliability of some funding models. In some cases, the South African government has not been able to fulfil its funding commitments in terms of forestry research and innovation. Mr B12, the Research Manager of Mondi Forests, noted that though the government has promised to meet the private sector halfway in funding forest innovation, the funds have not been forthcoming. According to Mr B12,

[71] Prof B46. Genomics Programme –FABI, UP, interviewed by Mushangai, UP, 19/09/2017

[72] Dr B5. Lecturer, FABI- UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

> We have a commitment by the government to meet us on an equal partnership in terms of research rand spent. In terms of the Forest Charter Council, we have a commitment from the government to do that, but the funds have never been forthcoming. Even though there is willingness, there is not always the ability to execute and implement.[73]

All of this points to the unreliability of the government as a funding partner, a factor that brings uncertainties in relation to the continuity of forestry innovation projects. The Forest Charter is an institutional mechanism to guide the interactions of forestry development partners. The conceptual framework (Chapter 3) emphasised the importance of institutions in bringing about predictability in a commercial enterprise. The disregard by the government in fulfilling its development commitments, as dictated by the Forest Charter, brings in uncertainties to the sector, thereby creating an environment that is incapable of attracting investment.

In connection with forestry industrialisation, limited funding implies difficulties of the South African Forestry Sector in catching up with other developing countries in terms of the application of the latest technologies in genomics, biotechnology, and forest product development. Dr B5 noted that, if bio-economy related research is to succeed in South Africa, there is a need for a significant cash injection of 'a few hundred million rands into the establishment of a dedicated typing facility'.[74] The Genomic Research Project (Appendix 1, Box 5), though discussed under the lack of skills rubric, demonstrated that, despite its achievement in the generation of new knowledge and technologies that have transformed forestry conservation, management, and breeding practices, the extent of possible benefits in relation to contributing to the economy has been limited by the lack of funding. The case noted that though South Africa has managed to get past the challenges of genomic and gene sequencing, which is cheap, phenotyping, remains one of the huge bottlenecks, because it is expensive.[75] Phenotyping has to do with the measurement of traits in a tree population and yield trials to monitor biomass accumulation over time.[76] Genotyping and phenotyping technologies are more important than ever in South Africa to improve the timber quality and the yield per hectare. This is so when

[73] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[74] Dr B5. Lecturer-, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

[75] Ibid

[76] Ibid

taking into consideration that commercial forestry is retreating from riparian zones, reducing the plantation hectarage, all with a negative impact on the quantity of production (Chamshama & Nwonwu, 2004). The success of genotyping and phenotyping processes would enable the production of trees that are resistant to drought; pests and pathogens[77] which are some of the major threats to plantation production in the era of global warming and climate change. Improving output per hectare is very important for the sustainability of the value chain as a whole especially in South Africa where the size of the plantation economy has already been reduced as a result of the land reform and environment regulations (as shown Chapter 2). As noted in Chapter 1, small-scale firms down the forestry value chain in South Africa are facing a shortage of timber, as most of the big firms channel the timber from their plantations to their pulp and paper mills. This brings in the imperative of employing the latest technologies to improve timber yields to enable sufficient supply to all players down the value chain. In the Genomics case study (Appendix 1, Box 5), it was noted that, in terms of phenotyping and genotyping, South Africa is still lagging behind China, Brazil, and Sweden, with highly 'advanced labs and greenhouses equipped with sophisticated high-resolution images and spectral images of the plants'.[78] As a result of the lack of funding, South Africa still relies on outdated laboratories, making it difficult to generate new knowledge and technologies to improve the competitiveness of South African firms on the international market. The competitiveness of the South African firms on the global market will be determined by strategic research capacity in disciplines, such as genomics and biotechnology with an influence on the future evolution of the industry.

Further, the Cirex Wasp case study (Appendix 1, Box 4) indicates that, despite the achievements of the research project and its benefits in terms of returns on investment, these achievements have not been optimised because of the lack of will on the part of government to fulfil its funding commitments in relation to implementing the Integrated Forest Protection Strategy of 2013.[79] [80]

The changes in the government's approach to forestry research funding should, however, be understood within the broader institutional changes aimed at redressing colonial injustices in

[77] Dr B5. Lecturer-, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

[78] Ibid

[79] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[80] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

relation to the distribution of the means of production. These processes may be regarded as creative destruction, with the effect of democratising the space to facilitate the participation of the formerly excluded in the economy (Smits et al, 2010). As noted by Schrempf, Kaplan, and Schroeder (2013), governmental policy may play a crucial role in radical changes by changing the direction of development. The South African democratic government's policy changes related to the forest sector are rooted in political, economic and social transformation aimed at integrating society as a whole by ensuring inclusive development as the epitome of enduring stability aligned to the dictates of sustainable development as articulated by international forestry regulatory bodies, such as the FSC and the ISO.

The changes point to the existence of interactions between the NSI and the Forestry SSI. The adoption of land reform as a national programme witnessed formerly white-owned land distributed to black farmers under restitution, redistribution, and land-tenure reforms. This was accompanied by a reduction in funding to the forestry sector, which 'is generally perceived as white-dominated' (Tewari, 2002). Much of the funding is now directed towards agriculture, especially under the Land Redistribution for Agricultural Development (LRAD), in a bid to demonstrate the viability of the land-reform programme by ensuring the productivity of all lands of the beneficiaries.[81] Other programmes by national departments with a focus on rural development have also been slanted in favour of agriculture as opposed to forestry. For example, the Comprehensive Rural Development Programme (CRDP, 2008), by the Department of Rural Development and Land Reform (DRDLR), has a clear focus on land, livestock, cropping, and agricultural commodities, rather than forestry resource development (DRDLR, 2009).

These changes have affected the ability of the forestry sector to leverage funding to enhance R&D hence efficiency and effectiveness in production. According to Prof B44, who was the coordinator of the forestry Management Research and Planning Forum (MAREP) that dealt with the integrated management of forestry resources during the apartheid epoch, the reduction of government forestry R&D funding has affected the ability to implement sustainable practices in the forestry sector.[82] Prof B44 observed that, under MAREP,

[81] Mr B27. Head of Forestry Department- Fort Cox, interviewed by Mushangai, Fort Cox, Eastern Cape, 06/11/2017

[82] Prof B44. Forest Ecologist, UP, interviewed by Mushangai, UP, 29/05/2017

> We were, dealing with plantation forestry. Tree breeding that is linked to plantation forestry. We had natural forests and we had grasslands and shrublands, which are more in the catchment areas. I started a project in 1986 on the growth of natural forests because growth is a key part of sustainable forest management. How far do the trees grow, how much can you take off every year, and the government supported with funding. Then some lady came in charge there and decided this is luxury research. But it is basic, everybody is looking for it. They stopped funding for that about 5 years ago. All these very useful long-term plans are not maintained. This whole thing was dissolved.[83]

This, according to Prof B44, affected the implementation of integrated forest practices.[84] While funding has been reduced from activities having to do with sustainable and integrated forestry management practices that were considered important under apartheid in managing grasslands, shrublands and catchments areas, the little remaining funding has been concentrated in research activities closely linked to land reform, the development of new technologies and innovations, such as genomics for the bio-economy, and for pests and pathogens research. Prioritisation with a focus on high impact projects is crucial in situations where resources are limited but, in South Africa, the impact of funding prioritised projects has been reduced because of short-termism in relation to the government and private sector's funding models.

The Sirex Wood Wasp case study (Appendix 1, Box 4) shows the importance of collaboration and funding in knowledge production and application but also provides a case where short-term funding limited the optimisation of remarkable scientific discoveries which could have been achieved by extending the discoveries through the implementation of the National Forest Protection Strategy approved by DAFF in 2011.[85]

The Cryphonectria Cubensis (Appendix 1, Box 3) and the Cirex Wasp (Appendix 1, Box 4) research studies demonstrate that innovation knowledge is collective. Big firms may produce scientific knowledge in their own laboratories but Bergek et al (2010) observed that firms rarely innovate based on their internal knowledge because of technological complexity and

[83] Ibid

[84] Ibid

[85] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

technological dynamics. It is because of this that the SI scholars put emphasis on technological cooperation or collaboration, as technological knowledge is by nature collective. However, in the cases referred to above, collaboration in South Africa has been crucial in the generation and diffusion of technological knowledge among the partners but the extent of this has been limited by the lack of funding or the inability of the government to fulfil its funding commitments, especially with reference to funding the National Forestry Strategy, which it approved in 2011 (FSA Annual Report, 2013). From the research projects the firms and universities gained technological knowledge while the government gained knowledge that informed the National Forest Protection Strategy, as approved by DAFF in 2011. The case of limited funding is worsened by the diversity in production orientation among the firms, which makes it difficult for them to pool together resources for R&D.

5.5 Firm diversity and coordination challenges in directing R&D activities

Diversity in production orientation among big firms, such as Mondi, SAPPI, Merensky Timbers, and others, makes it difficult for the formulation of a common R&D strategy for the sector as a whole. The different firms in the sector have different visions, making it difficult for them to cooperate to reduce transaction costs in R&D performance. As highlighted by Prof B48,

> The companies have different strategic research plans to the government and to the ICFR. They have essentially ring-fenced their strategic plans and do not have the same vision. Each company has its own vision and the parastatal government forestry areas have their own vision.[86]

The lack of common vision proved to be one of the major obstacles and interactional challenges working against cooperation by different players in the implementation of R&D at the sectoral level. Mr B12 elaborated on this when he stated that,

[86] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

> At the moment we do not have a clear understanding in the whole sector which includes government and private sector, and all the supporting institutions. There is no common vision on what the priorities are from a research point of view that we should be pursuing in our country to make the whole sector more competitive and to generate more wealth for the country. We have no shared vision of where we need to go as a country.[87]

This was further buttressed by Ms B39 when she explained that,

> There is no vision of what the future needs of forestry are. What needs to be done is for the sector to come to up with a vision for the future that will inform research. We are trying to guess all the time about what we are going to need or might need. The private sector does not have a forest research strategy. Researchers are providing solutions for the future but there is no forest research strategy from the sector. There is a government strategy which has no funding attached to it. A common research strategy would make such a difference. It is a small industry and if there was a common understanding of what the research needs of the future are, we could collaborate, form partnerships, and attract funding. All of those things could happen if you had that vision. They have not articulated on that.[88]

The lack of a common vision points to the lack of integration of the forestry SSI, mainly emanating from differences in production orientation. This challenge entails that the big growers, the medium growers, and the small growers want different research. Among the big growers there exist different research needs and so is the case among medium and small growers. This makes it difficult for research organisations to focus their research activities, especially when research funding is commonly pooled. As a result of the differences in production orientation, the firms in the sector do not speak with one voice, making it difficult for research organisations to focus their activities. The diversity of interests make research diverse and fragmented, with the already limited funds thinly spread across many small projects, trying to answer many different questions. This reduces the impact of research funds. This was one of the reasons that led to the dismissal of the director of the ICFR in 2017, as the industry complained that the institute had

[87] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[88] Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017

embarked on too many projects with little impact on industrial production.[89] The lack of a common vision among the firms partly emanates from the fact that the forestry value chain of South Africa has many categories of production, such as the pulp and paper category, the sawmilling category, and the pole timber category, involving different players (FSA, Forestry Fact, 2017). These categories are analysed in the sections below.

5.5.1 The pulp and paper category

Firms such as Mondi and SAPPI have the bulk of their plantation timber in South Africa for pulp and paper products.[90] The pulp and paper category has been the biggest contributor in the sector to the national economy in terms of the gross domestic product (GDP).[91] However, the forestry timber, pulp, and paper industries in South Africa are inefficient and wasteful, capable of extracting only 35-47% of value from the whole tree (Sithole, FIC presentation, Transnet Esselen Park, Kempton Park, 4 October, 2017). As a result, the core of R&D activities of firms in this category has been on the reduction of inefficiencies in production. According to Dr B8, the Research Manager at the SAPPI Technological Centre in Pretoria, the main R&D activities at SAPPI have been about ensuring the maximum conversion of fibre to pulp and paper products.[92] The conversion of fibre to pulp and paper products involves 'the use of enzymes for processing in the company's pulp and paper mills where the trees are broken down into pulp to be made into paper'.[93] As such, at SAPPI concerted effort has been directed at matching machines more to changing markets, reducing costs, improving efficiencies focusing on dissolving water pulp (DWP), virgin packaging paper, tissue paper, office paper, newsprint, and energy generation.[94] Fulginiti (1998) noted that productivity in agroforestry-linked businesses in the 18 countries he studied across the world was linked to inputs like machines. As a way of upgrading its processes, SAPPI invested R30 million at its Stanger Mill in upgrading the paper machines in 2015 and a further R70 million in sheeting and finishing operations at the mill in 2016 (Sappi Southern Africa Sustainability Report, 2016). In terms of Typek, these investments and innovations have the benefits of improving paper bulk and stiffness for better 'runnability' in printers and copiers

[89] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[90] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[91] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[92] Dr B8. General Manager- SAPPI Technology Centre, interviewed by Mushangai, Pretoria, 02/03/2018

[93] Dr B1. Research Manager, Genomics, 4Sight Futures, interviewed by Mushangai, Pretoria, 24/10/2017

[94] Dr B8. General Manager- SAPPI Technology Centre, interviewed by Mushangai, Pretoria, 02/03/2018

as the product now contains sugar cane bagasse pulp and enables a smoother surface for an excellent finish (Sappi Southern Africa Sustainability Report, 2016). These are incremental innovations demonstrating dynamic capabilities in terms of SAPPI's financial capabilities as a big player in doing it alone to upgrade and adapt rapidly in response to market trends. Dr B8 indicated that, in these processes at SAPPI, knowledge generation and transfer occur in the interaction with machine operators and when BSC graduates are trained at the firm's sites on how to run the new machines involved.[95] This is what Horden (2016) implied, that from propositional conceptual knowledge we derive other forms of specialised knowledge generalities but focus on occupational practices in providing technical solutions to technical problems. This would include engineering, which relies on general conceptual knowledge from the physical sciences. At the firm level, generalised specialised engineering knowledge is blended with tacit knowledge accumulated by senior employees in operating the specialised pulp and paper production machines and passed down to new employees through job induction. The blending process of the different types of knowledge is the motor-power driving the critical processes of innovation, as reflected by Schumpeter (1942) when he affirmed that,

> The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets, the new forms of industrial organisation that capitalist enterprise creates.

In relation to silvicultural practices, the pulp and paper production category has a different R&D objective. Their focus with regard to growing the resource base has been on the rapidity of tree growth and the maximum amount of volume that can be generated per surface area. The focus is now expanded to include the quality of the material timber because of opportunities for the extraction of value in further downstream processing activities.[96] The big firms in this category have been responding to mega global trends, such as the global shifts in demographics, technology, climate, the drivers of the international economy, and a carbon-constrained future (Sappi Southern Africa Sustainability Report, 2016). In anticipation of changes in the market with regard to the impact of technology on the demand for paper, the firms in the pulp and paper

[95] Dr B8. General Manager- SAPPI Technology Centre, interviewed by Mushangai, Pretoria, 02/03/2018

[96] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

group have been shifting their innovation activities towards packaging in terms of ‘white top liner boards and uncoated fine paper’, in the case of a company like Mondi,[97] and to specialty chemicals, in the case of a company like Sappi.[98]

Moreover, innovation activities in this category have also been intensifying towards the development of technologies for the manufacturing of products from wood waste. Dr B1 noted that there had been a development in the industry where firms are now looking ‘at trees not just as a source of supplies for pulp and paper, but new product streams for chemicals and bio-energy’.[99] For example, SAPPI has been leveraging this opportunity by planning expansions of dissolving wood pulp (DWP) production capacity at its Ngodwana and Saiccor Mills of up to 100 000tpa, beginning in 2017 (Sappi Southern Africa Sustainability Report, 2016:22). DWP is obtained when wood fibre is processed and purified to extract the cellulose polymers. The purified natural wood cellulose fibres are further dissolved by global users of DWP and regenerated or reformed for a number of applications, such as textiles and clothing (for example, viscose fabric which has a huge market in Asia), lyocell, acetate, microcrystalline cellulose (MCE), cellophane, and nitrocellulose (Sithole FIC presentation, 4 October, 2017). SAPPI has been collaborating with the CSIR with the aim of developing technologies for manufacturing some of these products that are currently imported by South Africa at a great cost (Sithole FIC presentation, 4 October, 2017). The focus has now been on improving resource efficiency by manufacturing with an emphasis on beneficiating waste material from the mills to improve the retention rate, hence the reduction in waste.

The processes are a component of bio-manufacturing, which involves biotechnology to produce commercially important biomaterials and bio-molecules for use in medicines, food and beverage processing and industrial applications (Visser, 2017). SAPPI has been collaborating in this area with the CSIR, especially after the establishment of the Biorefinery Industry Development Facility in Durban (2017), funded by the DST and the CSIR (Sithole, FIC presentation, Transnet Esselen Park, Kempton Park, 4 October, 2017). In this regard, SAPPI started the construction of a second-generation sugar extraction plant at Ngodwana Mill in 2017 (Sappi Southern Africa Sustainability Report, 2016). From all these developments, it can be seen that new technologies

[97] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[98] Dr B1. Research Manager, Genomics, 4Sight Futures, interviewed by Mushangai, Pretoria, 24/10/2017

[99] Ibid

require collaboration to resolve infrastructural challenges. Infrastructural challenges are interactional challenges referred to by the SI as *infrastructural failures* (Woolthuis et al, 2005) and are addressed mainly with the participation of the government, because of the huge costs involved. This is mainly because the private sector in most cases is not inclined to commit investments in technologies that have not proven their market viability (Schrempf, Kaplan, & Schroeder, 2013). The leading role played by the DST and the CSIR in financing the bio-manufacturing plant in Durban for the production of new and innovative forestry products proves what Velazco (2001) discovered, that the private sector in most cases followed the lead role played by the public sector in relation to investment in R&D. The weakness in this area of this category has been the absence of collaboration by the firms, something with the effect of reducing transaction costs in product development.

Bio-refinery R&D in the pulp and paper category of the forestry value chain makes use of waste products, such as bark, branches, sawdust, and process waste like black liquor, effluents, and sludge (Sithole, FIC presentation, Transnet Esselen Park, Kempton Park, 4 October, 2017). The pulp and paper industry in South Africa has been wasteful, producing 500 000 tons of sludge per year from the pulp, tissue, and paper mills (Sithole 2017). The sludge is an environmental hazard as it is land-filled or discharged into the ocean. This increases the carbon footprint of the industry. However, the enactment of the National Environmental Management Act: Waste Act 59 of 2008 exerted pressure on the industry for better management practices with regard to sludge disposal. The Act incentivised the beneficiation of sludge into consumable products to reduce the industry's carbon footprint. The area of waste beneficiation presents opportunities for new enterprises and if harnessed would improve tree utilisation to over 95% (Sithole, FIC presentation, Transnet Esselen Park, Kempton Park, 4 October, 2017). The sludge is composed of 60% organic matter and 40% inorganic matter (Sithole 2017). The inorganic matter can be converted into bricks while the organic matter can be converted into nanocrystalline cellulose and biopolymer plastics (Sithole, FIC presentation, Transnet Esselen Park, Kempton Park, 4 October, 2017). Some of the organic products in this area with a market in South Africa include hemicellulose sugars; pine oils and nanocrystalline cellulose (Sithole, FIC presentation, Transnet Esselen Park, Kempton Park, 4 October, 2017). The hemicellulose sugars that are lost in chemical pulping are an important source of xylose, which can be converted into xylitol, a low calorific sweetener, especially suitable for people with diabetics (Sithole, FIC presentation, Transnet Esselen Park, Kempton Park, 4 October, 2017). Pine oils that are a precursor of turpentine and phytosterols are also produced from pine waste materials (Sithole 2017). The oil has many industrial and household uses, such as cleaning products, disinfection, solvents, fragrances, and medicinal and aromatherapy products (Sithole 2017). These products are currently imported into South Africa. However, scientists, such as Prof Bruce Sithole from the CSIR and SAPPI, have been working on developing technologies required for the production of these products in South Africa. As mentioned above, SAPPI started the construction of a second-generation sugar extraction demonstration plant at Ngodwana Mill in 2017.

5.5.1.1 Challenges in the pulp and paper category

The sectoral developments in process and product innovation examined above represent both radical and incremental innovations, depending on scale, but, as of now, their optimisation is hampered by 'system weaknesses' in the South African SI. Mr B12, the Research Manager at Mondi Forests, noted that the Competition Act 89 of 1998 prohibits cooperation by big firms in product development, which increases R&D transactional costs by hindering the distribution of research costs among the players. The Competition Act, though designed to stimulate competition and to lessen entry barriers for new and small businesses through the avoidance of collusion by big firms, hinders cooperation in R&D for product development in this category. In this area and in relation to product development, it is inconceivable for SMEs to participate because they lack the operational, technological, financial, and R&D capabilities. It is therefore in the best interests of the country for institutions to encourage collaboration in product development, especially in areas in which the small businesses are unlikely to be participating. This would reduce research costs in product development, thereby boosting the competitiveness of the South African firms on the international market.

Despite the challenges in this area, a number of nuances in R&D characterise this category. The nuances, as highlighted in the research activities by SAPPI and the joint funding of the biorefinery facility in Durban by the DST and the CSIR, would not be captured if we are to conclude, as Prof B48 did when she said that,

> There is no strategic thinking of the entire value chain. Paper is no longer the most valuable product from the forestry industry and South African researchers have known that, but have done nothing about it. It is the new innovations around secondary pharmaceuticals, new molecular products, the production of lignin, polyphenols, tars, alternative products like honey and mushrooms and that has not been embraced. As a result, when the timber prices go down because of the decline in the demand for paper, the industry collapses. There is need for a better-integrated value chain research strategy.[100]

What Prof B48 is saying serves to reflect missed opportunities because of the lack of an integrated value chain approach to research. Nonetheless, it would be erroneous to ignore some of the developments, though small but critical, for the future of the industry as a whole. As indicated above, firms such as SAPPI have conducted trials with many products. This acknowledgement does not ride roughshod over weaknesses in the system as a result of the 'one-man band' approach to R&D by the firms in this category, mainly a response to the dictates of the Competition Act of 2003.

Prof B42, a lecturer in harvesting operations at the University of Stellenbosch, singled out infrastructural challenges as one of the major weakness negatively affecting the development of bio-manufacturing in South Africa.[101] The waste material for beneficiation is scattered across the country and this requires investment in infrastructure for collection to a central manufacturing point. The importance of a well-functioning infrastructure has been emphasised in the National Planning Commission Diagnostic Report (2011), the National Development Plan (2011), and the National Infrastructure Plan (2012). Well-functioning roads and rail systems are crucial in forestry systems integration for connecting the upstream and downstream production activities of the sector. Without this, huge costs are incurred in the transportation of materials. The study of Kiani et al (2008) to determine the relationship between agricultural productivity and agricultural research expenditures in Pakistan between 1970 and 2004 discovered that mechanisation and roads had contributed to improved productivity. The huge transportation costs in South Africa as

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[100] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[101] Prof B42. Lecturer, Forestry Harvesting, Stellenbosch university, interviewed by Mushangai, Stellenbosch, 27/06/2018

a result of the lack of integrated road and railway systems are disincentives discouraging the beneficiation of waste materials in the sector.

Another challenge in relation to bio-manufacturing relates to the struggle in the testing and validation of new and innovative products and technologies at market scale (Visser, 2017). For example, the SAPPI Tugela Mill developed saleable products based on lignosulphonate that are currently finding application in dust suppression in mines, in ceramics and as brick making concrete additives, but the lignosulphonate market has slumped, due to a downturn in the mining industry and the depression in the construction industry (Sappi Southern Africa Sustainability Report, 2016). The depression in the construction industry (from 2010), which uses lignosulphonate as a concrete additive, as well as in ceramics and brick making, has negatively affected the commercialisation and optimisation of these innovative products (Sappi Southern Africa Sustainability Report, 2016). This is worsened by the fact that investment finance in innovations is usually available after market entry.

It is important to note that innovative organisations undertake certain investments to accumulate financial returns. Investments in production once committed become fixed costs to be recouped through the sale of output. If a firm manages to generate financial returns immediately from its investments, the fixed costs can no longer be taken as an economic problem. However, Lazonick (2009) noted that the problem comes with the failure of a firm to recoup returns on investments immediately from the production and the sale of output. This problem, according to system of innovation scholars Chaminade and Edquist (2010), can be resolved with the participation of the government in providing the required market in the early stages of new technologies and products. Schrempf, Kaplan and Schroeder (2013:19) emphasised the need for the government to support innovation by acting ‘’as a lead user of the new technology’’. In South Africa, the government can stimulate the demand for lignosulphonate used in ceramics and bricks and as a concrete additive by providing the initial market, especially with a focus on the construction of RDP houses as an opportunity.

Despite some challenges, the pulp and paper manufacturing category of the value chain has many multipliers because of value addition. It has the potential to drive technology and innovation through technology absorption, diffusion, and R&D. In all these innovative processes, new jobs, products, and technologies can be created. This is crucial considering the emphasis by

Singer (1950) that the economic impact of investment is the multiplier effect in the form of improved ‘’income, employment, capital, technical knowledge, and growth of external economies’’ (Morris, Kaplinsky, and Kaplan 2006, p. 9).

Nonetheless, Dr B3 observed that, despite excellent R&D in bio-based natural products and processes, the conversion of outputs to commercialised products has been constrained by the limited availability of skills needed in product development.[102] Designing and engineering skills are the fulcrum in product development. Design and engineering skills were found to be in short supply in pulp and paper production.[103] The shortage of design and engineering skills is a systemic blocking mechanism in the South African forestry system of innovation. The failure of the national skills system to produce an adequate number of people equipped with design and engineering skills is negatively affecting product development in the forestry sector. The impact of the shortage of skills because of the weaknesses in the national skills system points to the interaction between the NSI and the forestry SSI. HESA (2010) recommended that the shortage of graduates in science, technology, engineering, and mathematics could be improved with an increase in the number of matriculants qualifying for university entrance, especially in science and mathematics.

Moreover, bio-processing and bio-manufacturing in the pulp and paper category are negatively impacted by limited government funding. Dr B5 regarded limited funding for the bio-economy by the government a setback in optimising opportunities in this area in South Africa.[104] The area of alternative products employing genetic modification is where huge advances have been realised in Europe, but in South Africa government support is yet to increase or to ‘come to the party’, as said by Mr B12 from Mondi,[105] to adopt some of these advances.[106] Government support is required in the construction of new laboratories and in supporting the formation of new enterprises.[107] The government may also support the bio-economy through the provision of an initial market for new products. Further, technological opportunities abound in this category, through the convergence of information and communication technologies in linking a firm’s

[102] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[103] Dr B8. General Manager- SAPPI Technology Centre, interviewed by Mushangai, Pretoria, 02/03/2018

[104] Dr B5. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

[105] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[106] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[107] Ibid

production line activities to improve efficiency and by reducing resource wastage between the different but connected production activities of a firm. Through adopting the internet and wireless sensing machines, production line machines can be monitored for the assessment of their conditions. As noted by Annamalai (2017), algorithms can reduce the costs of machine maintenance through predicting future failure conditions and enabling smart scheduling of preventative maintenance. The operationalisation of these technologies along the firm's production line requires collaboration between the scientists who are developing the technologies at science councils, such as the CSIR and the firms in the sector.

5.5.2 The sawmilling category

The second category in the forestry value chain involves firms in sawmilling activities. This category in South Africa includes firms such as Merensky Timbers, TWK, NCT, and others. The sawmilling grouping has a different R&D objective. Their concern is not only biomass but also the quality of the material. The saw-milling business demands careful breeding practices so that the timber produced would meet certain required standards, especially in the construction sector. In relation to this Dr B3, explains,

> We focus on tree improvement because we have large plantation areas. We also focus on processing and product development. We make sure that what we breed for the plantation is suited to what we process in sawmills and what we sell to the customer. In our breeding objectives, we breed for saw logs which would be different from breeding for pulp and paper purposes. Whereas pulp and paper research focus mostly on volume per hectare, although volume is one of our requirements, we also focus on quality in terms of diameter. Quality is mainly measured in terms of diameter, but also certain internal traits that you cannot visually see. That is important for sawmilling because most of the softwood, the pine material, is used for roofing purposes. So, that is important to keep the roof on a house so that it does not collapse. There are strict requirements in terms of two key engineering types of parameters. One is called *modulus of rapture* and the other is called *modulus of elasticity*. One is stiffness and the other is the strength. There is a national standard that you need to

> comply with. That is why we also do research in terms of tree improvement to ensure that the resource that we have actually meet those requirements.[108]

For consumer safety, the construction industry has to meet the required standards, such as the SANS 10400 Code of Practice for the Application of the National Building Regulations; SANS 10082 Timber Buildings; and SANS 10400 X: Environmental Sustainability (Werner-Slabbert-Senior, FIC presentation, 4 October, 2017). There exist a number of construction bodies to ensure that these regulations are met. Among these regulatory bodies are the South African Bureau of Standards (SABS); National Home Builders Registration Council; and the Institute for Timber Construction South Africa (ITC-SA) (Werner-Slabbert-Senior, FIC presentation, 4 October, 2017). The ICT-SA is a SAQA-accredited professional body for the engineered timber construction industry in South Africa. It is responsible for creating and maintaining standards in the industry by monitoring membership; promoting and marketing engineered timber structures; protecting consumers; ensuring compliant trade; and by investing in industry transformation through education and member development (Werner-Slabbert-Senior, FIC presentation, 4 October, 2017).

Much of the research related to timber quality and strength to meet standard requirements has been done by the University of Stellenbosch. This research was funded by the South African Lumber Products Organisation (SALPO), the precursor of Sawmilling South Africa.[109] The research discovered that quality in terms of stiffness was increased through stocking and forest management practices.[110] Stiffness is increased when trees are planted densely together, for the stress of trees planted close together translates into higher stiffness.[111] These discoveries partly confirmed those of Craib and O'Conner's silvicultural studies in the 1970s, as was noted in Chapter 2. Current research in this area has an international aspect, with Dr Drew (University of Stellenbosch) collaborating extensively with researchers at the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Australia.[112] Further, research in this area has been addressed by the ICFR, as funded by the timber levies through FSA. According to Dr B3, from

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108 Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

109 Ibid

110 Ibid

111 Ibid

112 Ibid

the ICFR studies, Merensky Timbers has benefitted from commercialising improved silvicultural-related practices in its plantations ‘’as the main silvicultural gaps been addressed over the years’’ (Crane 2017, p. 6).

The firms in this category, such as Merensky Timbers, SAFCOL, and Mondi, have also been working with the CSIR in improving solid wood properties, especially the production of non-splitting eucalyptus. In the juvenile-mature eucalyptus Florida Study (2007), Mondi, SAFCOL and Merensky in collaboration with Shell Forests (UK) and Fletcher Challenge (New Zealand), investigated the importance of traits for the production of saw-timber and veneer in *Eucalyptus grandis.*[113] The study showed that log-end splitting, diameter, height, and brittle heart are the traits with the greatest influence on the value of eucalypt solid wood products (CSIR, Twenty Years, 2011). These discoveries lead to strategic cooperative research by the CSIR and Merensky in 2007 to accelerate the breeding of high-value eucalyptus hybrids based on improved germplasm, quantitative genetics, and selection methodologies for the sawmilling industry (CSIR, Twenty Years, 2011). The aim was at improving adaptable germplasm with favourable growth qualities and less splitting timber. For genetic improvement, the researchers employed *Eucalyptus saligna* and *Eucalyptus urophylla* for the new hybrid[114]. The selection was based on wood formation and growth qualities[115].

Further, the research was done to reduce splitting in wood led to the development of five clones of *E. grandis* with low log-end splitting and low brittle heart (CSIR, Twenty Years, 2011). The clones have a rapid growth rate, and stable wood because of low log-end splitting than other eucalyptus trees[116]. The advantage of these clones had been a reduction in the loss on plantations due to brittle heart, thereby producing better value for veneer products.[117] As a result of these studies ‘we have changed our planting material dramatically from going just for pure species to hybrids that are now much more tolerant of low rainfall and high temperatures’.[118] Many students at masters and doctoral levels participated in these studies.[119] The cooperation between

[113] Dr B6. Tree Improvement and Reproductive Biology, CSIR, interviewed by Mushangai, CSIR, Pretoria 13/08/2016

[114] Ibid

[115] Ibid

[116] Ibid

[117] Ibid

[118] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[119] Ibid

Merensky Timbers and the CSIR was important in student training concerning access to their plantations.[120]

With regard to product development in this category, Merensky Timbers has been working with researchers from the University of Stellenbosch on the production of cross-laminated timber.[121] The research is funded by the Hans Merensky Foundation.[122] A number of students studying for BSc: Wood and Wood Products, whose bursaries are funded by the Hans Merensky Foundation, participate in the studies that are important in human resource development.[123] This research project is still ongoing.

All of the technological advances emanating from these studies are sector-specific, hence can only be explained within the confines of the SSI approach. Nevertheless, the interaction between the SSI and the NSI should always be kept in mind. For example, the skills required in most of these studies are produced in the NSI but find application in the SSI. However, systems' weaknesses prevented the optimisation of these studies. As noted by Dr B6, many students were left stranded when the government funding for the research by Merensky Timbers and the CSIR ended in 2009.[124] Moreover, with the end of funding, most studies whose products have reached near commercialisation stages were abandoned as researchers left to join other organisations.[125]

5.5.3 The pole timber category

The third category in the value chain includes the production of poles and mining timber, partly needed as props in mines. In terms of the value and contribution to the gross domestic product (GDP), this category has been declining due to the replacement of wood props in the mines with concrete substitutes (Chamshama & Nwonwu, 2004).

In analysing the interactional challenges, it is always important to note that the differences in production orientation by the various players in different categories of the value chain have an implication on interactions, partnerships, and collaboration in R&D. As noted by the Research

[120] Dr B6. Tree Improvement and Reproductive Biology, CSIR, interviewed by Mushangai, CSIR, Pretoria 13/08/2016

[121] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[122] Ibid

[123] Ibid

[124] Ibid

[125] Dr B6. Tree Improvement and Reproductive Biology, CSIR, interviewed by Mushangai, CSIR, Pretoria 13/08/2016

Manager of TWK, Mr B24, 'what might be of importance to the pulp and paper company, or the grower would not necessarily be of importance to the sawmilling industry'.[126] The diversity of firms, their production orientation, and differences of interests explain some of the interactional challenges as to which areas combined R&D funding should address. While some firms are only engaged in a part of the value chain, some firms' activities run across the value chain, hence the differences in research focus. The major challenge emanating from the lack of a common vision is that it will not be possible to adopt a systems approach, hence the lack of strategic thinking about the entire value chain. This increases information asymmetries and transaction costs, even in areas of common research interest, where costs could be distributed among the stakeholders. This is exemplified by the case of an attempt by Merensky Timbers in 2016 to adopt and adapt the water jets used in the automotive industry for cutting mag wheels as a replacement of the traditional forestry way of cutting logs with saw blades.[127] The innovation was meant to improve accuracy and reduce waste when cutting timber. In this attempt, Merensky had to invite an expert from Nine Signa for the testing.[128] Eventually, the attempt did not produce a good product and they could not use it.[129]

Three conclusions of interest to this study can be drawn from the water jet case. First, the case indicates that which Rajalahti, Janssen, and Pehu (2008) noted, that innovations in most cases have not been about creating new inventions but about adapting and using existing ones. In this case, Merensky Timbers' attempt indicates that firms in the forest sector should be open to technologies from other sectors and apply them in upgrading their processes. This is what Humphrey and Schmitz (2002, cited in Gereffi & Kaplinsky 2011) refer to as *inter-sectoral upgrading,* which involves leveraging expertise gained in one industrial sector in another sector. Second, the function of the water jet which Merensky Timbers wanted to adopt was of interest to most of the firms in the three categories of the forestry value chain, hence research costs could have been distributed, had there been collaboration. Thirdly, the case demonstrated what SI scholars Bergek et al (2010) and evolutionary economists Nelson and Winter (1977) have said in relation to the nature of technological knowledge as collective knowledge. Although Merensky

[126] Mr B24. Manager, Research and Development, TWK Agri (Pty) Ltd, telephonically interviewed by Mushangai, 13/11/2017

[127] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[128] Ibid

[129] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

Timbers has its own qualified engineers, the company had to invite an expert from Nine Signa, since they did not have the know-how pertaining to the technology they wanted to adopt. The case also demonstrates that which Bergek et al (2010) noted, that firms rarely innovate based on internal knowledge.

The area of tree breeding is a pre-competitive stage and opportunities exist for cooperation to expand the resource base for the benefit of all in the upstream or downstream activities of the value chain. Breeding R&D for expanding the resource base is crucial, especially now with the reduction of available land for plantation forestry, due to environmental regulations, land and agrarian reforms in South Africa. Plantation forestry had been located in high rainfall areas because both *Eucalyptus grandis* and *Pinus patula* prefer high rainfalls of above 1000mm per annum (Mayers, 2001). As a consequence of the menace posed by climate change, land reform, and legislation governing water and the environment in South Africa, forestry research should focus more on improving returns on plantations in low rainfall areas, on poor soils and in cooler areas formerly neglected by the industry. Research such as the provenance trial by the CSIR at a dry site receiving a mean annual rainfall of 750 mm at Salique in Limpopo should be collaborated on.[130] This study discovered that a 19-year *Eucalyptus camaldulensis* showed poor vigour and poor stem form as opposed to a 10-year *Eucalyptus camaldulensis* hybrid at the same site (CSIR, Twenty Years, 2011). In a trial at the same site, the *E. grandis* did not survive drought, as opposed to a hybrid of *E. grandis* and *E. camaldulensis* (CSIR, Twenty Years, 2011). The research is, therefore, offering much hope for areas without wood, hence prospects for expanding the resource base. In these studies, knowledge related to plant adaptability to different environments is generated in the process of interaction. Plant breeding is an area of common interest which affects all stages of the forest value chain and therefore an area whereby collaborative research may lessen the burden of funding R&D through the distribution of R&D costs among the stakeholders. The failure to cooperate in areas of common interest results in increased transaction costs in knowledge production and makes knowledge production more secretive for individualised research findings are an intellectual property of the firm involved (David, 2006). This limits the diffusion of knowledge and the development of capabilities among those firms with the least resources to fund their own research.

[130] [130] Dr B6. Tree Improvement and Reproductive Biology, CSIR, interviewed by Mushangai, CSIR, Pretoria 13/08/2016

The fragmentation of forestry research has been worsened by the establishment of in-house research departments by the big firms in the sector (Crane, 2017). Big commercial plantation firms, such as SAPPI, Mondi, SAFCOL, and Merensky Timbers, have established their own in-house R&D departments to serve their breeding and product development needs (Crane, 2016). This has led to the reduction in funding to the ICFR as an institution that has been entrusted with addressing industry-level projects, such as improved silvicultural practices and disease and pest interventions.[131] According to Crane (2016), the growth of in-house research activities by the big firms has had 'a knock-on effect' from 2013 onwards on industry-level research projects. Although there has been some collaboration in this category of the value chain, collectively funded R&D has been deteriorating since 2013, as a result of firms' 'we cannot afford the full cost of the ICFR' voices growing louder (Crane, 2016, p. 5).

Further, South Africa has not appreciated other areas of 'alternative products like honey and mushrooms'.[132] This differentiates South Africa from China, where the value chain produces a highly differentiated range of products. Kowero (FIC presentation, Transnet Esselen Park, 4 Oct 2017) is of the view that SAFCOL and other firms have to explore other products of good commercial value, like honey and mushrooms, and to promote their quality production, marketing, and trade to expand the industry's products range. It is with these products that do not require large scale investments, where community participation could be enhanced. These areas could also involve projects for households that do not participate in commercial forestry but in small-scale plantation to produce timber for own use. However, the challenge in South Africa is that community forestry has been neglected. These social dimensions of forestry development are not given much attention in the curricula of forestry skills development organisations in South Africa. As noted by Prof B48, students coming from the colleges,

> Understand very well the natural capital, how to plant a tree, how to trim the branches, when to cut it down, but they do not understand how to negotiate with the smallholder farmer who does not want to grow trees for paper, but for the roof of his house[133].

[131] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[132] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[133] Ibid

This points to the defects in the South African system in relation to social and small business development, as the focus is only on businesses that are considered growth oriented and not on social businesses. This focus has unintentionally resulted in the problem of selectivity, concentrating our knowledge and understanding on some forms of small businesses while neglecting or clouding our understanding of other forms of businesses, especially those classified unworthy of study, such as social businesses. Consequently, businesses that are not growth-oriented, such as social businesses, have not been thoroughly investigated as the emphasis has been on growth-oriented businesses fetishised as policy subjects. This constrains development in areas that are considered crucial by the rural constituent in South Africa. There is, therefore, a conceivable need for a better-integrated value chain research strategy in South Africa that encompasses other business and product areas that were not formerly considered important in the forest sector. More could have been achieved had different players managed to cooperate and pool resources around certain areas of common interest.

5.6 International collaboration

In Chapter 1, it was noted that problems of resource depletion, climate change, pests and pathogens, and global warming in relation to forest development cannot be addressed by focusing only at local levels and calls for collective and collaborative approaches that encompass the regional and post-regional collectives. More importantly, some regions are more advanced in certain technologies and some have cheaper labour than others, therefore, the importance of tapping into these markets. The need to resolve challenges operating at the global scale and for firms in some regions to acquire advanced technologies from other regions necessitates international collaboration. Moreover, globalisation has entailed new ways of organising production by firms, such as out-shoring. The big companies in the South African forestry sector, such as Mondi Forests, have operations in faraway countries, such as Thailand and Russia.[134] As such, developments at international levels are bound to affect production at national, regional, and sectoral levels. Interactions at these levels are crucial for decisions made at these levels have important ramifications for local skills development and the employment of R&D at local levels. Previously, under the apartheid regime, South Africa built its R&D capabilities through interaction with the international community by sending students to study abroad and by

[134] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

participating in international programmes, such as the MEDICOS programme. These international engagements were discussed in Chapter 2. The forestry SSI approach was crucial in these engagements for it is the only SI variant that caters for international dimensions and impacts national R&D capabilities that cannot be fully comprehended by the NSI and RSI because of their geographical limitations, as was noted in the conceptual framework (Chapter 3).

This study discovered that international collaboration is still crucial for the advancement and employment of R&D by firms in South Africa, as it was during the colonial and the apartheid periods. In connection with international collaboration, Mr B12 discerned that,

> International partners have specific expertise that is well suited to complement skills sets that we may have. We have collaboration with international institutions like the North Carolina State University where they have an organisation called CAMCOR. The campus there offers support even from a tree improvement point of view. There is some cover that one could get through international collaboration and buying some expertise to assist from time to time.[135]

It can therefore be seen that international collaboration is a strategic way of tapping into expertise that is not available in South Africa. The preceding section on firm diversity noted that firms such as Merensky Timbers, SAFCOL, and Mondi have been working with the CSIR and foreign firms, such as Shell Forests (UK) and Fletcher Challenge (New Zealand) in the Florida Study. Their study investigated the importance of wood traits for the production of saw-timber and veneers in *E. grandis*. International collaboration such as this allows for the collective generation, transfer, and application of knowledge among the collaborating partners. Besides, South Africa is still far away from the technological frontier in some areas of forest R&D and has to import and adapt foreign technologies. The Cryphonectria cubensis research (Appendix 1, Box 3); the Cirex Research Project (Appendix 1, Box 4) and the Genomics Project (Appendix 1, Box 5) underscore the importance of tapping into international knowledge. All of the three projects benefitted from Polymerase Chain Reaction (PRC) technique that they assimilated from the American research community. As noted by Prof B47,

[135] Ibid

> The PCR was developed in the US, and with international collaboration, learning about these technologies, being able to share information to optimise things, we were able to bring, fine tune and apply those technologies to our field in South Africa.[136]

Moreover, the Cirex Research project benefitted from the nematode that was imported from Australia. Dr B8 from the SAPPI Technological Hub (Pretoria) also noted the importance of international networking when he indicated that most of the technical equipment important in upgrading their pulp and paper processing plants is not manufactured in South Africa, but imported from western countries.[137] The above-referred case studies point to collaboration as crucial in knowledge generation and technological transfers. The participation of expatriate researchers in local contexts because of collaboration is also important in the adaptation and localisation of foreign technologies. As a result of technological complexity, technological knowledge cannot be transferred entirely without the participation of the seller. The purchaser always receives less complete information than that possessed by the seller (Nelson & Winter, 1977 in Joseph, 2009). Viewed in this way, international relationships and interactions become important as technical knowledge can only be fully transferred through interactions between the possessor and the receiver.

Accordingly, South African universities and research institutes have been tapping into international expertise through research, collaborating with a number of international partners in forestry R&D. The CSIR has had collaborative research on a project with the Australian Centre for International Agricultural Research (ACIAR).[138] The project was funded by the ACIAR (CSIR Twenty Years, 2011). The project aimed at enhancing commercial wood production in the medium rainfall zones of both Australia and South Africa.[139] It involved enhanced breeding strategies for eucalypt hybrids, and ‘’the generation of new and improved technologies for the generation and propagation of eucalypt hybrids for commercial production on marginal farmlands’’ (CSIR Twenty Years, 2011, p.10). According to Dr B6, the eucalypt hybrids from this project have already entered the commercial stage in South Africa.[140] As a result of this

[136] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[137] Dr B8. General Manager- SAPPI Technology Centre, interviewed by Mushangai, Pretoria, 02/03/2018

[138] Dr B6. Tree Improvement and Reproductive Biology, CSIR, interviewed by Mushangai, CSIR, Pretoria 13/08/2016

[139] Ibid

[140] Dr B6. Tree Improvement and Reproductive Biology, CSIR, interviewed by Mushangai, CSIR, Pretoria 13/08/2016

collaboration, the CSIR produces genetically improved *Pinus* and *Eucalyptus* species and hybrids with superior qualities for the pulp and saw-milling industries (CSIR Twenty Years 2011:26). The improved germplasm, which is an intellectual property of the CSIR, has been made available to commercial nurseries and researchers from South Africa, Africa, and the world (CSIR Twenty Years, 2011).

It can, therefore be seen that international collaboration is crucial for R&D in the local arena. First, in relation to the collaboration between the CSIR and ACIAR, the research was funded by the ACIAR. International collaboration can thus alleviate the scourge of limited R&D funding. Most significantly, collaboration facilitates interaction, sharing and learning by researchers from different countries. In praxis, collaboration allows for the cross-fertilisation of knowledge which, according to Schumpeter (1942, cited in Smits, Kuhlmann, & Shapira 2010), leads to creative destruction, affording those involved ‘’new combinations of hitherto disconnected ideas, knowledge domains, technologies, or markets’’. It is critical to note that collaboration in the above-cited cases was between partners from the forest sectors of different countries, for they have common technological interests. From this perspective, disruptive technologies in forestry R&D may require transgressing national geographical boundaries, for new ideas are not the preserve of local systems. The interplay between national dynamics and sector-specific dynamics linked to global-level dynamics are tied together through the SSI conceptual framework.

Further, South African universities have also been involved in collaboration with Chinese research organisation. Collaboration with China is crucial to tap into the Chinese expertise, for China and India have emerged as ‘’competitive producers of new knowledge and sites for innovation since the beginning of the 20-first century’’ (Lundvall et al, 2006, cited in Shapira et al, 2010). This collaboration provides fertile grounds for advancing scientific knowledge to problems besetting forestry sectoral firms in South Africa. An example of such collaboration is the Eucalyptus Pathology Programme between the China Eucalypt Research Centre (CERC) and the Forestry and Agricultural Biotechnology Institute (FABI) at the University of Pretoria (FABI, 2017). The CERC is the main organisation supporting the industry in China through eucalypt breeding. It possesses the knowledge and understanding regarding the challenges pertaining to the growing of Eucalypt species in China (FABI, 2018). In South Africa, FABI has been working closely with the industry on breeding and on pests and pathogens[141] [142]. The aim of the Eucalyptus Pathology Programme is to research and generate knowledge on common diseases and pests affecting the growing of Eucalyptus species in China and South Africa[143]. The Governments of China and South Africa fund the programme under the joint management of their science departments (FABI, 2018). Emanating from this case of collaboration have been the exchange programmes with researchers from FABI going to China and those from China coming to FABI.[144] Much has been achieved because of the collaboration and exchange programmes. The biology of many pests affecting eucalyptus plantations has been examined and described, and mechanisms devised to combat them.[145] According to Prof B47, the collaboration between research institutes in South Africa and China is bound to increase as a result of the BRICS bloc,[146] which is an international organisation headed by five developing countries (Brazil, Russia, India, China and South Africa), established in 2011. The collaboration between CERC and FABI, the CSIR and ACIAR, and that of Merensky Timbers, SAFCOL, and Mondi with the CSIR, Shell Forests (UK) and Fletcher Challenge (New Zealand) in the Florida Study, as indicated above, demonstrate that international collaboration may partly be the panacea to 'system weaknesses' or 'blocking mechanisms' related to the shortage of skills and the scarcity of R&D funding at national levels.

The significance of networks between universities was elaborated on by Prof B46 when he noted that, with their international counterparts,

> We have exchange programmes. They come here, work with us, and go back to their institutions. They have technologies or expertise that we do not have. We send students over there to be trained and they come back and apply the skills here, and vice versa[147].

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[141] Ibid

[142] Prof B46. Genomics Programme –FABI, UP, interviewed by Mushangai, UP, 19/09/2017

[143] Ibid

[144] Prof B46. Genomics Programme –FABI, UP, interviewed by Mushangai, UP, 19/09/2017

[145] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[146] Ibid

[147] Prof B46. Genomics Programme –FABI, UP, interviewed by Mushangai, UP, 19/09/2017

Prof B43 also noted that scientists from southern hemispheric countries, such as New Zealand, Australia, Chile, and Peru, have been coming to South Africa, while some South African scientists have been going to these countries to collaborate in research on issues affecting forestry production.[148]

The exchange of expertise has been a growing phenomenon in South Africa. South Africa is also spreading its tentacles in R&D collaboration, collaborating with the advanced and industrialised forestry sectors of Scandinavian countries. Prof B48 from the University of the Witwatersrand does, 'a lot of excellence works in forestry in the Scandinavian countries, reviewing all their forestry research'.[149] The Scandinavian countries are advanced in biotechnology. Collaborative programmes are crucial in the cross-fertilisation of ideas and the sharing of best practices by researchers from different countries working on similar issues. The programmes are cardinal, for successful systems of innovation are made up of ''complex relations characterised by reciprocity and feedback mechanisms'' (Edquist, 2006). This involves exchange relationships with international partners.

Moreover, international collaboration is also important for student development. Dr B5 from FABI-University of Pretoria noted that his PhD study involved going internationally to a collaborator in the USA and 'getting training on a critical technique'.[150] Dr B5 also noted that, at the University of Pretoria, they partly train their MSc and PhD students by sending them to attend international conferences, not just to get collaborators on their projects but also exposure to the international research community, enabling them to establish important networking opportunities.[151] As was noted in the Genomics case (Appendix 1, Box 5), the initiators of the project had to romp in a student who was studying at a European university before he could even complete his PhD. This was because of the shortage of skills in genomics in South Africa. As such, FABI (University of Pretoria) has some of its students on exchange programmes with prestigious research centres, such as the Max Perutz Institute.[152] The Max Perutz Institute based at the University of Vienna is a prestigious institute that focuses on molecular biology, which has

[148] Prof B43. Socio-ecology, Agroforestry, Soils- UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[149] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[150] Dr B5. Lecturer, FABI- UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

[151] Ibid

[152] Ibid

become crucial in determining the future evolution of forestry in a bid to improve the growing stock and the production of new value-added products.[153] In addition, Prof B48 emphasised the importance of international collaboration in student training, noting that one of her masters' students at the University of the Witwatersrand working on a forestry curriculum had to attend an International Union of Forestry Research Organisations (IUFRO) meeting in Freiburg in Germany in 2017, where she presented a research paper.[154] This was part of the 'Forestry Curriculum Research', an international survey of forestry curricula organised by IUFRO and run by the Department of Forestry in Finland.[155] It can therefore be seen that international collaboration is crucial in skills formation and in forestry knowledge generation and transfers between the collaborating partners.

Further, South Africa is affiliated to international forestry organisations, such as IUFRO and the Central America and Mexico Coniferous Resources Cooperative (CAMCOR). IUFRO provides the platform for networking, allowing for knowledge and information exchanges between international forestry scientists on matters relating to social science, conservation, sustainability, and commercial forestry, which are crucial to forestry resource development.[156] In fact, some forestry research organisations, such as the ICFR in South Africa, have also devised platforms whereby researchers representing international organisations, such as IUFRO, CAMCOR and others, can meet and deliberate on forestry issues with stakeholders including firms and governments officials. As noted by Ms 39, over the past ten years the ICFR has had annual symposia in partnership with IUFRO, bringing together forestry researchers from Tanzania, Ghana, Kenya and other countries across the world for sharing knowledge.[157]

In addition, Prof B47 from FABI indicated that they have been cooperating with CAMCOR, international universities, and research organisations, and the United States Department of Forestry on the protection of pines, eucalyptus, and other germplasm.[158] Such collaboration has become more important in the era of global warming and climate change with the rise of new

[153] Ibid

[154] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[155] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[156] Ms B39. Knowledge Manager-ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[157] Ms B39. Knowledge Manager-ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[158] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

pests and pathogens threatening forests. Pests and pathogens move around the whole world, such that a problem in Australia might be a problem in South Africa in the future. Consequently, collaboration is important to gain information and experience to be better prepared when problems currently in other countries get to South Africa. International collaboration is thus crucial from a monitoring and quarantine perspective. It is crucial to instituting monitoring mechanisms to check on 'how the diseases are moving, and what interventions you can put in place'.[159] This feeds into the production system because, if 'you have got this pest and disease and if it reaches the economic level then you have issues with your production'.[160] All the participants noted that international collaboration has become much easier with developments in information technologies, such as the internetworked computers, cellular phones, emailing, skyping, video-canferencing, and platforms of like twitter, facebook, Whats-up, and webinars.

5.6.1 Interactional challenges in international collaboration

A number of interactional challenges hinder international collaborations. Geographical location is one of these challenges.[161] The major issue with geographical location has to do with the climatic differences. The trees growing in the Northern hemisphere and in the Southern hemisphere may be different, leading to differences in research agendas by research communities from different regions.[162] Geographic and climatic considerations may therefore limit collaboration by researchers from different climatic regions to issues only affecting plantation forestry in both regions. Geographic and climatic considerations may even affect R&D by MNCs whose production activities are based in different regions. This was reflected by Mr B12 when he conceded that,

[159] Prof B43. Socio-ecology, Agroforestry, Soils - UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[160] Ibid

[161] Dr B5. Lecturer-, FABI - UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

[162] Prof B46, Genomics Programme –FABI, UP, interviewed by Mushangai, UP, 19/09/2017

> Mostly our international research has to do with packaging, environmental sustainability and environmental impact. We have some operations in Russia and Thailand, but very little spillover between the cold North and the warm South. From a forestry technology point of view, the type of technology would be limited to the genetic tools rather than specific observation methods.[163]

This was also stressed by Dr B5 from FABI, who noted that they have been collaborating with communities from the Northern hemisphere on eucalyptus and poplar breeding and biotechnology.[164] However, Dr B5 was quick to highlight that, researchers in the Northern hemisphere focus mainly on poplar, which is mainly grown there because of the climate, rather than on eucalyptus, which is a major resource for the Southern Hemispheric countries.[165] Their collaboration in this case is hinged on the fact that both are involved with population genetics and genetic modification because 'a lot of these different organisms are identical'.[166] The role of climatic and geographic differences in determining areas of collaboration was also underscored by Prof B43 from the University of Pretoria, who noted that they usually collaborate with scientists from the Southern Hemispheric countries, such as Australia, New Zealand, Chile, and Peru, because they will be working on 'the same material', as issues affecting forestry there are in most cases the same as those in South Africa, because of similarities in climates.[167] Structural variables, such as the climate and geographical location, which are beyond man's control, play a role in determining international collaboration and the employment of R&D in the forestry sector. These factors, though difficult to alter, are not static but also dependent on the sector of the economy, the period and distance from the technological frontier.

Moreover, international collaboration in forestry R&D is also negatively affected by fluctuations in macroeconomics. National macroeconomic stability has important ramifications for research collaboration. As explicated by Kowero and Spilsbury (1997:12),

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[163] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[164] Dr B5. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

[165] Ibid

[166] Ibid

[167] Prof B43. Socio-ecology, Agroforestry, Soils- UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

> Financial resources are subject to political and economic externalities, which can generate uncertainty in the funding environment and create serious strains on the institutions, inhibiting their capacity to deliver or meet expectations. … Externalities such as currency exchange fluctuations can greatly alter the buying power of the research budget. If a currency is devalued, then the buying power of the local currency research budget is reduced, especially so in relation to imported inputs, whilst that from external (hard currency) sources is enhanced in the domestic market.

Macroeconomic instabilities in South Africa during the Zuma administration brought about currency fluctuations that made it difficult for local businesses to interact beneficially with their international partners. Corruption instances during the Zuma presidency culminated in the usurpation of the executive powers by private individuals who came to have undue influence on the appointment of cabinet ministers *vis-à-vis* their private interests (Bhorat, 2017). The state capture case by the Gupta family and the unexplained dismissal of Nhlanhla Nene as Finance Minister on 9 December 2015 brought disturbances and currency fluctuations with negative effects on the ability of the country to attract investment (Marchant 2018:43). Nene's dismissal led to an outflow of foreign investments and a rapid decline of the rand, costing the Public Investment Corporation (PIC) over R100 billion (Marchant, 2018). This was related to market reaction emanating from scepticism that Nene's dismissal was done to entrench President Zuma's corrupt and unfettered access to the National Treasury (Marchant, 2018). The politically motivated dismissal of Nene affected the stability of all economic sectors, including forestry. As explained by Dr B4,

> Political instability causes volatile exchange rates. When the Nene issue happened, the Rand went up to R17, 50 or something to the Dollar - that was difficult for us. If we look at a lot of our research materials, and external service providers, that obviously makes things a lot more expensive.[168]

The decline of the rand increases production costs for 'all our technical equipment is not manufactured by us; we buy it from different suppliers outside the country. The decline of the rand makes it difficult'.[169] Currency fluctuations make it difficult especially for firms whose

[168] Dr B4. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

[169] Dr B8. General Manager: SAPPI Technology Centre, interviewed by Mushangai, Pretoria, 02/03/2018

productive activities depend mainly on imported capital goods. The impact of currency instability brought by the politically motivated dismissal of Nene as Finance Minister in 2015 on forestry technology transfers was further stressed by Ms B41 (Department of Environmental Affairs, DEA) with regard to innovative start-ups in the forestry sector. As Ms B41 explained,

> We did a whole project looking at the viability of pellets export. We had a project near Port Elizabeth but that was problematic because of the exchange rate and the costs of shipping. Even though the market in Europe was enormous at that point in time, the project proved unviable.[170]

All of this demonstrates that the local and international dynamics are always interacting with each other, but with an impact on local production. These challenges are in line with Zepeda's (2001) study, which discovered political stability and the policy environment to have been important vectors in stimulating agrobusiness productivity across the world.

Despite the existence of a number of policies aimed at propelling big and small businesses, the corruption factor and patronage dynamics in post-apartheid South Africa limit the impact of these policies on business development. The policies such as the National Small Business Act (NBA 1996), Integrated Small Business Development Strategy (ISBDS, 2003), National Industrial Policy Framework (NIFP, 2007), Accelerated and Shared Growth Initiative South Africa (ASGI-SA, 2008), and the National Informal Business Upliftment Strategy (Nibus, 2013) have tried to follow the legalistic advice by De Soto's (2002) and of systems scholars, such as Shapira (2010), to reduce the bureaucratic and regulative hurdles allowing for the formalisation of small businesses to allow for the ease of doing business in South Africa. However, even if the success conditions for formalising small businesses and for growing other forestry businesses and for ensuring capital formation were all created, there exists a powerful pushback factor in South Africa that comes with the entrepreneurial culture developed around cronyism, capturing state rents, and rampant corruption through the ruling party-state nexus, as exemplified by the state capture case. Thus, post-apartheid South Africa is already showing signs of morbid degeneration in its embrace of globalised capitalism. All of these negative developments have an impact on macroeconomic stability, which to some extent is determined by the interaction

[170] Ms B41. Deputy Director: Strategic Support in the Office of the Chief Director of NRM, interviewed by Mushangai, DEA, Cape Town, 09/06/2017

between national and international dynamics. It is therefore imperative to nip in the bud the corrupt tendencies in the South African body politic to achieve macroeconomic stability if positive gains are to accumulate in the interaction of local firms with their partners in the international sphere. These challenges in the South African forestry SSI are made worse by epistemological blockages in addressing skills gaps in certain but crucial R&D areas.

5.7 Skills gap

Sections 4.5.1 and 4.5.1.1 on the pulp and paper category of the forestry value chain noted that the forestry sector of South Africa is negatively impacted by the shortage of high-level design and engineering skills needed in product development. As will be noted below, there is also a shortage of the high-level R&D skills in areas such as genomics, genetics, and quantitative genetics required in breeding and improving the planting stock in the forestry sector. The South African forestry SSI is also inefficient because of the shortage of system analytics skills. Quality R&D that drives the economy requires education at masters and doctoral levels (HESA, 2014). In a bid to increase the postgraduate rate to address the shortage of high-level R&D skills in South Africa, the National Plan for Higher Education (2001) set a target graduation rate of 33% for masters and 20% for doctoral graduates (HESA, 2014, p.). However, by 2011, the masters graduate rate was at 19% against the 2001 benchmark of 33% and the doctoral rate was at 13% against a benchmark of 20% (NPC, 2011, cited in HESA Portfolio Committee, 2014, p. 5). The 2012 Green Paper acknowledged that ‘’the number of overall graduate qualifications obtained, particularly PhD graduates, is too low’’ (DHET, 2012, p. 11). Nonetheless, there has been a slight increase in research and publication output, enrolment of postgraduate students and the number of graduated postgraduates. In 1995, 13.7% (70 964) of the total student enrolment at universities was made up of postgraduate students (CHE, 2004, p. 281). The postgraduate aggregate number had doubled from 70 964 to 138 608 by 2011 (CHE, 2004, p. 281-2). Of this figure (138 608), 71.6% (99 224) was made up of black students (CHE, 2012, p. 20). In 2010, there were 40 124 graduates (CHE, 2004, p. 281-2). This was made up of 30 083 postgraduate diploma/honours graduates, 8618 masters and 1423 doctoral graduates (CHE, 2012, p. 20). Of the 40 124 graduates, 23 782, making up 25% of the graduates, were black students (CHE, 2004, p. 281-20). The postgraduate enrolment and outputs have, however, remained very low in relation to national economic and social development needs, with a marginal increase of 1.8% in the size of the postgraduate student body between 1995 and 2010 (HESA Portfolio Committee 2014, p. 5). This is made worse by the poor graduation rates for masters and doctorates. Despite the 1.8% incremental gains, postgraduate production is still very low in South Africa, especially when compared with other developing countries. For example, while all universities in South Africa produced 1423 doctoral graduates in 2010, the University of Sao Paulo alone in Brazil produced 2244 doctoral graduates (HESA Portfolio Committee, 2014, p.5). Further, South Korea and Brazil produce 187 and 48 doctoral graduates per million of the population respectively, but South Africa produces only 28 doctoral graduates per million of the population (HESA Portfolio Committee, 2014, p. 5).

Some gains have, however, been made over the years in the production of PhDs. The Higher Education Management Information System (HEMIS, 2017) data shows the number of PhD graduates from all South African universities has increased from 1423 in 2010 to 2797 in 2016. This represents an improvement but still not comparable to the University of Sao Paulo’s 2010 figure of 2244 and still below the NPC recommendation for more than 5000 PhDs per year. There is therefore a need to increase the post-graduate rate per million of the population, if South Africa is to catch up with other developing countries. Evidence, however points to a number of hindrances in the achievement of this feat.

5.7.1 Epistemological blockages as systemic blocking mechanisms

The National Planning Commission (NPC, 2012) emphasised that ‘’the number of science, technology, engineering, and mathematics graduates should increase significantly’’ and proposes that by 2030 there should be ‘’more than 5000 doctoral graduates per year’’ (1423 in 2010) and that ‘’most of these doctorates should be in science, engineering, technology, and mathematics’’ (p. 319). Currently, there is a shortage of science and mathematics skills mainly resulting from the failure of the Department of Basic Education (DBE) to feed the Higher Education system with an adequate number of students with pass marks in science and mathematics. The HESA Portfolio Committee (2014) recommended that the shortage of graduates in science, technology, engineering, and mathematics could be improved with an increase in the number of matriculants qualifying for university entrance in sciences and mathematics. Despite this push, Prof B42 from the University of Stellenbosch noted that ‘the mathematics and science level among the Black and Indian students coming into the university are low and not what they should be'.[171] This, impacts negatively on the acquisition of high-level skills in critical areas required by the forestry industry. Dr B4 observed that the skills shortage in the forestry sector was not a general one, but prevalent in specific areas considered crucial by the industry.[172] These areas include breeding, quantitative genetics,[173] engineering skills in pulp and paper production, biotechnology,[174] skills in systems analysis[175] and modelling and logistics.[176] Most of these skills are high level, obtained at masters and doctoral levels. The shortage of such skills within the NSI but with an impact on the forestry sector indicates that weaknesses in the NSI have negative implications for productivity improvement within the forestry sector in South Africa. As indicated by Dr B3,

> There is definitely a skills gap in terms of genetics, and specifically in terms of quantitative genetics. If we had vacancies, it is extremely difficult to fill. We are mostly focused on quantitative genetics, and that is where we do not have enough people coming.[177]

This demand was elaborated on by Mr B12, noting that,

> Many of the specialist areas like tree breeding where you need somebody with strong quantitative genetic skills, it takes 10 to 15 years to train a proficient tree breeder. In our industry, we only have, 8 or so of them.[178]

The critical nature of the shortage of these skills was noted by Dr B2 (Research Manager, 4Sight Futures), who initiated the Genomics research project at SAPPI. Dr B2 noted that, in 2009, they had to employ a South African doctoral student who was studying at a university in Europe before he could even complete his thesis.[179]

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[171] Prof B42. Lecturer, Forestry Harvesting, Stellenbosch university, interviewed by Mushangai, Stellenbosch, 27/06/2018

[172] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

[173] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[174] Dr B8. General Manager- SAPPI Technology Centre, interviewed by Mushangai, Pretoria, 02/03/2018

[175] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[176] Prof B42. Lecturer, Forestry Harvesting, Stellenbosch university, interviewed by Mushangai, Stellenbosch, 27/06/2018

[177] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[178] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[178] Ibid

[179] Dr B2. Research Manager, Genomics, 4Sight Futures, interviewed by Mushangai, Pretoria, 24/10/2017

Further, Prof B48 identified a shortage of qualifications in systems analysis in the forestry sector.[180] Forestry systems analysis involves processes associated with planting all the way to harvesting, 'doing analysis on whatever we want to measure, it may be the efficiency of nutrient utilisation, the carbon content, how many trees can be harvested, what is the recruitment rate – the growth of the trees as a function of nutrients, all of those aspects, and how that impacts on the environment'.[181] Systems analysis involves the integration of information technologies with firms' production systems. However, South Africa is 'very bad at managing using IT in the loading of the trucks, the sorting of the timber, the tolerance of putting it through sawmills to get the right size of planks with the least amount of wastage'.[182] The area of systems analysis is critical in matching trees to the environment, nutrient utilisation, reducing transport costs and increasing accountability and transparency in the transportation of raw materials from plantations to factories. Systems optimisation offer many opportunities for the application of the fourth industrial revolution smart technologies. The fourth industrial revolution involves the automation of processes and data exchanges between humans and physical systems in manufacturing technologies (Mtsweni, 2017). It is an area that involves the convergence of production processes with information and communication technologies. The processes from matching the trees with the environment, improving nutrient utilisation, and the transportation of materials from plantations to the mills, can all be linked with communication and information technologies (internet of things), allowing for information flows in ways that improve efficiency and transparency. The extent of the shortage of people qualified in systems optimisation was emphasised by Prof B48, who noted that,

> There is one computer modeller in the country that optimises timber harvest by location. She knows that there is a patch of trees in this district in Mpumalanga and it needs to be harvested in one- or two-years' time. She knows it needs to go to the mill in that certain location and you cannot take it to the wrong mill because it's soft timber that is going to be used for pulpwood. When she dies or retires, her knowledge is gone.[183]

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180 Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

181 Ibid

182 Ibid

183 Ibid

This shortage of high-level skills in the forestry sector of South Africa is made worse by the fact that other developing countries, such as Brazil and in Asia, have been able to attract experienced South African forestry scientists. As noted by Prof B47, Brazil and countries in Asia are 'taking a lot of our foresters and forestry scientists to go and work for them, so they poached and brain drain us'.[184]

The shortage of people with skills in utilising emerging technologies for effective production is affecting the creation of new jobs and wealth for the country. The provision of these skills at universities depends on the ability of the DBE to supply universities with students with pass marks in sciences and mathematics. However, the OECD (2007) noted that the Basic Education system of South Africa was not effective in producing high school graduates with skills in science and mathematics, adequately prepared for university education. As such, the 2030 target by the NPC (2012) to produce ''more than 5 000 doctoral graduates per year'' with most of these in the areas of science, engineering, technology, and mathematics would not be realised unless the blocking mechanisms causing the DBE to fail to produce more high school graduates with pass marks in science and mathematics are resolved.

5.7.2 Staffing

Statistics reveal that the percentage enrolment at South African 'institutions' of higher education has improved since 1994 (CHE, 2014). The HESA Portfolio Committee (2014) noted that the participation rate of students increased from 15% in 2001 to 27.3% in 2011. Though this is a blessing, it has also had some negative impact on the performance of R&D. The growth in enrolment figures has not kept pace with funding, as reflected in the slow growth of qualified university lecturers. Only 34% of academics at universities in South Africa have doctoral degrees (HESA, 2014). Doctoral qualifications are a prerequisite for undertaking high-quality research and in supervising doctoral students. The shortage of qualified lecturers at national 'institutions' of higher education has had a negative impact on the quality of R&D in the forestry sector. As elaborated by Prof B47, an entomologist at the University of Pretoria,

[184] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

> We are continuously turning away students because there are not enough professors to do the training. A professor can only train so many students at a time; otherwise, the quality of that training also drops. You have only limited hours per day. Even if we have 10 more professors in our group that have their salaries covered, then we need to fund the research cost to take in those students.[185]

The impact of limited funding of universities on the development of R&D capabilities in the South African forestry sector was also underlined by Prof B42 when he reflected that,

> Despite the government's push for more Ph.Ds. the same number of lecturers is expected to do more and more. Unfortunately, in our university system, professors have to do the lecturing for undergraduates and for post-graduates. In the US system, for example, post-graduate and undergraduate are separate colleges or universities. A researcher focuses on research because that is a specific type of personality in training researchers; the lecturer is a different type of personality and focuses on lecturing. Here, we have to manage both of those in 99% of the cases.[186]

As such, Dr B7 opined that forestry research and innovation could only be optimised if enough funding is provided to build the capacity needed for R&D in the country.[187]

Another challenge within the South African post-school system is that capacity is not evenly distributed across universities. Formerly white universities in South Africa have more qualified staff and advanced infrastructure than formerly black universities. With regard to Venda university, Prof B48, who chairs the national forestry initiative, noted that, 'The University of Venda is terrible, has no resources, and staff with PhDs'.[188] It is for this reason that HESA (2014) observed that, ''the research performance of universities is uneven with 10 universities (out of 26) producing 86% of all research and 89% of all doctoral graduates'' (p. 6). The OECD (2007) emphasised that, if South Africa is to build an effective SI, it has to create that critical mass needed for R&D. This requires more funding into higher education. The growth in the number of universities and of enrolment figures in a bid to cater for the previously disadvantaged

[185] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[186] Prof B42. Lecturer, Forestry Harvesting, Stellenbosch university, interviewed by Mushangai, Stellenbosch, 27/06/2018

[187] Dr B7. Programme Coordinator Forestry & Veldfire Management- NMU, interviewed by Mushangai, NMU George Campus, 07/04/2018

[188] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

has not been matched by the growth in the number of lecturers. The shortage and uneven distribution of qualified lecturers across South African universities impact the quality of forestry education and the employability of graduates coming from different ‘institutions’ in a way that reproduces apartheid inequalities. As a result, the NPC (2012) realised the need for qualified lecturers in building R&D capabilities when it called for ‘’capacity to provide quality undergraduate teaching’’ and for ‘’the qualifications of higher education academic staff’’ from the 34% with doctorates in 2012 to over 75% by 2030 (pp. 318-319).

The impact of the shortage of skills in the optimisation of R&D is demonstrated in the Genomics case study in Appendix 1, Box 5. The Genomics project illustrates the hindrance imposed by the shortage of skills in the employment of R&D in South Africa. The fact that at the inception of the project the initiators have to rely on a PhD student who was yet to complete his thesis at a European university demonstrates the extent of the shortage of R&D capabilities in the area of genetics and quantitative genetics in South Africa. However, this challenge was lessened through the collaboration between the universities and the government. The impact of the shortage of high-level R&D skills is worsened by the inability of universities to train many students in this area, due to limited infrastructure.

5.7.3 University infrastructure

Many universities in South Africa lack research infrastructure, facilities, and equipment. These challenges reflect system weaknesses, which constrain the enrolment and production of postgraduates and especially doctoral graduates. Formerly white universities and research organisations, such as the University of the Witwatersrand, University of Stellenbosch, University of Pretoria, and Nelson Mandela University, have developed infrastructure (HESA, 2014). Most of the resources (laboratories, qualified lecturers, among others) are concentrated at these organisations. As such, these organisations have the capabilities to offer the quality education and knowledge demanded by the industry. Nevertheless, most of the universities have inadequate student accommodation, and have old infrastructure and equipment shortages (NPC, 2012). These challenges are more pronounced at formerly black universities, such as the University of Limpopo and the University of Venda (HESA, 2014). The differences in infrastructure affect the quality of education received by students studying for similar programmes at different organisations. It is for this reason that the NPC (2012) has called for

‘’uniform standards for infrastructure and equipment to support learning, promote equity and ensure that learners doing similar programmes in different organisations receive a comparable education’’ (p. 317). These challenges affect the ability of the formerly black universities in linking up with the firms in the development of ‘thick’ networks important in R&D in the knowledge economy.

5.7.4 Networks between universities, firms and the state

HESA (2014) noted that, ‘’South Africa … lacks dense networks between universities, state, and business that are found in other countries which facilitate the movement of people, knowledge, expertise, and experience between universities and the public and private sectors and innovation’’ (p. 6). From the interviews with personnel from forestry organisations, such as FSA, Mondi, SAPPI, Merensky, NCT, and TWK, it was established that forestry firms are represented on boards of faculties at the University of Pretoria, University of Stellenbosch, Nelson Mandela University, Fort Cox College, and the Institute of Commercial Forestry Research, among others. This was deemed necessary to ensure the alignment of forestry skills and knowledge production with the demand for modern knowledge required for innovation by the firms. Consequently, the curriculum for forestry studies at most research organisations and university faculties are a result of interactions between firms and academia and research organisations.

Important to note is that interactions between universities and firms are determined by the capabilities of knowledge-producing organisations to produce the types of knowledge valued by the forestry industry in the modern world. Morrow (2009, cited in Lotz-Sisitka, 2009) defined epistemological access in terms of access to knowledge that is highly valued in the modern world. The study noted that, in their interactions with educational organisations, the major firms in the sector have little consideration for the University of Venda and colleges such as Fort Cox in their R&D activities. The research managers from Mondi, Sappi, Merensky, NCT, and TWK, did not even mention Fort Cox and the University of Venda in their research activities. Mr B12 noted that Mondi funds the forest molecular genetics programme under Prof B46 at the University of Pretoria.[189] He also indicated that Mondi has a chair in forest pathology under Prof Mike Wingfield at FABI-University of Pretoria.[190] Mr B12 highlighted that,

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[189] Mr B12. Research and Development Manager, Forests Mondi South Africa, interviewed by Mushangai, UKZN, 27/10/2017

[190] Ibid

> We have some linkages with the University of Stellenbosch, Nelson Mandela University, and the University of Kwa-Zulu Natal. In the past, we have worked with the University of Free State and with Mary Scholes at the University of Witwatersrand.[191]

Dr B8 from SAPPI noted that, 'We work with the University of KwaZulu-Natal, University of Pretoria, and the University of Stellenbosch'.[192] The Research and Strategy Manager of Merensky Timbers, Dr B3 noted,

> We employ many people that went to these universities (Stellenbosch University, University of Pretoria, and University of the Witwatersrand). I came from the University of Pretoria. Most of the staff in my research department was educated at the University of Stellenbosch.[193]

Dr B3 also noted that Merensky Timbers consulted with the CSIR.[194] The Research Manager of TWK, Mr B24, noted that,

> We have identified certain universities with different expertise and as industry we co-fund certain projects. They have access to our resources if they want to do trials. The University of Pretoria and the Nelson Mandela University come here at least twice a year to do trials on our lands.[195]

The Technology Manager of NCT, Mr B13, also noted that 'we have university level partnerships with UP, UKZN, US, and NMU'.[196] From all these testimonies, it can be noted that the industry mostly interacts with traditionally white universities.

Further, data from the interviews with the research managers at Mondi, SAPPI, and Merensky indicate that the big firms have not been interested in community forestry. Community forestry is one of the areas defining the forestry curriculum at the University of Venda and at Fort Cox

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[191] Ibid

[192] Dr B8. General Manager- SAPPI Technology Centre, interviewed by Mushangai, Pretoria, 02/03/2018

[193] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[194] Ibid

[195] Mr B24. Manager, Research and Development, TWK Agri (Pty) Ltd, telephonically interviewed by Mushangai, 13/11/2017

[196] Mr B13. Forestry Technology Manager- NCT Forests, telephonically interviewed by Mushangai, Johannesburg, 26/06/2018

College.[197] The big firms are also less interested in silviculture, which was their major focus in the 1960s, as reflected in Chapter 2. In fact, the Research Manager of Mondi Forests, Mr B12, noted that, the major firms had contracted most of their silvicultural activities.[198] According to Mr B12, the industry is now more interested in the types of knowledge providing solutions to challenges affecting forestry production worldwide.[199] These include responses to global warming and climate change, and the production of drought-, pest- and disease-resistant trees through studies in quantitative genetics, genomics, and biotechnology.[200] Even though the Research Director at FSA, Dr B4, is of the view that there is no shortage of skills in the forestry sector,[201] the research managers from Mondi, SAPPI, NCT, TWK and Merensky Timbers noted that there was a high demand for breeding, quantitative genomics and more/less in biotechnology and that vacancies in these areas were difficult to fill. There is rather a need for connecting together the rather disjointed and discordant nature of the South African forestry system through interactions as a way of addressing the colonial and apartheid legacies and of developing capacity by the different organisations involved.

5.7.5 Epistemological access and the shortage of skills

The challenges confronting higher education in South Africa are made worse by the distribution in the national income, whereby only a few blacks have managed to join the middle class. Morrow (2007) coined the term *epistemological access*, implying access to knowledge demanded in the modern world and the challenges involved (Lotz-Sisitka, 2009). However, in his discussion of the concept, Morrow differentiated between formal access (access to an institution) and epistemological access (access to the knowledge that institution distributes; Du Plooy and Zilindile, 2014). Important to consider is that Morrow, in his discussion of the concept of epistemological access, took notice of the importance of history and context in defining factors impacting knowledge acquisition and hence skills formation. These factors are related to political, social, and economic vestiges of the colonial and apartheid periods which continue to cast some shadow over current development in South Africa. These structural dynamics interact

[197] Mr B27. Head of Forestry Department- Fort Cox, interviewed by Mushangai, Fort Cox, Eastern Cape, 06/11/2017

[198] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[199] Ibid

[200] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018

[201] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

with institutional-level factors, such as the lack of resources, the assessment and qualification specifications, issues of college and management procedures, and a lack of qualified lecturers, in denying or in making epistemological access unattainable for children from the formerly disadvantaged communities in South Africa.

As a result of the above-referred dynamics in South Africa, the formerly white universities, such as the University of the Witwatersrand, University of Stellenbosch, University of Pretoria, and Nelson Mandela University, and research organisations like the ICFR are still not freely accessed by black students wanting to pursue forestry studies. With regard to the University of Stellenbosch, Prof B42 noted that,

> ...demographics are changing as we are taking more previously disadvantaged Black, Coloured and Indian students but at the same time we realised that their mathematics and science levels are low. So, we have increased our admittance requirement for mathematics to try and get in students that we are sure will get through their period of studies. If you take in students who the country has set up to fail, we will be wasting our time and their time. We lose taxpayers' money.[202]

Further, Prof Wingfield, the Director of FABI and the head of the prestigious Centre of Excellence (CoE) in Tree Health Biotechnology (CTHB) at the University of Pretoria, raised concern pertaining to demographic representation in their programme. He noted that,

> Like other CoEs, the CTHB has … to work intensively to improve the demographic profile of its student body. In this regard, it has pursued various initiatives to attract South African students from traditionally disadvantaged backgrounds into the programme. Although all CoEs have reported reasonable levels of success in improving their demographic composition, the overall situation must still be improved considerably.[203]

Despite institutional reforms to democratise formal access, the above statements show that race is still a factor with regard to access to prestigious 'institutions' of education in post-apartheid

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[202] Mr B27. Head of Forestry Department- Fort Cox, interviewed by Mushangai, Fort Cox, Eastern Cape, 06/11/2017

[203] Steenkamp, ET and M, Wingfield (2013), Global forest research, science education and community service positively impacted by a unique Centre of Excellence in Tree Health Biotechnology, *Southern Forests, 2013, 75(2) 3-4,*

South Africa. The above interviewees' statements demonstrate that the South African National Skills System is still less integrated, as noted by the OECD (2007).

The type of knowledge that is acquired by someone from an education institution determines his or her employability. This in turn differently affects the employability of students graduating from different universities. As a result of differential endowments at formerly white universities and formerly black universities, the NPC (2012) noted that 'race remains a major determinant of graduation rates', and that this has ''major implications for social mobility and … for overcoming the inequalities of apartheid'' (p. 16). This is reflected in the forestry sector when Prof B48 from the University of the Witwatersrand explained that,

> All of my 15 postgraduates are employed at high levels. One now is the head of SAPPI, the other one is the head of the department at NMU, and the other is the head of the department at Stellenbosch. There are two that have become heads of departments in the United States. The manager of the nursery at SAPPI is my student, the manager of Biotech and Sustainability at MONDI was my student, and the SAPPI director in Swaziland is my student.[204]

This contradicts what was observed by Mr B27, the head of forestry studies at Fort Cox, who noted that most of his students are having difficulties in securing jobs, let alone permanent jobs in the industry. Consequently, Mr B27 noted that,

> The major challenge that we have is this white and black thing. People are still dwelling on this issue of white and black. If people can be removed and taken out of that then there will be much progress. We can achieve more together. The white people are still learning at the same universities, taught by the same lecturers, taught the same content.[205]

It is partly because of these dynamics that most of the high-level positions in the industry are occupied by white people. This has generated the perception of the forestry industry as a white-dominated industry (Tewari, 2003). This perception is bound to persist with a negative impact on

[204] Ibid

[205] Mr B27. Head of Forestry Department- Fort Cox, interviewed by Mushangai, Fort Cox, Eastern Cape, 06/11/2017

investment if the factors that hinder epistemological access within the higher education system are not addressed. The Department of Labour's Employment Equity Report (2018) noted that the lack of equitable representation at top and senior management levels in all sectors of the economy 24 years after the dawn of democracy ''does not bode well for the future sustainable economic growth of the country as we continue not to be inclusive and representative of the demographic population distribution in the workplace in terms of population groups'' (p. 55). For example, Africans make up 78.5% of the national economically active population (NEAP) while the White (NEAP) is at 9.1% but across all sectors white South Africans occupy 67.7% of all top management positions and 56.1 of the senior management positions while the percentile for African South Africans is at 14.3% and 22.1% respectively (DOL, 2018, p.18, 22). This is mainly explained in terms of differential access to higher education and epistemological access.

However, the question to be answered pertains to interactional challenges and how this affects systems integration and the application of R&D in the forestry sector. First, it has been noted that students from poor schools lacking mathematics and science skills cannot be enrolled in highly demanding programmes, such as genetics, quantitative genetics, engineering, biotechnology, systems analysis and modelling. These students are mostly from black communities, meaning to say that inequalities will persist in South Africa, as the employability of these students is not guaranteed. Second, it has been observed that formerly black universities, such as the University of Venda's interactions with firms are limited because of the lack of capabilities to provide skills and research that address issues pertaining to firms' productivity and profits (genetics, quantitative genetics, engineering, biotechnology, systems analysis, and modelling). As a result, the chances of graduates from these universities being employed in high positions by the big firms in the sector are limited. Thirdly, formerly white universities have a productive relationship with the big firms in the sector because they have the capabilities to provide the skills and to conduct studies that are highly demanded by the industry. The firms also fund the research activities at formerly white universities through research chairs. Fourth, most of the students with access to the highly demanded programmes at universities are white students from well-to-do communities whose schools are resourced to teach science and mathematics successfully as subjects required for enrolment in the highly demanded forestry programmes. Fifth, since there is a close relationship between the formerly white universities with capabilities to generate knowledge that is highly demanded by the industry, it means that this knowledge will be easily accessible to the big firms and less likely to be accessible to the small firms and beneficiaries of the land reform. This factor limits the application of R&D by all firms in the sector. Without this knowledge, the small firms are unlikely to catch-up with the big firms in the sector, meaning that the forestry sector will remain dominated by the white-owned firms.

5.8 Conclusion

This chapter has revealed that the South African forestry SSI has been negatively impacted by a number of blocking mechanisms that result in the system being less integrated. The blocking mechanisms emanate from interactional challenges between the stakeholders. The blockages produce a system that is not integrated, but in themselves are caused by the lack of systems integration. It was noted that, in some instances, the absorption of new knowledge and technologies is hindered by the inability of researchers to communicate their findings effectively. This is worsened in cases in which the firms would not have participated in the research processes, as exemplified by the case of the fire pathways research. Further, interactional challenges that limit the optimisation of research findings are also a result of the short-term approach to research funding. This limits research activities to addressing short-term challenges and fails to accommodate the long-term strategic research needs of the industry. Short-termism limits R&D to solutions of a particular problem, rather than providing a broad understanding of the problems affecting the sector. The Cryphonectria Cubensis case (Appendix 1, Box 3) demonstrated that much more could be achieved when basic research is regarded as the starting point in forestry R&D. The case shows that, as with pests and pathogens, forestry challenges cannot be resolved by a focus on applied research alone but also on basic research that informs applied research.

Moreover, the existence of different firms with different production orientations also affects the level of collaboration between different firms. Different production orientations may be a cause of unnecessary schisms between the stakeholders as to which research should be prioritised, especially in cases in which resources are commonly pooled. Moreover, the lack of research collaboration since 2013 is also linked to a rise in the establishment of in-house research departments. Though this may be important in reducing the turnover time especially with regard to economies of speed; it increases research costs.

The challenges in R&D are compounded by the shortage of skills in critical areas that have transformed forestry production, especially in the Scandinavian countries. There is a shortage of high-level innovation skills in the South African NSI that have a negative impact on forestry production. Among the skills in high demand are skills in breeding requiring knowledge in genetics and quantitative genetics; systems analytics; and product design. University training for these skills requires that the Department of Basic Education (DBE) produces high-school graduates with pass marks in mathematics and science. The DBE has been failing on this and as a result the shortage of these skills will continue to affect the sector in the future thereby limiting innovations and the improvement of efficiency by firms in the sector. In addition, the ability of universities to produce these skills is hampered by internal and external economic, social, and political issues, mainly the vestiges of the apartheid's politics of exclusion. Further, a shortage of qualified doctoral staff at universities, especially the formerly black universities, affects negatively the ability of universities to provide the skills that are critically needed in the sector. Thus, the forestry SSI is always affected by weaknesses in the NSI.

These challenges are made worse by infrastructural blockages, as in the lack of roads and railways, connecting the upstream and downstream activities in the sector. Infrastructural challenges also affect the advancement of the bio-economy, as the South African sector lacks modern laboratories and equipment when compared to other developing countries, such as China and Brazil.

Despite these challenges, few pockets of excellence can be discerned in the sector. Knowledge and technologies have been generated, as exemplified in the Cryphonectria Cubensis case (Appendix 1, Box 3) and in the Sirex case (Appendix 1, Box 4) and the Genomics case (Appendix 1, Box 5). These cases show that more could be achieved when there is collaboration in research activities. The collaboration between the universities and the firms lessens the burden of the shortage of skills and reduces the burden of research funding, by distributing expenses among the partners. Further, where there is cooperation some streams of funding from the government through THRIP and the Sector Innovation Fund (SIP) have been opened for these sources fund collaborative projects rather than standalone research activities. Though the funding from THRIP and the Innovation Fund is not enough, it has had an impact on forestry innovation, as noted in the Sirex research project, the Genomics research project and in the funding of the bio-manufacturing industrial facility in Durban.

The existence of many projects in the sector indicates that research has mainly been focused on projects, hence the lack of an integrated approach with a focus on the value chain as a whole. This has been mainly a result of the government's failure to implement the Integrated Forest Protection Strategy (2011) and the Integrated Strategic Forestry Plan (2013), all of which had been approved by DAFF. There is, therefore, a need for value addition through collective risk mitigation and risk management with a holistic approach encompassing the value chain as a whole.

Despite the challenges involved, South Africa is progressing, as witnessed in the discussed case studies. Important to consider is Kuhlmann and Shapira's (2010) observation that successful SIs develop their special competitiveness and strength gradually over time. South Africa experienced ruptures of creative destruction in its transition from apartheid to democracy in 1994. Considering this, South Africa's system is still in the process of integrating and stabilising its NSI and hence the forestry SSI.

Lastly, though workplace-based learning is important, as was demonstrated in the sawmilling category with reference to SAPPI's innovative activities, the chapter demonstrated that in most cases innovation knowledge is collective and the locus of this knowledge is in the networks rather than in the firm. In the Cryphonectria cubensis case (Appendix 1, Box 3), the Sirex case (Appendix 1, Box 4) and the genomics case (Appendix 1, Box 5) knowledge and technologies were generated in the process of interaction by researchers from different organisations. Further, in the water-jet case, Merensky Timbers had to invite an external expert because firms rarely innovate based on internal knowledge. Thus, a convergence of factors explains why the South African forestry SSI is less 'integrated' (OECD, 2007) and suffers from 'weak coordination, linkages and limited resources and capacity' (Greenberg, 2010).

Chapter 6: Non-R&D and DEEM activities in the South African forestry sector

6.1 Introduction

Chapter 1 noted that small businesses face a myriad of challenges that hinder their upgrading. Small businesses require various forms of support, ranging from development finance, managerial skills, and enterprise development to agricultural technical skills, to be sustainable (AgriSETA, 2016). Various perspectives have been advanced as to how the challenges confronting the small businesses could be addressed. The Integrated Small Enterprise Development Strategy (ISEDS, 2004-2014) assumes that the challenges could be addressed through the expansion of small and medium-scale enterprise support strategies, information, research, monitoring, and evaluation. The support strategies would involve technology transfers, incubation, and the commercialisation of business services (DTI, 2003). These activities, as the AgriSETA (2016) posits, could be effected by promoting innovation with a focus on agricultural tools, methods and practices among small emerging farmers and through exposure to innovation practices by large commercial farms and where possible to facilitate innovation by SMEs themselves. However, innovation scholars, such as Chaminade and Edquist (2010) and Shapira (2010), and the legalistic perspectives of De Soto (2002) believe that the proposed solutions could be effected by policies that focus on national or state regulatory, tax, bankruptcy, labour market and legal regimes within which SMEs have to operate. De Soto (2002) considers the nemesis to development of the SMEs in developing countries to lie in the immense bureaucracies and legal strictures, which are behind the growth of market distortions and high transaction costs, making it difficult for small businesses to operate within the formal sector. The solution to this lies in the deregulation, debureaucritisation and simplification of the legal strictures to allow small businesses to operate freely in the formal sector unfettered by the obstacles therein (De Soto, 2002). In South Africa, a number of policies, policy frameworks (for example, NSBA,[206] ISBDS,[207] NIPF,[208] ASGI-SA,[209] BNG,[210] and others) and support and financial schemes (Nibus,[211] SEDA,[212] Khula,[213] and Samef) have been put into place to address the challenges

[206] National Small Business Act of 1996

[207] Integrated Small Business Development Strategy of 2003

[208] National Industrial Policy Framework of 2007

[209] Accelerated and Shared Growth Initiative South Africa 2006

[210] Breaking New Ground of 2005

[211] National Informal Business Upliftment Strategy of 2013

confronting the SMEs. Despite the existence of these policies and schemes, evidence still shows that many SMEs are underperforming and collapsing within their formative stages (Kgosana, 2013).

The lack of integration of the South African NSI (OECD, 2007) as seen in ‘weak coordination, weak linkages and lack of capabilities (Greenberg, 2010) is partly blamed for the limited benefits of the SI to the economy. The Small Business Project (SBP, 2009, cited in Mushangai, 2015), noted that government policies are failing because they are not provided as a compact set but in an isolated manner. The SBP (2009) went on to quote the DTI admitting that it has failed because, ‘’we are doing things on such a minuscule scale that given the needs and challenges we will not be able to make an impact’’ (p. 1). The fragmented nature of government policies and support schemes aimed at propping up and propelling SME development result in the fragmentation of resources, hence limiting resource optimisation and impact on the development and sustainability of the SMEs in South Africa. SMEs require various forms of support to be provided in a concentrated and coordinated manner, if these support and financial schemes are to have a positive impact. The lack of integration which results in uncoordinated efforts in stimulating SMEs is partly the reason behind the emergence of the SETAs as important sectoral organs to act as intermediaries to engage ‘’with stakeholders in the workplace, establishing their needs, and ensuring that providers have the capacity to deliver against these’’ (White Paper 2014, p. xvi) or as brokers ‘’to assist in brokering university-employer collaborations as well as providing advice and resources to facilitate work-integrated learning’’ (White Paper, 2014, p. 41). In their role, the SETAs are supposed to initiate innovative projects, to provide labour market intelligence, to support skills formation through learnerships, and apprenticeships and to support the formation of high-level R&D skills through the provision of bursaries (DHET, NSDS III, 2011). These roles are supposed to be played in partnerships with the stakeholders in determining the skills needs of firms in their sectors and in ensuring that graduates are absorbed to boost innovation by businesses (DHET, NSDS III, 2011). However, as will be noted below, the SETAs as organs in the skills system are suffering from all sorts of vicissitudes, rendering them inefficient and ineffective in delivering their set objectives. Evidence points to the fact that most innovative work by SMEs, especially emerging farmers and growers in the forestry sector,

[212] Small Business Development Agency

[213] Khula Enterprise Finance

is occurring outside the skills system through the partnerships between the SMEs and big firms. These partnerships have proved to be one of the most effective ways of transferring business and technical skills to SMEs, despite the fact that some of these relationships are exploitative, requiring regulative institutions to address the asymmetric power dynamics that characterise them.

This chapter critiques the interaction of SMEs with the components of the forestry SSI, such as agricultural colleges, big firms, university faculties, financial organisations, SETAs, and other government agencies, to determine systems failures and how they could be addressed in propelling the development of small businesses. The focus is on skills development and innovation activities mainly aimed at adopting and adapting existing knowledge and technologies. Small-scale businesses usually do not have the capabilities to collaborate with research organisations to conduct basic research to produce new knowledge and technologies but rely on existing knowledge and technologies, which they customise to upgrade their processes, methods, and products. Important to note is that the OECD (2007) observed that innovation for small businesses with a focus on technology for poverty reduction had been neglected in South Africa in favour of mainstream R&D, innovation and big science. The first part of the chapter answers the question: *What are the key challenges affecting effective interaction in DEEM and R&D by universities, research institutes, government agencies, and (small) firms in the forestry sector of South Africa?* The second part of the chapter addresses the question*: What are the key challenges faced by the AgriSeta and the Fibre Processing and Manufacturing SETA (FPM SETA) in facilitating interactions in R&D skills formation?* The chapter is based on 34 interviews with officials from government departments, universities, agriculture colleges, NGOs, industrial organisations, small business owners, workers, and students. SMEs of various characteristics were interviewed. These included cooperatives in tree-growing activities, such as NCT and TWK, contractors in dry and wet milling activities, small scale projects funded by the government in downstream processing and manufacturing activities, such as the eco-furniture industries in Mpumalanga, cabinet manufacturers in the Orlando Industrial Park in Soweto, and lastly informal roadside cabinet sellers in Soweto.

6.2 Lack of funding and technological upgrading by small firms

The lack of funding for small businesses is one of the 'system failures' (Smith, 2010) in South Africa's NSI. Despite the existence of many policies and financial schemes articulating the importance of financial access for SMEs, evidence points to the lack of development finance as one of the major challenges in small businesses development in South Africa's forestry sector. The lack of funding impacts negatively on the ability of small businesses to upgrade their production systems in the upstream timber growing activities and in the downstream harvesting, processing, and manufacturing activities.

6.2.1 The impact of lack of funding on small growers

With regard to the upstream tree-growing activities, the small growers lack the financial resources to buy improved and fast-growing germplasm, which is resistant to pests and pathogens and has a higher yield per hectare.[214] This challenge is worsened by the fact that most research organisations serve the interest of their funders, which are the big firms with financial capabilities. Ms B39, the Knowledge Manager at the ICFR, noted that their breeding programmes are proprietary, meant for their funders, and do not cater for the needs of the small growers outside the FSA.[215] The public research organisations meant to address the technological needs of the SMEs in the forestry sector, such as the agricultural colleges, are hampered by a lack of funding from the government. Mr B27 indicated that, in 2009, Fort Cox College started a breeding programme meant to supply small scale growers with improved germplasm but failed to maintain it because of the lack of funding.[216] As such, the germplasm that the small growers depend on is of the old varieties, not linked to rapid scientific advances in genomics and the production of fast-growing and disease-resistant hybrids.[217] [218] This challenge denies the SMEs the opportunity to embark on creative destruction to improve their processes. Although the CSIR is producing improved germplasm for all in the sector, the small growers lack the financial capital required to buy the improved germplasm.[219]

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[214] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[215] Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[216] Mr B27. Head of Forestry Department- Fort Cox, interviewed by Mushangai, Fort Cox, Eastern Cape, 06/11/2017

[217] Ibid

[218] Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[219] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

The Financial Mail (20 Sept 2015) noted that agribusinesses are increasingly driven by scale. The small growers are the most affected in instances of pests and pathogens because of the limited scale of production. As noted by Dr B3,

> The impact of pests and diseases on small growers would be much more than on large corporate growers. At Merensky Timbers we have 55 000 hectares of pines and 11 000 hectares of eucalyptus. If we lose 500 hectares it is still significant, but would not kill the business. However, if a small grower with 1000 hectares loses 500 hectares he is out of business because he does not have scale. The impact is much greater. The lack of funding affects the efficiency of the small-scale growers in transforming production, hence their sustainability in the long run.[220]

The same scenario was also provided by Prof B47, an entomologist from the University of Pretoria, who noted that,

> One of the issues being discussed with government is forest protection strategy. We have a growing number of small-scale farmers. These people have half a hectare, 1 hectare, or 20 hectares of plants. When a pest or pathogen comes in, it kills their trees or makes them grow half as fast as they should. Who supports these people? How are they supported? From a quarantine or legislative perspective if we detect a pathogen or disease, a private company could afford to cut down and lose 10 hectares or even 1000 hectares to prevent it from spreading, but the private guy cannot afford to lose half a hectare or more.[221]

The lack of resources by small growers for improved germplasm, to respond to the threats of fire, pests, and pathogens, coupled with the absence of economies of scale, increase risks, making it difficult for them to access development finance from financial organisations. Bortagaray and Ordóñez-Matamoros (2012) observed that innovation for and by small-scale businesses and communities involve high risk and uncertainty, hence incentives for private sector investment are low. This very fact, according to SI scholars Chaminade and Edquist (2010), should motivate deliberate strategic government intervention. As such, Mr B27 recommends that DAFF should

[220] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[221] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

intervene by implementing SMEs support programmes, like those in the agriculture subsector, such as the Comprehensive Agriculture Support Programme (CASP), to support the small growers financially if their sustainability is to be realised.[222] However, financial support from the government in this section of the value chain has not been forthcoming. Currently, the National Forestry Protection Strategy approved by DAFF in 2013 is only funded by the industry.[223] The strategy is important in monitoring the threat of pests and diseases in the landscape and in ensuring that intervention measures are put in place.[224] The financial resources provided by the industry are not enough to monitor all areas across the country and therefore the need for the government to contribute with additional resources.[225] The lack of government support in this case places the SMEs at high risk, should there be fire, disease, and pest outbreak, as they do not have the mechanisms in place to respond to such threats effectively.

6.2.2 Lack of funding and process innovation

Improving the efficiency and effectiveness of production systems is partly a function of machines. Machines are important in process innovation. According to Blind (2010), process innovations in the form of new or improved technology are crucial for the production or the supply of new goods and services. Process innovations are considered essential for efficiency, productivity, and competitiveness (Cozzens, 2010). This is so because the employment of machines brings about economies of scale, speed, and scope and reduces the cost of labour. Efficiency in this case relates to the ability of firms to make profits by cutting costs through mechanisation or labour rationalisation or through the production of quality products competitively. Businesses may reduce costs to customers through process innovation or organisational improvements. The competitive production of goods and the selling of goods at cheap prices is one of the strategies that enable market entrenchment by small businesses in relation to their competitors. As noted by Porter (1990), process innovation as a competitive strategy is about being different and ‘’choosing to perform activities differently or to perform different activities than rivals in order to deliver a unique mix of value’’. Nonetheless, process innovation by small businesses in the South African forestry value chain is hindered by the lack

[222] Mr B27. Head of Forestry Department- Fort Cox, interviewed by Mushangai, Fort Cox, Eastern Cape, 06/11/2017

[223] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[224] Ibid

[225] Ibid

of financial resources for the purchase of capital goods required in upgrading their production functions. Mr B15, the Small Business Manager at FSA, observed that the SMEs in the sector do not have the required harvesting and extraction machines to improve efficiency in relation to scale, scope, and speed.[226] The lack of harvesting and extraction machines and of vehicles or trucks to transport the logs from the harvesting sites to sawmills increases production costs. Fulginiti (1998), in his study of 18 developing countries across the world, noted that productivity growth was linked to inputs like machinery. As a result of the lack of machines, small businesses in the forestry sector have continued to rely on hand labour, employing many people at a huge cost to meet production targets in time.[227] [228] Thus, process innovation with the effect of improving processes, and thus the efficiency and effectiveness by the SMEs, is hindered by the lack of funding for capital equipment. This was reflected well by Mr B49, the Technical Manager of DEA Eco-Furniture Industries, in relation to their dry mill operations in Ga-Rankuwa,

> The big challenge is that we can cut down trees but we do not have enough kilns, that is the right drying capacity. We put out the tender and got two kilns. It is about R3, 5 million for one. We put one with a drying capacity of 100m3 per month in a factory at Ga-Rankuwa. However, if you look at Ga-Rankuwa factory production, that 100m^3 of wood is not enough for a week's work. The problem is that we are cutting different timber of four or more species and this is different from plantation people who are cutting one species. Because of the lack of kilns, we mix the different timber into one kiln. These different species have different densities and traits and the drying method should be different. The lack of kilns is therefore a big challenge for us on the drying part. Our people they believe in air drying but if you are looking into mass production then timber must be put into a controlled environment as quickly as possible. This is important to have more control over the timber you are cutting. As a result of the lack of enough kilns we have timber that is lying outside and we do not have control over

[226] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[227] Mr B13. Forestry Technology Manager- NCT Forests, telephonically interviewed by Mushangai, Johannesburg, 26/06/2018

[228] Ms B32. Senior Manager- Transformation, SAFCOL, interviewed by Mushangai, Nelspruit, Mpumalanga, 26/10/2017

> it. That is where we are losing a lot of money. From a technical point of view, we have to capacitate the factories to improve efficiency.[229]

The lack of kilns as a challenge in drying processes was also noted by Ms M, a dry mill contractor in Heidelberg-Mpumalanga. This means that the challenge is a general one among small businesses in the sawmilling subsector of the forestry value chain. As Ms M explained,

> We do not have enough kilns to dry. We are using blue-gum eucalyptus and the solar kilns we have do not have the effect of drying the kind of planks we are using. We need to get the kind of kilns that are suitable for the planks that we are working with. These solar kilns are not suitable because most of the time our planks crack when they are already in the dry-mill. They are not producing the planks we want. The kilns we are using are hundred percent not for this wood.[230]

These testimonies provide the evidentiary basis demonstrating the negative impact of the lack of financial capabilities on the ability of small businesses to acquire suitable technologies to improve their processes in meeting their production targets on time. As such, workplace learning and the generation of knowledge acquired through demonstrations in the application of new technologies at the workplace is curtailed. The above reflection by Ms M shows that without financial capabilities, SMEs are compelled to rely on cheap and sub-standard machines not suitable for quality production.[231] Product innovation is dependent on process innovation. As noted above by Ms M, the lack of suitable kilns is causing the planks they are producing to crack.[232] Accordingly, the quality of products to be produced from cracking planks is compromised over time, hence financial resources are wasted on products the marketability of which is not guaranteed. Without an established market for products, the sustainability of small businesses cannot be assured.

The lack of advanced machinery used by SMEs is despite the fact that many of them displayed their readiness for improved technologies in building their capabilities. For example, most of the small businesses in the manufacturing parts of the value chain have readily assimilated

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[229] Mr B49. Technical Manager- DEA Eco-Furniture Industries, interviewed by Mushangai, 27/06/2017

[230] Ms B38, Small Drymill Business Contractor, interviewed by Mushangai, Mpumalanga, 30/06/2017

[231] Ibid

[232] Ibid

information technologies in their marketing activities. Mr B20 and Mr B30, whose businesses are located in the Orlando Industrial Park, confirmed that most of their marketing activities involve conversations with people pressing for orders of cabinets through media such as Facebook and WhatsApp.[233] [234] The lack of financial capabilities by SMEs for advanced technologies and machinery is hindering these firms from embarking on creative destruction to improve their functions, processes, and products in a way that replaces outdated ways of doing things.

6.2.3 Lack of funding and product innovation

Furthermore, the lack of funding for machines limits the ability of SMEs to upgrade in relation to product innovation. The Eurostat's Oslo Manual (2005, cited in Blind, 2010) defines product innovation to include innovations covering both goods and services introduced to the market which are new or with improved characteristics. Product innovation is hampered by the lack of financial capital to buy the required machines as reflected by Mr B49:

> Our focus should be to turn the whole tree into money. We do not have the machinery to turn the waste into value-added products. Of the trees we are cutting, we cannot use anything that is 200mm and smaller. There are other machines that can use 200mm or smaller logs. There are two types of machines. In one of these machines when you can put your log in it, it takes a thin layer off and then you make something like plywood that you mould like the bucket of the chairs and then you upholster it. So, that is a new product. We do not have the machinery for taking waste products and turning it into money like chippers, briquette, and for moulding and making chairs. Even the leaves we can pack. In some countries they are taking leaves and making essential oils. If we have the right machines we can use the whole tree. Currently, we are only focusing on 20% of the tree instead of 100%, because 80% of the woodcut is waste. We have to concentrate on turning the waste into money and by doing that can contribute to self-sufficiency.[235]

[233] Mr B20. SME Owner, Cabinet manufacturer, interviewed by Mushangai, Orlando Industrial Park, Soweto, 28/06/2019

[234] Mr B30. SME Owner, Cabinet manufacturer, interviewed by Mushangai, Orlando Industrial Park, Soweto, 28/06/2019

[235] Mr B49. Technical Manager- DEA Eco-Furniture Industries, interviewed by Mushangai, 27/06/2017

Efficiency in an age in which plantation forestry resources are threatened by the effects of global warming and climate change coupled with the accompanying pests and pathogens has to focus on sustainability of the resource base on which the whole value chain depends. Innovation in the forestry sector has to improve resource efficiency by reducing wastage in production. Currently, processing activities in the sawmilling subsection of the value chain are wasteful, with the recovery rate per tree in South Africa at 48% (35-47%[236]) whereas in other parts of the world they are pushing it up to 60%.[237] The recovery rate is much worse among the small-scale enterprises, standing at about 20%.[238] It is therefore imperative to make available funding for SMEs to upgrade their production activities through the acquisition of machines required to turn waste products into use values. Waste beneficiation by SMEs would result in product diversification.

Product innovation and diversification are important strategies in opening new streams of income, thereby enhancing the sustainability of SMEs. The lack of requisite machinery was also noted by manufacturing SME owners in the forestry value chain to be a hindrance to product diversification. Mr B30, a cabinet manufacturer whose business is located in the Orlando Industrial Park, indicated that he only had a few hand tools, equipment, and a compressor which he bought while on his previous job.[239] Mr B30, a manufacturer of small wooden cabinets for the low-end Sowetan market, indicated that he has been considering product diversification through the manufacture of up-market tables and chairs but does not have the capital to buy advanced machines for moulding, and upholstering to shape the bucket of the chairs.[240] The lack of machines was also considered a hindrance to business expansion by Mr B20 who also manufactures wooden cabinets in the Orlando Industrial Park for the low-end Soweto market.[241] As a result of the lack of machines and equipment, most of the SMEs in the Orlando Industrial Park manufacture very small wooden cabinets of a similar design. As such, production diversification has not been a feature defining the competitive capabilities of these SMEs but

[236] Sithole FIC presentation, 4 Oct 2017

[237] Mr B26. Director- Sawmilling South Africa, telephonically interviewed by Mushangai, Johannesburg, 07/04/2018

[238] Ibid

[239] Mr B30. SME Owner, Cabinet manufacturer, interviewed by Mushangai, Orlando Industrial Park, Soweto, 28/06/2019

[240] Ibid

[241] Mr B20. SME Owner, Cabinet manufacturer, interviewed by Mushangai, Orlando Industrial Park, Soweto, 28/06/2019

such values as, ‘honesty and the ability to produce quality products’.[242] According to Mr B20, ‘Once you produce quality products and your customers know that you are reliable, they refer other people to you and through that your client base will keep growing’.[243] The lack of machinery therefore limits the competitive strategy options that SMEs can adopt in building their businesses.

Product innovation implies the ability to adapt and change through new product designs in relation to market dynamics. Product diversification ensures continuity of the business in case of the market of the business’s main product closing up. Ms B41 recommended that,

> It is important to have other lines that bring in additional revenue and a good market. Without that, you can have everything else but if you do not have a market for your product you may as well just close up the shop.[244]

The inability by most of the SMEs to achieve product innovation and diversification partly explains the collapse of most SMEs in their formative stages. The Minister of Trade and Industry, Rob Davies, noted that four out of seven SMEs in South Africa collapse within their first years of formation (Kgosana, 2013). In a highly competitive environment, firms have to innovate as both product and process innovations allow them to survive in the long run by keeping ahead of their competitors. Ms B39 noted that the aim in developing small businesses is not to keep them small but to grow them into going concerns. This requires SMEs to gain capabilities in developing new consumer goods, new methods of production or transportation, and ‘’the new markets, the new forms of the industrial organisation’’ (Schumpeter (1942, cited in Blind, 2010). In the Schumpeterian perspective, innovating firms enjoy a temporary monopoly that provides them with rents. Rents entail advantages over competitors.

6.2.4 Lack of funding and business tenders

Limited funding for upgrading production activities makes it difficult for small businesses to acquire tenders from big businesses. Big businesses are concerned with satisfying their markets and emphasise efficiency and effectiveness in terms of meeting contractual agreements in

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[242] Ibid

[243] Ibid

[244] Ms B41. Deputy Director: Strategic Support in the Office of the Chief Director of NRM, interviewed by Mushangai, DEA, Cape Town, 09/06/2017

relation to the quantity and quality of the product and the speed of delivery. Most of the SMEs in the forestry sector of South Africa lack the capabilities to meet these requirements. An example of this was provided by Mr B49 in connection with their factory in Ga-Rankuwa. Mr B49 noted that, because of the lack of capacity, their Ga-Rankuwa factory has been unable to meet the orders for school desks by the Department of Basic Education in South Africa.[245] Further, Ms B32, the Transformation Manager at SAFCOL, noted that in their harvesting and transporting operations, 70% of the contracts are for established businesses because they have the capacity to deliver.[246] She, however, conceded that SAFCOL had set aside 30% of the tenders above R50 million of the work in logistics for SMEs in line with government preferential procurement framework, because 'we are saying it would not be so bad if the SMEs do not perform well'.[247] As Ms B32 emphasised,

> I want to link that to the reliability of the SMEs that are being offered contracts. Are these new players within the industry reliable? Remember we spend so much money from research up to harvesting and then there is no transport, what is the whole exercise for? This thing goes with competencies; you have to be competent. We usually work with established businesses and we do not look at emerging contractors. We look at real businesses because this is very expensive. You must have the financial capacity. So, for us, logistics is for established businesses because they have the right financial capacity, the right managers in place, and the right skills. There is a low appetite by SAFCOL to give these guys work because they are not going to deliver. The work that an established company could have taken two days, these guys are going to take five days. These are risks and challenges that we face with SMEs. They are companies you give an order today and you expect delivery tomorrow but you will only get delivery next month.[248]

As a result, the SMEs lose business because they do not have the financial capabilities required to meet contractual agreements. Without these capabilities, the reliability of the SMEs is compromised. The big businesses in the sector would not risk their operations by awarding

[245] Ibid

[246] Ms B32. Senior Manager- Transformation, SAFCOL, interviewed by Mushangai, Nelspruit, Mpumalanga, 26/10/2017

[247] Ibid

[248] Ms B32. Senior Manager- Transformation, SAFCOL, interviewed by Mushangai, Nelspruit, Mpumalanga, 26/10/2017

tenders to small businesses whose capabilities have not been proven. Enhanced operational capabilities by SMEs improve their chances of winning tenders to do business with established firms. This very fact would improve the sustainability of SMEs for linkages with established businesses will expose them to skills and technologies at the disposal of these firms (AgriSETA, 2016). Nevertheless, Shapira (2010) noted that the efficiency of a system of innovation is realised in the support in growing and upgrading the production activities of SMEs. The lack of such support, as in the award of tenders to SMEs within the forestry sector of South Africa, points to weaknesses in both the NSI and the SSI that hinders process and product innovation and thus the survival of most SMEs. These weaknesses also prevent the implementation of innovative projects emanating from the work of researchers.

Important to note is that there are areas in an economy that demand government intervention, areas in which the private sector would not invest as they are considered marginal and providing low returns on investment (Bortagaray & Ordóñez-Matamoros, 2012). For example, the envisaged participatory community forestry related to social aspects of innovation will not succeed without the government's commitment to funding. As noted by Prof B44,

> We did a lot of work on the harvesting of bark for traditional medicine. We tried to work with DCAST and DWAF. They are the reason why community participation in forest management does not work in practice. We formed an association with the rural society of Eastern Cape and they were willing to change the way they do things, but DCAST and DWAF did nothing. Now they say it is the community's problem when they talk about participation in forest management but they did nothing to promote it. I wish there was better collaboration between the universities, the government, and companies who deal with it.[249]

Innovation in the forestry sector is thus limited by the lack of government support in the form of funds for innovative projects. The lack of funding for innovative projects in areas considered unviable by the private sector limits the extent of a collaboration of a triple helix nature. It is critical to note that most of the innovations by SMEs are incremental, concerned with the adoption and adaptation of existing ideas and technologies. The lack of funding to enable the

[249] Prof B44. Forest Ecologist, UP, interviewed by Mushangai, UP, 29/05/2017

adoption and adaptation of existing technologies by small businesses reflects the lack of integration in the South African NSI (OECD, 2007) and the forestry SSI (Greenberg, 2010). This is largely a result of the failure by the government to support small businesses and the unwillingness of financial organisations to take risks in financing SMEs (Mahembe, 2013). All of this reflects weak coordination, weak linkages, and the limited capacity of the SSI, with a negative impact on growing the capabilities of small businesses.

6.3 Lack of funding as a result of the lack of business skills

This chapter’s introduction alluded to the existence of many policy frameworks (for example, White Paper 1995, NBA, ISBDS, NIFP ASGI-SA, BNG, Nibus, and others) articulating the need for the provision of financial support to small businesses. The section also noted the various organs and schemes of government (IDC, SEDA, Khula, and Samef) that have been put in place in South Africa to operationalise financial support for small businesses. More importantly, major transformations have been realised in the financial sector, with most of the banks now having ‘promotional or workshops to help SMEs’ (National Credit Regulator, NCR, 2010, cited in Mushangai 2015:58). The NCR (2010) further noted that the negotiated Financial Sector Charter of 2004 (amended in 2017) was likely to reduce the structural bottlenecks of the apartheid era in responding to the financial needs of the SMEs (Mushangai, 2015). Consequently, the NCR (2013) indicated that, commercial banks’ clientele base of the people from underprivileged backgrounds has been increasing in South Africa over the past two decades (Mushangai, 2015). Further and emanating from the policy frameworks and the financial schemes in place, the World Bank study of 2007 noted the reduced barriers to financial loans in South Africa, with SMEs’ applications for loans taking 4.13 days to process as compared to the international average of 11.03 days (Mushangai, 2015). Despite the existence of a number of policy frameworks and financing schemes designed for small businesses within the South African NSI, funding has remained a challenge for many SMEs. Chimucheka and Rungani (2011) observed that the number of rejections for financial applications by small businesses is still unacceptably high and that this may be as a result of a lack of collateral (37%), a lack of balance sheet (17%) and a lack of viable business plans (7%). Moreover, where funding is provided, the World Bank (2007) noted that an SME application takes around two times more days than other applications. It is assumed that rejection or delays in processing SME applications may relate to a lack of quality information or incomplete applications by the SME owners, emanating from the lack of business skills.

The lack of financial support is deemed worse for those involved in agribusinesses.[250] Moreover, those operating in the forestry subsector of agribusiness are in a worse position than agriculture and fisheries.[251] [252] The argument is that forestry is being discriminated against in government programmes and this affects the capitalisation SMEs in the forestry subsector of agriculture.[253] This was confirmed by Mr B27, who noted that,

> In Agriculture, there is the CASP (Comprehensive Agriculture Support Programme), by which money is given for infrastructure development on the farms. A farmer without means can apply for that money and be supported. That support is not there in the forestry sub-sector. DAFF has to see to it that the scheme is put in place to be able to respond to the needs of the small growers and small to medium enterprises that are operating in the forestry sector.[254]

Further, Mr B15 noted the absence in South Africa of a programme or a project that has been supported by the government to support small growers.[255] He also noted the non-existence of development finance instruments in South Africa that are relevant and applicable for forestry or timber growing people.[256] As he elaborated,

> I was sitting in a meeting yesterday and some people told us that, we have lots of money, but I am still not convinced because I have not seen their conditions. People would say that they have lots of money, they can lend you the money, and then they say we would like to have our money back after 3-years and the trees have not got to maturity, so where are you going to get the money to pay them back.[257]

[250] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017
[251] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017
[252] Prof B48. SAPPI Research Chair, Wits University, interviewed by Mushangai, Braamfontein, Johannesburg, 31/01/2018
[253] Ibid
[254] Mr B27. Head of Forestry Department- Fort Cox, interviewed by Mushangai, Fort Cox, Eastern Cape, 06/11/2017
[255] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017
[256] Ibid
[257] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

It is for this reason that the *Funding and Business Support* discussion at the Forestry Industrialisation Conference (FIC, Transnet Esselen Park, Kempton Park, 4 October, 2017) recommended the provision of tailor-made and commercial financial support to SMEs in the forestry sector. Much of the funding available does not suit the tree-growing business, demanding long-term investments whereby trees may take 15 to 25 years to reach maturity before harvesting. Tree growing is a long-term investment, which increases the risk for investors of committing their money. Ideally, the government should play a major role in the area, as was the case under Apartheid.

Although it is true to say that most of the funding schemes in the NSI are not customised to the needs of small-scale growers but saying that all of the funding schemes available are not appropriate for the forestry sector, as claimed above by Mr B15, is reductionist, as such an argument does not entail a deep understanding of the forestry value chain as a whole. Important to consider is that most of the funding schemes at the disposal of small businesses in other sectors of the economy are also appropriate for small businesses in downstream processing and manufacturing activities whose turnover time is far shorter than that required by growers. As such, there must be other reasons why small-scale forestry enterprises in downstream activities are failing to secure funding from funding organisations.

Ms B32, the Transformation Manager at SAFCOL, is of the opinion that race is still an issue in democratic South Africa in relation to business financing. According to Ms B32,

> Banks can give an overdraft to a white person to build faster but the black people do not even have those benefits. The black-owned companies will go to loan sharks and if they fail to pay on time, they lose everything[258].

The above testimony from Ms B32 is important in demonstrating the extent of the lack of financing for small black-owned businesses in South Africa. However, it remains just as what it is, an opinion lacking explanatory power as to why in most cases businesses owned by white people have easy access (as noted by the Forest Charter (2008) and AsgiSA (2008)) compared to small scale black-owned businesses. The issue is not about race *per se* but that most white people have business skills and experience to produce remarkable and bankable business plans and

[258] Ms B32. Senior Manager- Transformation, SAFCOL, interviewed by Mushangai, Nelspruit, Mpumalanga, 26/10/2017

proposals when compared to most black SMEs owners.[259] As highlighted by Hall (1998), the black-owned SMEs in the sector are marginalised, as they ‘’are least likely to know about available opportunities and mechanisms to *apply for funds*. They are least likely to have access to the information, literacy, education, and knowledge to produce a business plan and to negotiate with lenders to borrow money’’ (p. 454). This relates to skills shortages among the small businesses to integrate and make links within the forestry SSI to run their businesses efficiently. The shortage of skills, especially among the rural communities, is linked to the history of skills development and access to resources under apartheid. In democratic South Africa, this is explained in terms of path dependence, as resource commitments by the democratic governments have continued to marginalise rural development, as was under Apartheid. The Apartheid development paradigm has continued to cast some shadow over access to business skills in the rural constituent. As observed by Mr B15, with regard to SMEs in the forestry SSI,

> There is zero business occurring among small businesses as nobody knows how to keep accounting books. Nobody knows how to measure whether business is good or bad. They do not know what is written on investment, so basic business management is a requirement. They also need soft skills; how do you conduct a meeting and how to resolve conflicts. These are community businesses and where there are human beings there will be conflicts *which need to be managed.*[260]

This was further articulated by Ms B41 (DEA) who noted that the critical ingredients for successful businesses in the sector have been,

> the owners being very driven and good at what they do. This includes being able to keep a good handle on the business, its business vision and human relations within their business, the market and the suppliers. You also need diversification of products.[261]

[259] Ms B36. The Director of the Centre for Small Business Development, University of Johannesburg (UJ), interviewed by Mushangai, UJ Soweto Campus, 10/10/15

[260] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[261] Ms B41. Deputy Director: Strategic Support in the Office of the Chief Director of NRM, interviewed by Mushangai, DEA, Cape Town, 09/06/2017

The area of business skills is crucial in building relationships, if the small businesses in the sector are to secure funding from financial organisations. The Director of the Centre for Small Business Development at the University of Johannesburg, Ms B36, noted that there are many resources but, without business skills, the funders will not commit their resources for small business development. In supporting her argument, Ms B36 noted that,

> There are a lot of resources. The issue pertains to skills. In 2014, we ran an investor conference at the University of Johannesburg (UJ). It brought in investors from different countries. One investor pledged R1, 4 billion, right here at UJ in one meeting, but they started to question, 'is this, the calibre of entrepreneurs you have in the country?' So, money is there. I was speaking to another person about the things that one has to go through when doing financials. Somebody writes a page and tells you, I am going to do this business but there are no projections. They do not have the skills; they do not have the capacity. Nobody will fund you no matter how many institutions you send your proposal to. The SMEs owners do not attend business meetings even when invited. People need to take initiative, nobody will bring a plate to you every day, this will not happen. By going to meetings, you can learn many things; you can do that by observation.[262]

The small business owners require training in basic accounting skills, marketing**,** cash flow management, operational skills, and access to value chains. Dr B3 noted that this is one of the major weaknesses in the curricula of organisations responsible for forestry skills development, for 'you cannot ignore the financial side that is important. The scientist would not understand the cost-benefit component to it, but they will try and solve the problem, but in this process, it still needs to be economically viable'.[263] The curriculum of organisations such as Fort Cox, NMU and other forestry faculties do not emphasise financial management.[264] Without these skills, it is difficult for one to operate and grow an enterprise successfully. The lack of business skills is a disabling factor for small businesses in coming up with thorough and watertight business plans as important instruments when applying for funds. This deficiency makes it impossible for black

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[262] Ms B36. The Director of the Centre for Small Business Development, University of Johannesburg (UJ), interviewed by Mushangai, UJ Soweto Campus, 10/10/15

[263] Dr B3. Research and Strategy Manager Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[264] Prof B43. Socio-ecology, Agroforestry, Soils**,** UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

SME owners to pass the assessment tests by the financial organisations or to observe and respond to business trends (Mushangai, 2015). Mr B10, who owns an informal small cabinet-making workshop, in Soweto applied twice to the National Youth Development Agency (NYDA) for funding but never got a response.[265] It is most likely that he failed to secure funding because of the informality of his business and a weak funding proposal, as he had not received any form of business training with regard to writing businesses proposals.[266] The lack of business skills among the start-ups was highlighted by Ms B37, a wet mill contractor at a Heidelberg factory when she noted that,

> I started working here; I had nothing to be a business person. I then registered my company. I now have the CIPRO documents, Labour documents, and other labour related issues.[267]

However, she noted that financial management was still a problem.[268] Had it not been for affirmative action, it is highly unlikely that Ms B37 would have been awarded a contract by SANParks because of a lack of business skills. Without clear business proposals and up-to-date financial statements, the banks and other financial organisations concerned with recouping profits from their investments will not be able to release their money, as noted by Ms B41 from DEA.[269]

6.4 The challenge of informalisation and business financing

The lack of funding in the sector is much more pronounced among informal businesses. Mr B26, the Director of Sawmilling South Africa, observed that the sawmilling subsection of the value chain has many informal enterprises.[270] According to Mr B26, most of these informal enterprises are ‘highly mobile and they are difficult to get hold of’.[271] The informal businesses in the sawmilling subsector do not have fixed addresses. They are highly mobile because they are

[265] Mr B10. Small business owner, Soweto, interviewed by Mushangai, Soweto, Jabavu, Johannesburg, 20/09/2017

[266] Ibid

[267] Ms B37, Small Drymill Business Contractor, interviewed by Mushangai, Mpumalanga, 30/06/2017

[268] Ibid

[269] Ms B41. Deputy Director: Strategic Support in the Office of the Chief Director of NRM, interviewed by Mushangai, DEA, Cape Town, 09/06/2017

[270] Mr B26. Director- Sawmilling South Africa, telephonically interviewed by Mushangai, Johannesburg, 07/04/2018

[271] Ibid

always moving to places at which the timber to be harvested is located. Mr B26 also noted that, because of their mobility, the lack of fixed addresses, and the informal nature of their businesses, it is difficult for them (Sawmilling South Africa, SSA) to connect these SMEs with skills and financial organisations.[272]

The challenge to development with regard to the informal nature of small businesses was also noted in the furniture manufacturing segment of the forestry value chain. It is critical to highlight that some extra-legal businesses are even invading formalised industrial parks in South African townships. The Orlando Industrial Park (Soweto) is a formalised industrial park established to facilitate the development of formalised small businesses in propelling township economies. This is supposed to happen through the diffusion of knowledge and technologies among the firms located close together in an industrial park. However, one of the main features characterising the Orlando Industrial Park is that most of the small furniture manufacturing firms operating in this formalised industrial space are not registered and are owned by Mozambicans and Zimbabweans.[273] This points to the domination of township entrepreneurship by foreign nationals, a fact which seems to suggest that local people are much more inclined to seek employment than to set up their own businesses.

Mr B30explains that the extra-legal nature of his business operating in the Orlando Industrial Park is a result of the fact that he 'does not have the papers' to work or to register and operate a business in South Africa.[274] He is on a visiting visa to South Africa, which he periodically renews.[275] Without a work permit or other permits required to operate a business Mr B30 could not have his business registered, as required by the law. The lack of the required documents to stay and run a business in South Africa deprives Mr B30 of many opportunities important in growing small businesses.[276] This would include the opportunity to apply for business capital from funding organisations and the opening of a personal or business account. Mr B30 indicated that, since he does not have a bank account, he saves his money by investing in houses in Mozambique.[277] However, he indicated that he has been operating for three years and would like

[272] Ibid

[273] Mr B30. SME Owner, Cabinet manufacturer, interviewed by Mushangai, Orlando Industrial Park, Soweto, 28/06/2019

[274] Mr T. SME Owner, Cabinet manufacturer, interviewed by Mushangai, Orlando Industrial Park, Soweto, 28/06/2019

[275] Ibid

[276] Ms B35. Roadside cabinet seller, (Soweto-Jabavu), conversation with Mushangai, 26/06/2019

[277] Ibid

to save in order to formalise his stay in South Africa and to have his business registered. Mr B30 also indicated that his business has to grow first because, once registered, he has to meet all the requirements in terms of taxes and labour registration, which come with business registration but which he cannot afford at the moment. Thus, the fear of the cost burden of registration is also part of the multiple factors why SMEs' owners operate within the extra-legal sphere or delay in registering their enterprises.

The Orlando Industrial Park supplies many roadside wood cabinet sellers in Soweto. Ms B35, a roadside cabinet seller in Soweto-Jabavu, indicated that her suppliers are the furniture manufactures from the Orlando Industrial Park.[278] Ms B35 noted that she has been in this business for five years.[279] Ms B34, another roadside wood cabinet seller in Soweto, indicated that she has no need to set up her business at a mall because 'people know where I am based now' and because 'I cannot afford the high rentals'.[280] She indicated that she is staying close by to her market place, hence does not need to pay for transporting the cabinets to and from the selling point.[281] Both, Ms B35 and Ms B34 are foreign nationals.[282] This fact may also be another reason preventing them from renting outlets at the malls because they lack the necessary documents required to operate businesses in South Africa. The roadside cabinet sellers indicated that they do not have much capital to purchase the cabinets in 'bulk' to receive a discount.[283] They also indicated that they could not buy many cabinets at a time because they do not have the space to keep them.[284] However, the roadside furniture sellers are crucial for the survival of the cabinet manufacturers in Soweto. They are an important component of the Orlando Industrial Park supply and distribution network, providing important connections between manufacturers and consumers.

Nevertheless, the roadside cabinet sellers face a number of challenges, including a lack of capital and a lack of safe places to store their cabinets and they are also exposed to the vagaries of weather, as they operate in open spaces along streets. All of these factors are linked to the

[278] Ibid

[279] Ms B34. Roadside cabinet seller, Mphuti street (Soweto-Jabavu), conversation with Mushangai, 26/06/2019

[280] Ms B35. Roadside cabinet seller, Mphuti street (Soweto-Jabavu), conversation with Mushangai, 26/06/2019

[281] Ibid

[282] Ibid

[283] Ibid

[284] Ibid

informal nature of their businesses. These challenges confirm what De Soto (2000) noted when he emphasised that formalised property regimes are secure, and increase the owner's credit worthiness with formal 'institutions', and that they are more productive and likely to lead to business improvements. Having an accountable address is important for an enterprise, for it enables the collection of debts and taxes and makes assets more fungible and combinable, hence facilitating the development of market transactions (De Soto, 2000).

In contrast to the situation pertaining in the sawmilling subsector of the forestry value chain or in the manufacturing subsections, such as the Orlando Industrial Park, Ms B41[285] noted that their first eco-coffin furniture firms in KwaZulu-Natal received financial support from the World Bank. This is because their business had been formalised, had clear business plans, had a fixed address where the sponsors could come to 'monitor and evaluate progress', had 'a competent management team' and had managed to give the World Bank a clear business proposal.[286] Further, the eco-furniture school desk project contractors in the saw-milling and dry-milling operations at the Heidelberg factory (Mpumalanga) noted that, before they were awarded their contracts, SANParks, which is responsible for the implementation of the project, contracted people to assist in training the new contractors in the areas of business registration, financial management, operations management, human resources management and in meeting the regulation requirements in terms of safety, labour regulations, and tax requirements.[287] [288] All of this demonstrates the importance of business skills and business formalisation for the survivability of SMEs.

While some stakeholders in the forestry sector complain about the lack of customised financial schemes for small scale growers, SMEs in the downstream activities of the value chain whose turnover time does not exceed 15-25 years have more options. The lack of funding for these businesses cannot be solely explained in terms of the lack of customised financial schemes for the forestry sector, as presumed by Mr B15, the Small business Manager at SFA,[289] and Mr B27,

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[285] Ms B41. Deputy Director: Strategic Support in the Office of the Chief Director of NRM, interviewed by Mushangai, DEA, Cape Town, 09/06/2017

[286] Ms B41. Deputy Director: Strategic Support in the Office of the Chief Director of NRM, interviewed by Mushangai, DEA, Cape Town, 09/06/2017

[287] Ms B38, Small Drymill Business Contractor, interviewed by Mushangai, Mpumalanga, 30/06/2017

[288] Ms B37, Small Wet Mill Contractor, interviewed by Mushangai, 30/06/2017

[289] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

the Head of Forestry Studies at Fort Cox College.[290] An encompassing explanation of the lack of funding for SMEs in the downstream processing and manufacturing activities would be in terms of multiple realities or a convergence of factors whose vortex revolves around business formalisation and the lack of business skills, as indicated in the discussion above.

Informal businesses, however, appear to be resilient when compared to other enterprises emerging mainly as a result of government-support schemes, such as the eco-furniture industries. The informal businesses do not have elaborate machines comparable to those in the eco-furniture factory at Heidelberg, which is financed by the National Treasury. In most cases, these businesses were started from the savings by the owner when she or he was working somewhere for someone else. According to Mr B30, he managed to save to buy the necessary equipment while he was working for his uncle[291]. Mr B20 indicated he started his business from his own savings when left his job in 2010.[292] Both Mr B30 and Mr B20 have been in the business of making wooden cabinets for more than four years.[293] The major reasons for their resilience emanate from an entrepreneurial spirit. The people who own informal businesses are driven by the need to succeed and did not become entrepreneurs as a result of an invitation to join a business scheme by the government. This points to what was noted by Bongani Mabuse (2014) of the City of Johannesburg at the Conference of the Social and Solidarity Economy organised by the Centre for Social Economy and Social Entrepreneurship (CSESE), University of Johannesburg.[294] Mabuse noted that grant making 'is not a stimulus but savings. Your savings are very important. Government adds to what is there. Communities have to save. Entrepreneurship must be there in the community'. In comparison to government supported schemes, such as the eco-furniture factories, these small businesses were established from the owners' savings and have been able to open up markets for their cabinets. This is different from the eco-furniture factory at Heidelberg, the market of which is guaranteed by the Department of Basic Education (DBE). It is doubtful whether the eco-furniture factory at Heidelberg would survive if it were to lose government support in the form of finance, machinery, skills development and the market for its products, provided by the Department of Basic Education.

[290] Mr B27. Head of Forestry Department- Fort Cox, interviewed by Mushangai, Fort Cox, Eastern Cape, 06/11/2017

[291] Mr B30. SME Owner, Cabinet manufacturer, interviewed by Mushangai, Orlando Industrial Park, Soweto, 28/06/2019

[292] Ibid

[293] Mr B20. SME Owner, Cabinet manufacturer, interviewed by Mushangai, Orlando Industrial Park, Soweto, 28/06/2019

[294] CSESE- University of Johannesburg, Conference of The Social and Solidarity Economy, Sunnyside Hotel, Johannesburg 03/09/2014

Nonetheless, the owners of informal businesses complained about the lack of government funding support in growing their businesses. Mr B20 revealed that 'the ANC came and promised to inject some cash into the businesses but never returned after elections'.[295] However, Mr B20 indicated that he has not applied for funding from anyone as he was not aware of any funding agencies.[296] This, points to the fact that a lack of information may be a hindrance to optimising opportunities in growing one's business. Despite being successful on his own terms, Mr B20 is of the opinion that things could have been better had he received the financial support required to buy the machinery needed to diversify his product range.[297]

6.5 Development finance organisations and small business development

In the discussion at the FIC (FIC, Funding and Business Support: Kempton Park, 4 Oct 2017), the business financiers identified a number of issues which they considered when investing in businesses. Ms Molebo Mothibe from Nedbank noted that they have balance-sheet and security-based funding models.[298] They have a suite of funding instruments including loan, bridging, trade, property, and vehicle finances and that their funding covers SMEs and large enterprises.[299] The funding may be applied for buildings, plant and equipment, and working capital.[300] Further, Ms Mothibe indicated that they collaborate with the private and public sectors in leveraging resources and support for SMEs.[301] However, in relation to SME funding she noted investment challenges in relation to the security of markets and own contribution.[302] Further, Mr Steven Ngubane from the Industrial Development Corporation (IDC), which is one of the biggest development financial 'institutions' (DFIs) in South Africa, noted that they have developmental and risk-based funding models for supporting new and expansionary commercial industrial enterprises.[303] They have a suite of funding instruments, including debt, equity, quasi-equity, and special pro-forestry schemes, such as the Forestry Project Development Fund.[304] The IDC

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[295] Mr B20. SME Owner, Cabinet manufacturer, interviewed by Mushangai, Orlando Industrial Park, Soweto, 28/06/2019

[296] Ibid

[297] Ibid

[298] Ms Molebo Mothibe (Nedbank). Funding and Business Support: Discussion, Kempton Park, 4 Oct 2017

[299] Ibid

[300] Ibid

[301] Ibid

[302] Ibid

[303] Mr Steven Ngubane (Industrial Development Corporation, IDC). Funding and Business Support: Discussion, Kempton Park, 4 Oct 2017

[304] Ibid

funding scope covers SMEs and large enterprises and may be applied for land, buildings, plant and equipment, and working capital.[305]

Further, the IDC collaborates with the private and public sectors in leveraging resources and support for SMEs.[306] Mr Ngubane also highlighted investment challenges related to market security and own contribution.[307] Lastly, Ms Shareen Osman from the DTI, which is mandated to oversee the industrialisation of South Africa, noted that they have developmental impact and co-funding (grants) based models and that they support new and expansionary commercial industrial enterprises.[308] They have a suite of investment instruments, including the Black Industrialist Scheme (BIS), Agro-Processing Support Scheme (APSS), Strategic Partnership Programme (SPP) and Export Marketing and Investment Assistance (EMIA).[309] Their funding covers SMEs and large enterprises and they collaborate with other Development Financial 'Institutions' (DFIs) and the private sector in leveraging co-funding for SMEs.[310] However, the common issues that cut across these funding organisations revolve around the provision of tailor-made support to SMEs in relation to business planning, securing markets, projects' structuring, and financial planning.[311] [312] [313] Business skills in these areas were recognised as crucial for successful businesses, especially when applying for funds. The FIC discussion recognised that the SETAs were working on addressing SME development and capacity building. Though skills were raised as the main challenge in funding, other important issues were also acknowledged, such as the balance sheet and own contribution when applying for funding.[314] [315] The issues pertaining to the balance sheet and own contributions are difficult to manoeuvre around, especially considering that most of the SMEs start from a position of sufferance.

[305] Ibid

[306] Ibid

[307] Mr Steven Ngubane (Industrial Development Corporation, IDC). Funding and Business Support: Discussion, Kempton Park, 4 Oct 2017

[308] Ms Shareen Osman (DTI) Funding and Business Support: Discussion, Kempton Park, 4 Oct 2017

[309] Ibid

[310] Ms Shareen Osman (DTI) Funding and Business Support: Discussion, Kempton Park, 4 Oct 2017.

[311] Ms Molebo Mothibe (Nedbank). Funding and Business Support: Discussion, Kempton Park, 4 Oct 2017

[312] Mr Steven Ngubane (Industrial Development Corporation, IDC). Funding and Business Support: Discussion, Kempton Park, 4 Oct 2017

[313] Ms Shareen Osman (DTI) Funding and Business Support: Discussion, Kempton Park, 4 Oct 2017

[314] Ms Molebo Mothibe (Nedbank). Funding and Business Support: Discussion, Kempton Park, 4 Oct 2017

[315] Mr Steven Ngubane (Industrial Development Corporation, IDC). Funding and Business Support: Discussion, Kempton Park, 4 Oct 2017

The three funding organisations, Nedbank, IDC, and the DTI, also raised the importance of security of markets. This fact is important considering that the small firms have to pay back the loans, which may be difficult to accomplish in the absence of markets for their products. It is for this reason that state procurement capacity has also to be improved to secure markets for SMEs. Further, the issue of partnerships was raised at the FIC in leveraging funding for SMEs. However, as was noted above, DAFF, which is the government department responsible for forestry resource development, does not have partnerships related to SMEs forestry development projects. This is despite evidence demonstrating that the vexation pertaining to the burden of financing upgrading and innovative projects by SMEs through the adoption and adaptation of existing knowledge and technologies can be lessened through collaboration, as demonstrated in the Timber Winch project (Appendix 1, Box 7) and the Heidelberg eco-furniture school desk project (Appendix 1, Box 6). The encouragement of partnerships and collaboration by Nedbank, the IDC, and the DTI, as national organisations in leveraging resources for SMEs development, points to the interaction between the components of the NSI and the SSI in development. The lack of opportunities among the SMEs also points to a lack of information, which can be bridged, with the services of extension officers in rural areas.

6.6 Extension services and technology transfers

The technologies required by small businesses are already there in most cases but what is needed is their transfer and adaptation by the SMEs. For example, the CSIR (2011:12) produces improved germplasm for all sizes of firms in South Africa. Also, the machines needed in harvesting and processing operations are available in South Africa from companies such as Enviro-Chainsaws, Nukor, and Wood-Mizer.[316] In addition, the quality of timber depends on silvicultural skills that can be learnt in most cases through demonstrations of silvicultural practice in the fields. Further, harvesting operations demand a certain set of skills that can be learnt through demonstrations on the field, as was noted above in the Eco-furniture School Desk case study Appendix 1, Box 6. Moreover, operations in dry mills and wet mills demand skills that can be consolidated through demonstrations, as noted in Appendix 1, Box 6. However, according to evolutionary economists, Nelson and Winter (1977) and SI scholars, Bergek et al (2010), technological knowledge cannot be easily transferred because of technological

[316] Mr B49. Technical Manager- DEA Eco-Furniture Industries, interviewed by Mushangai, 27/06/2017

complexity. Technological complexity implies that firms can rarely command all relevant knowledge internally (Bergek et al, 2010). As a result of complexities, technological knowledge cannot be transferred in its entirety without concerted interaction between the possessor and the receiver (Nelson & Winter, 1977, cited in Joseph, 2009). The transfer of this knowledge requires close interaction and trust between individuals and organisations alike. As noted by Maskell and Malmberg (2002), technological knowledge is tacit and can be transferred mainly through such activities as observation, comparing and monitoring the activities of others and through experiential learning. People may have the knowledge but may not know to apply it, hence the importance of mentors and agricultural demonstrators in the agroforestry sector. The complexity in the transfer of technological knowledge was demonstrated by Ms B36, the Director of the Centre for Small Business Development at UJ, when she noted that,

> ...you will find that a lot of people have attended programmes, they have certificates, but what have they done with that information? The people who are giving you the information have done their bit. They go through a financing module and give them the templates to use. They go back home and they file them. Whose problem is this? The SME owners need to be responsive; they need to assimilate the knowledge that they are having.[317]

It seems that Ms B36 fails to consider the complex nature of technological knowledge with regard to how it is applied, especially when dealing with SMEs. The *how* part of this knowledge cannot be acquired through reading textbooks at universities and colleges or by revisiting notes from a workshop. Mentoring, as emphasised by Prof Du Plessis, is crucial in the transfer and application of such knowledge by SMEs. Prof Du Plessis, the Director of the Potchefstroom Business School at the North West University, noted that, for the transfer and application of knowledge among the SMEs, there is a need for,

> an independent institution which advises and mentors entrepreneurs about business ... You can teach someone to be the best artisan but he needs to manage cash flow, administration and marketing … he cannot learn in the classroom - he needs someone to help and mentor him (Vollgraafe, 2011).

[317] Ms B36. The Director of the Centre for Small Business Development, University of Johannesburg (UJ), interviewed by Mushangai, UJ Soweto Campus, 10/10/15

The same goes for the artisanal and technical skills needed by SMEs. South Africa has recently seen a number of activities by universities trying to connect with SMEs in a bid to transfer knowledge and to improve their sustainability. Research organisations and universities in South Africa have over the years devised the means to ensure that new knowledge and technologies produced reach the end users (Ranga, 2013, cited in Bergman, 2014). As stressed by Prof B47 from UP, 'we do a lot of field days organised by our funders Mondi and SAPPI to educate and train the foresters so that they can help with monitoring and surveillance and implementation of what we do. Small growers are invited to field days'.[318] Also, Ms B39 from the ICFR noted that they disseminate knowledge and technologies through peer-reviewed papers and demonstrations at field days. Prof B42, a systems expert from the University of Stellenbosch, noted that they had devised a website (www.forestproductivity.co.za) on which they share all information in connection with productivity improvement.[319]

Despite the growth of knowledge-sharing platforms, it was, however, noted that language and the complexity of knowledge from universities are factors working against the application of such knowledge by SMEs for process and product upgrading. A number of research organisations are, however, trying to improve on the language front. For example, Prof B47 from UP noted that they now train extension officers to communicate in local languages.[320] Miss S from the ICFR also observed that their technicians are 'effective Zulu speakers'.[321] Despite these developments, Mr B15, the Small Business Manager at FSA-UKZN, raised the fact that the knowledge generated by universities and research institutes is generated at 'certain levels and has to be interpreted to be easily understood by the end user so that he can apply it'.[322] The decoding and simplification of knowledge from universities and research institutes are important vectors if the technical knowledge from big science institutes is to be easily understood and made applicable by end-user small-scale growers. There is thus a demand for extension officers for this undertaking. This confirms what was noted by Velazco (2001), that human capital was important for the success of extension programmes and technological change. The importance of this was emphasised by Ms B39 from the ICFR, who noted that technological knowledge needs face-to-

[318] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[319] Prof B42. Lecturer, Forestry Harvesting, Stellenbosch university, interviewed by Mushangai, Stellenbosch, 27/06/2018

[320] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[321] Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[322] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

face interactions and demonstrations if it is to be absorbed, assimilated, and applied by SMEs in the forestry sector. Ms B39 explained,

> Technology transfer requires face-to-face interaction. Personal contact and practical demonstration are by far the most successful way to do technology transfer. We are looking into the future at things like app development, toolkits, and other technologies. They will support technology transfer, but the most effective technology transfer tool is face to face contact because communication is dialogue. If you produce new knowledge or technology, you are just putting stuff out there. If you go and meet with someone face to face you start to enter into a dialogue, you listen, you look, and if you start listening and looking then you learn.[323]

This is the reality which Ms B36, the Director of the Centre for Small Business Development at UJ, failed to comprehend when she noted above that a lot of people have attended training programmes and have certificates but have done nothing to apply the knowledge gained from workshops. The know-how part of knowledge cannot be grasped by attending programmes but through demonstrations, as noted in the DEA Heidelberg Eco-Furniture school desk project in Appendix 1, Box 6.

Collaboration is crucial in addressing most of the challenges in building the capabilities of the SMEs in the forestry sector. The Heidelberg Eco-furniture school desk project (Appendix 1, Box 6) demonstrates that most of the challenges pertaining to the growth and development of SMEs identified in the preceding sections with regard to financing, mechanisation, product development and the need for demonstrations in knowledge and skills transfer can be addressed through collaboration by the stakeholders in the sector. The project was a result of a partnership between the DEA and the Department of Basic Education to produce cheap school desks for rural schools in South Africa at a factory in Heidelberg in Mpumalanga. The activities at the Heidelberg factory start with the harvesting of Invasive Alien Species (IAPs) and end with the delivery of desks to rural schools in South Africa.

[323] Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017

The Heidelberg school desk project demonstrated the advantages of collaboration for a number of reasons. First, collaboration made it possible to avoid confrontations that would have affected the forestry industry as a whole. The literature reviewed in Chapter 2 noted that, since the late 1930s, after the Jonkershoek Hydrological experiment, plantation forestry was declared a stream flow reduction activity (Bennett & Kruger, 2015). The exotic tree species, such as eucalyptus, poplar, wattle, and pines, were pronounced invasive trees, which consumed a great deal of water as compared to indigenous vegetation (Meander, 2017). These species forming the backbone of the plantation economy were to be managed to prevent them from colonising natural eco-systems, so as to preserve water and to conserve biodiversity (Meander, 2017).

The conflict between the foresters and the government with regard to water has continued between the democratic governments and the forestry industry, forcing the industry to retreat from riparian zones. This conflict, if not managed, would have ruined the industry's image concerning international sustainable forestry management practices, as determined by the ISO and the FSC. Had this happened the forestry industry would not have been able to access the lucrative European and American product markets. However, because of 'talk', the industry managed to enter into an agreement with the government's Working for Water Programme. The agreement managed to clear the dissonance and to bring the government and the industry to work together in removing the invasive species from the colonised areas. In return, the Working for Water Programme agreed to publicise the effort of the industry in a way that portrays a positive image concerning environmental conservation (Mondlane, Van Wilgen, & Shuttleworth, 2011). Innovation scholars, such as Storper (2006), emphasise the importance of 'talk' in resolving differences in the process of production.

Second, the cooperation between DEA and the Department of Education created a market for the school desk project. SI scholars, such as Chaminade and Edquist (2010), emphasised the importance of the government in providing the initial market for start-ups for their innovative products, if they are to be sustainable. Thirdly, the cooperation between DEA and SANParks (an entity of DEA) allowed SANParks to implement and manage the project. This was important in making links with machine-producing companies to which tenders were awarded to provide machines needed for processes from harvesting to the manufacture of desks. Fourth, the collaboration between DEA and the National Treasury enabled the project to secure the initial seed funding that was needed to start producing at the Heidelberg factory. The Heidelberg factory has also benefitted from the provision of the infrastructure required for a factory set-up from the Lesedi local municipality in Mpumalanga.

Fifth, collaboration between the industry and machine tool firms facilitated the training of the workers at harvesting and manufacturing points on how to operate the machines. Innovation scholars, such as Maskell and Malmberg (2002), noted that production knowledge, much of which is tacit knowledge, is transferred through observation, comparing and monitoring the activities of others. In the eco-furniture school desk project (Appendix 1, Box 6), it was noted that the know-how type of knowledge required by SMEs was transferred comprehensively through demonstrations in interactions between the producers of machines and end-users. The transfer of know-how requires interactions between the end-users and the extension officers in the assimilation and application of know-how in harvesting, delimbing, wet-milling, and drying and the operations of machines in cabinet making. In the eco-furniture school desk project, the machine manufacturing companies, such as Enviro Chainsaws, Nukor and Wood-Mizer, were able to provide the extension services required in facilitating the acquisition of the skills needed by the personnel at the Heidelberg eco-furniture factory to operate the machines. The importance of this was stressed by Mr B25, a machine operator at the Heidelberg factory, when he noted that,

> We get people to come and train the workers here because we have the machines. People from Nukor actually come and do the training here on the actual machines so that they can see that the people can actually use the machines, instead of training them at Nukor and then coming here and fail to use the machines. Sometimes they go outside and train, the trainee looks and checks if they can do it and then could issue certificates once they see that the people can now do the actual job.

All of this was facilitated by government intervention.

Velazco (2001) and Kiani (2008) demonstrated the importance of the participation of both the private and public sectors in R&D. In all this, the government plays important roles in capacity development, infrastructure development, coordination, and regulation, among others. Likewise, the Heidelberg Eco-furniture school desk project (Appendix 1, Box 6) demonstrates the role of the government in facilitating interactions and collaboration between the producers and users of knowledge and technologies. It is mainly through this that the problem of the receiver receiving less and incomplete knowledge from the possessor of such knowledge could be lessened, as noted by Nelson and Winter (1977, cited in Joseph 2009).

Nonetheless, the challenge in the South African forestry value chain, especially in the upstream tree-growing activities, has been the shortage of knowledge-transfer officers. Mr JB, the Research Manager at DAFF's Forestry Scientific Services (Pretoria), which interfaces the users of information and the generators of information in the sector, noted that they have been operating under pressure due to the shortage of extension-service personnel, emanating from limited funding by the government. In relation to this, Mr JB reflected,

> Our team has only 4 people, and of the 4 people, there is only one person that focuses on planted forest resources. One person is dedicated to the planted forest resource which includes plantation forestry, urban forestry, and agroforestry. More of his time is now going into urban forestry. When it comes to commercial forestry, our involvement is very thin because of capacity constraints. We have only four people servicing from Cape Town to Messina to satisfy a population of 56 million. The biggest challenge we have as an industry is to have the research and innovation that is developed, communicated to the end user.[324]

The shortage of extension officers, especially in state departments, focused on rural development, has prevailed since the 1990s. The Department of Lands and Agriculture has been rendered ineffective in achieving the targets of the land reform because of the shortage of staff and the lack of a budget for the programme (DLA 1997:21). One of the long-term targets in this instance is the fostering of production on land acquired by the beneficiaries of land reform (Hall, 1998). This is a requirement that could be augmented by extension officers to facilitate knowledge transfer and understanding the culture of growing trees. The shortage of forestry extension officers and the discrimination (as forestry stakeholders argue) against the forestry subsector in DAFF worsens the unequal distribution of extension officers between the agriculture and forestry subsectors. As noted by Mr B15,

[324] Mr B9. Manager- DAFF, Forestry Scientific Services, interviewed by Mushangai, Pretoria, 25/10/2017

> There are 900 people employed as agriculture extensions by the government, and only 8 employed by the government in this province (KZN) as forestry extensions. The 8 people are meant to be servicing 17 000 small-scale timber growers. How is that going to happen? Even if the knowledge is there, the people to transfer this knowledge are not there, the bridges are broken.[325]

The shortage of extension officers as a challenge in growing small businesses was further emphasised by Dr B4, the Research Director of FSA, when he noted that

> A lot of small growers do not have the communication networks like big farmers. How do we get the information to small businesses to make sure they understand and implement it? This is a challenge because the government has no formal extension services within forestry. The lack of forestry extension services is our biggest challenge in communicating and implementing research and having it rolled out instead of just being at the universities. The best way we can improve our efficiencies in research is by focusing on communicating our information and having it implemented instead of doing research and not using it.[326]

Consequently, the lack of technological transfers and of the application of research and innovation by the small-scale growers can be partially attributed to interactional challenges emanating from the shortage of extension officers in providing interfaces between the producers of knowledge and technologies and the end-users. Without extension officers, the interface between research organisations and small businesses is lost and with it the transfer of knowledge and technologies from these organisations to SMEs within the forestry SSI. Edquist (2006) noted that successful innovation systems are made up of ‘’complex relations characterised by reciprocity and feedback mechanisms’’ (p. 193). The lack of reciprocity and feedback mechanisms points to the dis-integrated nature of the South African SI as noted by the OECD (2007). Rajalahti, Janssen, and Pehu (2008) observed that successful cases of innovation have not been about creating new inventions but about adapting and using existing ones. In South Africa, as illustrated above, the public services that dominate extension services are beset by limited funding, weak linkages, and limited farmer participation (Ngomane, 2003). This

[325] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[326] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

challenge is worsened by the lack of social capital by SME owners, as indicated by Dr B4 when he said, ‘small growers do not have the communication networks like big farmers or the corporates’.[327]

6.7 Social capital and the transfer of knowledge

Social networks and solidarity groups are important in protecting small business owners from the vagaries of unpredictable business environments (Mushangai, 2015). Putnam (1995) has taken social capital to refer to the connections among individuals, the social networks, and norms of reciprocity and trustworthiness (cited in Mushangai, 2015). As a set of connections, social capital provides for individuals within social groups with the norms and sanctions allowing individuals to cooperate and assist each other for the benefit of all within the social network (Mushangai, 2015). As such, social capital forms the basis for trust and the exchange of business ideas and technologies. Trust is crucial in reducing uncertainties in the business environment. It is gained mainly through sustained interactions over time (Schrempf, Kaplan, & Schroeder, 2013). It enhances group solidarity, encouraging the easy flow of information among the members of a social group or a social network. According to Soete (2010 cited in Schrempf, Kaplan, & Schroeder, 2013), trust has a positive influence on the rate of innovation because it reduces the risks accompanying innovation, especially connected to financing innovation. The small businesses in the South African forestry sector lack linkages with skills development organisations, and financial organisations and are rarely included in the networks of big firms.[328] The SMEs in the South African forestry sector lack various forms of support, ranging from development finance; managerial skills, and enterprise development to agricultural technical skills, to be sustainable (AgriSETA, 2016). These challenges could be addressed by encouraging the SMEs to innovate and by promopting innovation with a focus on agricultural tools, methods and practices through exposure to activities of the established firms in the sector (AgriSETA, 2016). This is an enterprise requiring linkages to be established between the SMEs and firms and with skills and financial organisations. Linkages would facilitate skills, knowledge and technology spillovers from the big firms and skills organisations to SMEs. Further, linkages with

[327] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

[328] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

development finance organisations within the South African SI would lessen the burden of financing innovation by SMEs.

The problem of knowledge, technology transfer, and innovation by small businesses in the forestry sector is worsened by the lack of extensive networks, making it difficult for them to learn the best practices from other businesses in their clusters. The limited interaction between SMEs and big businesses was demonstrated by Mr B15 when he noted that, ‘If I was to put it on a scale of 1 to 20, I would say the level of interaction is at 3’.[329] With regard to links between SMEs and research institutes, Prof B46, a genomics professor at the University of Pretoria, elaborated that,

> We do not have much contact with the small growers. There is not much we could say to the small growers, because we are working at technology and development that they are not accessing right now.[330]

This lack of linkages differentiates South Africa from European cases where governments have established links between universities and small businesses. Nonetheless, the big firms in the sector have links with universities and their own scientists are always interacting with those from research organisations. It follows that the big firms have fewer challenges in accessing, decoding, and implementing new knowledge and technologies from research organisations. Facilitating linkages between small businesses and big businesses in the forestry sector would accentuate the accumulation of positive spillovers to small businesses.

Moreover, SMEs are disorganised and this makes it difficult for them to speak collectively and competently with a single voice in lobbying the government to fund their activities. The SMEs represent, ‘’unorganised communities … not able to express a realistic demand’’ (DLA, 1997, p. 23). Industrial organisations in the sector, such as the FSA and Sawmilling South Africa, mainly speak for the industry as a whole and do not address the specific needs of SMEs (Pons-Vignon, 2014). The big firms who fund these organisations prioritise their own needs to the detriment of the SMEs. There is therefore a need for special industrial bodies in the sector to augment the voice of SMEs, if their needs are to be prioritised.

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[329] Ibid

[330] Prof B46. Genomics Programme- FABI, UP, interviewed by Mushangai, UP, 19/09/2017

The lack of financial support and of linkages with other organisations have been concerns for the industry, especially with the threat posed by land reform, which is bound to reduce the land possessed by the big firms. As such, the concerns of the big firms have also shifted to the ability of the small businesses to meet their timber requirements should they lose their land because of land claims. The number of small growers emerging as a result of the land reform processes has already ballooned to 24 190, owning up 3,5% (45 000 ha) of the land owned by FSA (XIV World Forestry Congress, Financial Mail, 10 September, 2015, p. 9). Considering that agribusinesses are driven by scale, Mr Lippert the CEO of Merensky Holdings has this to say,

> The lumber industry is definitely a long-term business; we wait up to 25 years to harvest a tree. For communities, it is difficult to get into the industry at that level. Can you imagine a community that can plant and waits 22 to 25 years and take the risk? For this reason, shareholding has been provided free of charge to have them enter into this long-term industry and benefit from the value chain (XIV World Forestry Congress, Financial Mail, 10 September, 2015, p. 9).

This is a true reflection of the realities of the plantation forestry economy. The big firms threatened by the consequences of the land reform have devised partnership schemes with communities to preserve their resource base. Through partnerships, skills are transferred to communities in the forestry value chain. Through partnerships, the big firms like Mondi and SAPPI have been transferring skills through their out-grower schemes. Accordingly, Mr B15, the Small Business Manager at FSA noted that,

> Schemes by private sectors, such as the Mondi Khulanathi Scheme, the Sappi Project Grow Scheme, and NCT are very good in transferring technical forestry skills – how do you plant a tree, how do you weed, how do you do fire breaks. Most of the small-scale timber growers came into existence because of these schemes.[331]

Mr B15went on to note that there has not been a project along these lines that has been supported by the government. Although this might be true in relation to small growers, the sentiment does not hold when we consider the forestry value chain as a whole. For example, the eco-furniture school desk project (Appendix 1, Box 6) is an initiative of the Department of Environmental

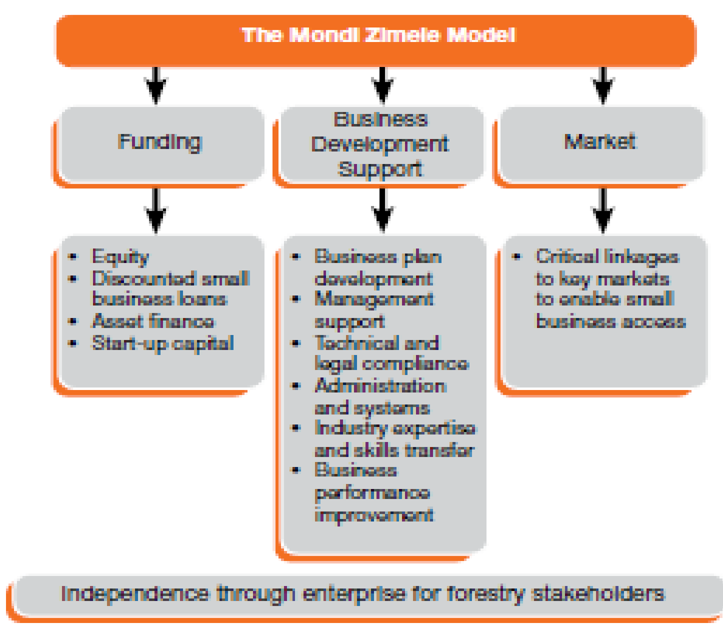
[331] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

Affairs. The virtuosity of linkages in the transfer of knowledge and technologies is clearly demonstrated by the Mondi Zimele case study below.

6.7.1 Value chain opportunities and SMEs development: Monde Zimele case study

The Mondi Zimele scheme was established in 2007 as a subsidiary of Mondi Limited, with four main objectives which are as follows: to promote sustainable economic empowerment in Mondi's forestry value chain; to encourage job creation and local economic development in forestry communities; to facilitate the availability of sustainable timber by private growers including the support and development of new emerging community forestry businesses; and to nurture and support forestry-aligned small businesses to increase the economic and job-creation potential of Mondi's land holdings (Mondi Zimele Brochure, undated, www.mondizimele.co.za). In a bid to achieve the set objectives, the Mondi Zimele scheme offers a number of services enabling small business development, as shown i*n Figure 1*.

Figure 1



Source: Mondi Zimele Brochure, undated: www.mondizimele.co.za

The scheme has funding that is focused on three main areas, which are supply chain business development; forestry partners' programme; and community small business hubs (Mondi Zimele

Brochure, undated). With supply chain business development, Mondi Zimele established a supply chain fund for businesses operating within Mondi's value chain. The scheme provides funding to the maximum of R5 million per deal to achieve the development of SMEs along its supply chain (Mondi Zimele Brochure, undated). The fund is available as equity, loan, or asset finance. The emphasis is on the achievement of BBBEE and the sustainability of small businesses through direct business support (Mondi Zimele Brochure, undated). The Forestry Partners Programme targets emerging land owners and community forestry enterprises in developing sustainable forestry businesses. The programme leverages the forestry technical know-how and infrastructure of Mondi in supporting emerging small businesses. [332] The Community Small Business Hubs fund small businesses both in and outside Mondi's value chain but within Mondi's areas of operations (Mondi Zimele Brochure, undated). The focus is on the empowerment of the youth and women through facilitating small business development through the provision of loans (Mondi Zimele Brochure, undated). In the main, these activities are part of Mondi's corporate social responsibility but meant to build relationships of trust with communities to avert the negative consequences of land claims on timber supplies. According to Trevor Abrahams, the Secretary-General of 14th World Forestry Congress, projects such as these tackle the most challenging aspects of rural development in forestry through human capital development and the capitalisation of small projects, allowing small forestry businesses to confront challenges with regard to access to improved germplasm, harvesting equipment, and techniques in dealing with the threat of fires (XIV World Forestry Congress, Financial Mail, 10 September, 2015, p. 9).

An example of a project undertaken under the Mondi Zimele scheme was the transfer of 5500 hectares that was under claim in the Kranskop district of KwaZulu-Natal to the Isigedlane Community Trust in 2011 (Mondi Zimele Brochure, undated). The deed facilitated Mondi and the community trust to sign a leaseback agreement of 20 years. The lease agreement requires Mondi to transfer skills, enabling the community to perform forestry operations (Mondi Zimele Brochure, undated). This is critical in preparing the community to take over forestry operations from Mondi at the end of the lease agreement. Should this development happen, it will lead to ownership that is 'small and community-based' with corporates becoming the buyers of timber

[332] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

(XIV World Forestry Congress, Financial Mail, 10 September, 2015, p.9). In operationalising the agreement, Mondi and the community established a silviculture contracting business, Sibuyile Investments (Pty) Ltd, to facilitate business planning, management support, legal compliance, administration systems, and technical and financial management skills transfer (National Skills Authority, NSDS 111 Review, 2018). As noted in the case discussed above, these are some of the skills found to be lacking among the SME owners, hence curtailing the growth and development of their businesses.[333] The fact that Sibuyile Investments now (2018) employs 190 people and manages all aspects of the silviculture business, including land preparation, planting, maintenance, fire prevention and management of open areas for conservation, testifies to the success of the model. It can therefore be discerned that the transfer of skills and technologies to small forestry enterprises can be accomplished by developing their social capital through linkages with big firms, as noted by the AgriSETA (2016). The Mondi Zimele-Sibuyile Investments (Pty) Ltd demonstrate the existence of innovative partnerships crucial in the transfer of knowledge and technologies from the big firms to small-scale businesses.

Five major things determined the success of the Mondi Zimele scheme. First, the scheme is demand-led. Second, Mondi Zimele promotes partnership between the government and big business in coordinating and supporting SMEs on a large scale. For example, the Development Bank of South Africa contributed a R70 million grant, which together with Mondi's own contribution enabled the establishment of a R140 million Mondi Zimele (Pvt) Ltd Jobs Fund (Whyte 2018). Thirdly, the scheme provides support and mentorship over a medium to long-term basis. This allows the weaknesses in the design of the scheme emerging over time to be identified and addressed. Fourthly, and in contrast to other schemes, the Mondi Zimele scheme provides a set of support measures which has an advantage of overcoming standalone interventions, such as financing and training. This is important considering the SBP's (2009) sentiment that, government policies are failing because they are not provided as a compact set but in an isolated manner. Fifth, the scheme provides access to markets for small businesses. The availability of a market for the products of SMEs is crucial for it is one of the issues considered by development finance institutions (DFI) such as the IDC, Nedbank, and the DTI, in assessing applications for capitalisation by small businesses. Ms B41 (from DEA) noted that, without a

[333] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

market, the sustainability of SMEs is impossible to achieve.[334] The multi-pronged nature of the Mondi Zimele scheme explains its success as a model that should be emulated by other support schemes within the South African environment.

Similarly, cooperatives in the forestry sector have demonstrated their critical role in the transfer and application of skills among the small businesses in the sector. Cooperatives such as the NCT and TWK have well-established extension services to assist their new members with accessing funding and technologies.[335] [336]

The growing importance of the partnerships between the big and small business owners in the forestry sector should be looked at within the context of changing institutions with a focus on black economic empowerment (BEE). The most important components of broad-based black economic empowerment (BBBEE) touch on direct empowerment (centred on management and ownership), human resource development (skills development and employment equity) and indirect support (enterprise support, preferential procurement, and residual support) (Mushangai, 2015). Preferential procurement promotes BBBEE through the allocation of preferential scores to enterprises with higher BBBEE contributions. This is deemed an effective way to create market access for small businesses in an environment characterised by extreme monopolies. Code 500 of the BBBEE codes outlines principles to be observed in the determination and measurement of the level of affirmative procurement (Mushangai, 2015). Under Code 500, BBBEE entrepreneurs are supported through assistance in the creation and enhancement of operational and financial skills (Mushangai, 2015). Code 600 outlines the principles applied when determining the level of enterprise development (Mushangai, 2015). The BBBEE residual elements recognise other factors that may also boost black entrepreneurship and this is dealt with under Code 700 (Mushangai, 2015). The pronounced BBBEE interventions have the small, micro, and medium enterprises owned by the black people as their beneficiaries. In line with boosting their BEE scores, established firms in the forestry sector have been compelled to enter into partnerships with SMEs.

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[334] Ms B41. Deputy Director: Strategic Support in the Office of the Chief Director of NRM, interviewed by Mushangai, DEA, Cape Town, 09/06/2017

[335] Mr B24. Manager, Research and Development, TWK Agri (Pty) Ltd, telephonically interviewed by Mushangai, 13/11/2017

[336] Mr B13. Forestry Technology Manager- NCT Forests, telephonically interviewed by Mushangai, Johannesburg, 26/06/2018

BEE was conceptualised at a national scale and through sectoral institutions, such as the Forest Sector Charter, it was customised to accommodate the specific characteristics of the forestry sector, as a sector largely focused on rural development. As such, it can be noted that institutions within an SSI may have the effect of incentivising innovative schemes for the transfer of skills from established firms to small businesses, in this case the emerging small-scale growers. Mr B24, the Technology Manager of TWK Cooperative, noted that, though it is difficult to work with new small-scale enterprises, they have tried to meet their BBBEE commitments with regard to machinery, logistics, and markets. According to Mr B24, the challenge of working with small growers is that,

> We can have the best technology on the table, but if the person on the other side of the table cannot afford it then it is difficult to sustain the sector as a whole. When talking about small growers, there is no use for research in high technology. We are busy with a lot of interventions where we are doing small and low-level technology. We go through steps to implement it and that is costing a lot of manpower and a lot of input. The hope was that the government would do it, but it is not. Now we are doing it as a company because we have got a BEE scorecard to fill in. We work with SMEs because it makes business sense. Today it is an investment; tomorrow we hope it will return the profits to us.[337].

The words ‘We go through steps to implement it’ indicate the importance of mentoring and demonstrations in knowledge and skills transfer, especially when working with small businesses.

Further, Mr B13, the Technology Manager at the NCT Cooperative, noted that though it is very expensive to provide extension services, they provide services to assist their new members with pest management, research, mechanisation, and improving efficiencies in logistics. Mr B13 stressed that,

[337] Mr B24. Manager, Research and Development, TWK Agri (Pty) Ltd, telephonically interviewed by Mushangai, 13/11/2017

> It is of no use to say you will double your production if you use a chainsaw when one has a bow-saw, but worse still to say I am not going to do business with you because you do not have a chainsaw. Instead, you say, let us see the method we can get you to a level where you can have a chainsaw. Thus, in some of the communal areas, we help small businesses with financing on getting things like a chainsaw. We organise contractors to transport their timber because they cannot afford tractors and trailers and that gets deducted from the price. We have a very high labour input into that, but we are training the guys to be businessmen on their own.[338]

Moreover, the importance of cooperatives is also realised in securing markets for emerging small businesses. As noted by Mr B24, TWK makes sure that everything that comes out of the small growers' plantation is marketed.[339] He emphasised that even the small branches and twigs of timber are chipped and exported, usually to Japan.[340] In addition, cooperatives have been helpful in assisting their members with ISO certification. As noted by Mr B13 of NCT, the ISO certification processes are very expensive and most of the small businesses under the NCT have not yet been certified.[341] Thus, Craig Norris of the NCT and Steve Germishuizen of Africa Environment Solutions initiated the Smallholder Project in 2013 to investigate the certification of small-scale plantation under the FSC system (FSC Annual Report, 2016). Despite the challenges involved, the ISO certification is important as it enables small businesses access to lucrative European markets, which shun uncertified products.

The effectiveness of Mondi, Sappi, Merensky, and cooperative schemes by NCT and TWK in small business development in the sector is demonstrated by the case of Enock Mvelasi, who became a member of the NCT small grower cooperative scheme in 1998.[342] Mvelasi was nominated as the NCT small-scale farmer of the year in 2017.[343] Mvelasi noted that the NCT scheme was critical in growing small businesses, for a number of reasons, among which was the provision of technical advice, seedlings, markets, and bonuses.[344] As a result of the success of his

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[338] Mr B13. Forestry Technology Manager- NCT Forests, telephonically interviewed by Mushangai, Johannesburg, 26/06/2018

[339] Ibid

[340] Ibid

[341] Mr B13. Forestry Technology Manager- NCT Forests, telephonically interviewed by Mushangai, Johannesburg, 26/06/2018

[342] SA Forestry magazine, August 2017, p.8

[343] Ibid

[344] Ibid

business, Mvelasi now employs 35 people in harvesting operations and 8 in planting operations.[345] In the words of Mvelasi, 'NCT helped much in uplifting my family standard of living'. Just like the Mondi Zimele scheme, the effectiveness of the NCT small business scheme is anchored on the ability to provide a set of support measures ranging from bonuses, technical advice, seedlings, and competitive mill-delivered price, as opposed to standalone interventions, such as financing and training.

The partnership schemes are important but the entrepreneurship spirit is paramount if those supported are to succeed as entrepreneurs.[346] It is important to note that, even before joining the NCT cooperative, Mvelasi was a determined entrepreneur, who started by purchasing a tractor and a trailer to haul community sugar cane to a local mill in KwaZulu-Natal.[347] He also purchased timber plantations and land from a local chief to increase his plantation hectarage.[348] This indicates what Ms B41 noted when she said that some of the conditions of success for small businesses include the owners of the businesses 'being very driven and good at what they do'.[349] The entrepreneurship spirit and the desire to succeed are therefore some of the characteristics of successful business owners.

Despite the positive effects of cooperatives on improving the production activities of small businesses, Dr B3 emphasised that this should not be taken as an excuse by the government to abdicate its responsibility in supporting small-scale businesses, as was done in the forestry sector by the colonial and apartheid regimes.[350] Further, it is also critical to note that, though partnerships are crucial in the development of small businesses, innovation by small businesses may still be hampered by asymmetric power relations in partnerships in value chains.

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[345] Ibid

[346] Ibid

[347] Ibid

[348] Ibid

[349] Ms B41. Deputy Director: Strategic Support in the Office of the Chief Director of NRM, interviewed by Mushangai, DEA, Cape Town, 09/06/2017

[350] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

6.8 Power dynamics in the value chain and the lack of trust between big and small firms

6.8.1 Contracts

In South Africa, the processes of deregulating and liberalising the economy, which started in the 1980s, were completed in ten years and left the major firms in the forestry sector with two main functions: the nursing of trees and the ownership of plantations (Pons-Vignon, 2014). All of the other functions, such as silviculture, felling, and transport, were taken up in most cases by the former managers of the big firms, who were encouraged to set up their own firms (DOL, 2015). Therefore, starting from the late 1980s, outsourcing was considered an efficient way of organising production in the forestry sector of South Africa. Mr B12, the Research Manager at Mondi Forests, explained that the growth of outsourcing emanating from liberalisation and deregulation were hinged on,

> Competitive reasons to get better management of the costs and the difficulty with labour legislation as firms did not want to deal with that complexity anymore. It is much better to have other people dealing with it than trying to solve it yourself.[351]

Outsourcing and contracting were embarked on as new ways of organising production by big firms to enhance efficiency by removing activities that increased overheads. The big firms in the sector resorted to outsourcing their most dangerous productivity activities, especially in harvesting (Pons-Vignon, 2014). On the contrary, Mr B12 from Mondi Forests denies that outsourcing was selective and targeted those activities that reduced profits for big firms.[352] With regard to this Mr B12 explained,

> We are fully contracted. We have no employees participating in forestry activities, we only have management. It’s not that we are picking something and saying these are the most dangerous, let us outsource, that’s, no, no, no. All of it is outsourced, so we have an outsource model. We only have 270 odd employees in our forests, whereas there may be 4000 people working in the forests.[353]

[351] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[352] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[353] Ibid

What cannot be denied is that outsourcing left the major companies with specialised activities demanding a high level of specialised knowledge, such as breeding, pulp and paper production, and emerging biotechnology applications in product development.

The emergence of the contracting systems has been seen as a creative way of stimulating the development of small black businesses within the sector, but some of the ways in which the systems are designed, hamper the development of small contractual enterprises (Pons-Vignon, 2014). Generally, some of the contractual agreements in the sector, whether be they government or private sector schemes, are very exploitative. In some cases, the contractor receives his or her payment well after the agreed date. As noted by Ms B38, a dry mill contractor in Mpumalanga, 'The thing is sometimes we do not get paid earlier'.[354] Late payments hinder the timeous execution of plans. In such a case, the contractor has to persist with work despite delayed payment, for fear of losing the contract. This is the case with Ms B37, a wet mill contractor in Mpumalanga, who explained in relation to payment that,

> It is never on time. It is one of those challenges that we have as contractors. Sometimes you get to a point where you say I cannot take it anymore, but at the end of the day, you do not want to lose your job.[355]

This is what Pons-Vignon (2014) implied when he said that the negotiation of these contracts is heavily tilted in favour of big businesses. The existence of a large number of small players waiting for contracts leaves contractors with no option but to accept the dictates of the big businesses when negotiating contracts (Pons-Vignon, 2014). Unequal power relations ensure that the well-established businesses have leverage in the negotiation of contracts with the small-scale players. These contracts impact negatively on the potential of small players in terms of upgrading with regard to the employment of machines and a skilled labour force.

The exploitation of small businesses by the big firms in the sector closes the accumulation space for the small players making it difficult to save and accumulate to buy the appropriate machinery to upgrade their businesses. Thus, upgrading may be partly a function of the type of relationships the small businesses have with the big established businesses in the value chain. This is a

[354] Ms B38, Small Drymill Business Contractor, interviewed by Mushangai, Mpumalanga, 30/06/2017

[355] Ms B37, Small Wet Mill Contractor, interviewed by Mushangai, 30/06/2017

problem mostly in areas in which big businesses are concentrated. Mr B26, the Director of Sawmilling South Africa, observed that big firms, such as Mondi and SAPPI, control the timber-growing subsector of the value chain and that there is no room for accumulation by small businesses.[356] Nevertheless, Mr B26 conceded that the sawmilling subsector is less concentrated and there is room for accumulation by small businesses since it has a smaller number of big firms.[357] However, worth considering is what the Research and Development Manager of Mondi Forests, Mr B12, noted when he said, 'firms are for profit'.[358] This calls for the need for monitoring mechanisms to ensure fairness in the relations between the big and small firms in the forestry value chain of South Africa.

The problem of the concentration and power relations in the forestry sector is a challenge that can be addressed by institutions ensuring that contractual agreements between the big and small businesses are adhered to. In most cases, the exploitation of small businesses occurs where partnerships are dominated by big private firms. To some extent this is different when the big firms concerned are state-owned. For example, Ms B32, the Transformation Manager at SAFCOL, noted that, as per government regulation, the contractors are supposed to be paid within 30 days but at SAFCOL they pay them within 15 days. These differences are important in understanding the dynamics in the sector, as determined by ownership. The differences also serve to indicate that the South African forestry sector is still less integrated, and less coordinated when compared to other countries, such as Canada, China, and Sweden.

6.8.2 Leases

The land restitution programme has seen tracts of land being transferred from plantation firms to claimant communities. However, because the land is bought from the companies by the government on behalf of communities but with trees on the land still owned by the same companies, the communities are forced into leaseback permits with these companies. These partnerships can therefore be described as forced partnerships and may take a variety of forms. As a result of the limited competence of their voice (small businesses) in negotiations, most of

[356] Mr B26. Director- Sawmilling South Africa, telephonically interviewed by Mushangai, Johannesburg, 07/04/2018

[357] Ibid

[358] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

these arrangements do favour the big firms. In the case of community-owned plantations, the companies cannot work with all members of the community, but with a select few.

In these partnerships, the communities are assisted to open community companies whose representatives interact directly with the plantation firms.[359] The processes usually result in elite capture, to the detriment of the communities involved. In other arrangements, beneficiaries of land reform are persuaded into some 'out-grower schemes' by plantation firms, such as Mondi and SAPPI, whereby inputs in terms of chemicals and improved germplasm are provided to community growers in return for monopoly over their produce.[360] It is important to note these arrangements are perceived differently by the different partners involved. According to Mr B12, the Research and Development Manager at Mondi Forests,

> A number of the land-owners are quite happy to lease their land for specific purposes, and maybe over time acquire the skills to farm it properly. There is a lot of effort trying to mitigate any negative impact there.[361]

From the position of big businesses, the communities are happy with the out-grower schemes. However, it is necessary to point out that these schemes compel the small growers to sell their harvests to those firms that would have assisted them with inputs. This deprives the small growers of the opportunity to maximise their gains by choosing the most lucrative markets. As noted by the Research and Strategy Manager of Merensky, Dr B3,

> As a small grower you do not necessarily want to sell your timber to a saw-mill or to a pulp and paper mill, you want to sell it where you can get the best price. So, you want to service a saw-mill, a pulp and paper mill, and possibly also for poles, and many of those industries within the sector.[362]

The lack of other options to maximise returns on commodities as a result of unfair partnership arrangements have meant conflicts, especially in cases in which the small firms choose to disregard the initial contractual arrangements with regard to accessing markets. As explained by Prof B47 from the University of Pretoria,

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[359] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[360] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[361] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[362] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

> The small guys do not have breeding programmes supporting them. The industry has issues with small growers. They say let us have an agreement and we will provide you with our clones, and expertise to grow and maintain them but after 7 years or 10 years you must sell that timber back to us. Sometimes, you cannot blame people, they look for who can give them the best price, and so, the company involved ends up losing their investment. Things like that create some problems in the sector.[363]

The big firms regard supporting small firms as an investment, but then, when it comes to marketing, the small firms regard selling their products only to a specified firm as exploitation. Despite these schisms and dialectics, Mr B15 the Small Business Manager at Forestry South Africa, affirmed the indispensability of the role of big firms in the development of small businesses.[364]

Nonetheless, those who claim the indispensability of big businesses in the development of small businesses in the forestry value chain are usually blind to the benefits shared between the partners, which in most cases favour the big firms. Prof B43, the Research Chair of SAFCOL at the University of Pretoria (UP), has been working with the government in designing schemes to ensure that, in partnerships between the beneficiaries of land reform and private firms, the benefits accrue to both parties.[365] According to Prof B43, the current schemes in place, though beneficial and allowing some of the SMEs to upgrade, ensure that most of the benefits accrue to the big firm. Prof B43 explained,

[363] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[364] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[365] Prof B43. Socio-ecology, Agroforestry, Soils, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

> There has to be in community science what we call passing on the stick. That is to say when do you actually empower the communities to have the freedom to decide where to sell their timber? But as long as the big firms with the model they have are helping, it is always at the expense of the small growers. The models we are working on now are showing that if a big firm says they will work with you on land under claim, it will say, 'OK we pay to rent your land so that you can grow these trees for this one rotation. We will be paying rent because we are on your land but the trees belong to us. But make sure that the trees are well'. Those rents are reinvested into maintaining the plantations and the communities are left with nothing. It is like any other country, for example where they grow tobacco with the tenant, the big firms always win. These are some of the things that one has to look at. Partnerships are there, they are working but more for the benefit of the big firms in the industry, and not small firms.[366]

Most of the partnerships in South Africa's agriculture and forestry SSI are riddled with unfair practices to the detriment of the communities involved. The unequal partnerships and the injustices accompanying them in relation to the ownership of the means of production and the sharing of benefits are exemplified by the case of H farm in Mpumalanga.[367] Though the farm was considered by the Department of Land Reform and Rural Development (at the time of visiting, 2015) as a success model,[368] the arrangement at the farm proves otherwise. The farm was acquired under the Land Reform for Agricultural Development programme (LRAD) and was leased back to former workers.[369] The current joint management can be said to be functional, but the power relations at the farm are defined along racial lines. The black director seems to be less powerful, with all decisions made by the white director. Since the company was acquired in 2003, no dividends have been shared, on the pretext that the farm is not generating profit.[370] This

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[366] Prof B43. Socio-ecology, Agroforestry, Soils**,** UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[367] Mr B22. DLDR Provincial Director, Discussion with the Sociology of land Reform team from Wits University, Mpumalanga, o6/11/2016

[368] Ibid

[369] Ibid

[370] Mr B16. Trustee-Worker, H Farm, interviewed by Mushangai, 06/11/2015

is despite the fact that the farm has expanded into Lesotho and Swaziland and plans are afoot to establish a branch in Mozambique.[371]

Further, an examination shows that, there is not much skills transfer at H farm, for the black workers are involved in manual and technical skills without any business skills being passed on to them. The other contentious issue with regard to this partnership concerns continuity in terms of ownership. When the farm was acquired, the workers were retained as trustee workers entitled to profit sharing.[372] However, according to the white Director at H Farm, Mr B28, upon death, a member is naturally eliminated from the trustee and his or her relative receives R100 000 as insurance and 'that's it'.[373] The fact that a family member cannot inherit a member's position in the company leaves a lot to be desired and the government has to intervene to ensure long-term benefits for the beneficiaries. Moreover, the workers complained that some of them were being dismissed for trivial reasons without compensation, which amounts to the elimination of trustee membership[374]. Although, the land-reform programme is important, the ''emphasis on strategic partnerships with large-scale commercial sector means that the lion's share of the benefits is captured by others'' (Davis & Lahiff, 2010). This sentiment was also voiced by Mr B14, the Director of the now-defunct Rural Action Committee, an NGO that worked in Mpumalanga, who noted that the differences in race, wealth, and business know-how meant that the benefits are always in favour of private firms rather than the communities.[375] The asymmetric nature of the partnerships calls for regulatory institutions to ensure that benefits accrue to both parties involved.

Section 25 of the South African constitution (1996) is very clear on land restitution for victims of past discriminatory laws and practices, including the return of land or redistribution where possible and practicable to enable people to gain access to land on an equitable basis and to ensure secure tenure rights for the occupiers. The realisation of these goals will remain elusive if this trend of dispossession by means of strategic partnerships is to continue. These partnership approaches have been promoted by the government to ensure skills transfers and capacity

[371] Ibid

[372] Mr B28. Director- H Farm, interviewed by Mushangai, Mpumalanga, 06/11/2015

[373] Ibid

[374] Mr B11. Worker-trustee, H Farm, interviewed by Mushangai, Mpumalanga, 06/11/2015

[375] Mr B14, The Director of *Rural Action Committee (now defunct), interviewed by Mushangai*, Mpumalanga, 06/11/2015

building, but some of them are proving to be unfavourable to the beneficiaries of land reform. Since sustainable development is about improving people's livelihoods, some of the current partnerships between small businesses and big firms are not geared to achieve this. Nonetheless, the Mondi-Zimele Scheme and the schemes by NCT and TWK, as noted above, have proved to be good models and important in redefining strategic partnerships if the benefits of the land reform programme are to accrue to beneficiary communities in the forestry sector. The NCT, Mvelasi case highlighted in preceding sections testifies to the benefits of some of these partnership schemes.

6.9 Lack of alignment in government departments

The challenges by small-scale forestry businesses are worsened by the misalignment between government departments, a misalignment that has resulted in the failure of government departments to extend their support. For objective and meaningful change that will transform power relations in the forestry sector, there is a need for alignment between government departments in policy execution. There is a lack of alignment between government departments in forestry development, mainly manifesting itself in the disjuncture in skills production and transfer, the lack of the provision of post-settlement support to beneficiaries of land reform, and in the existence of contradicting policies. In the field of skills development, Fort Cox and other agricultural colleges have been at the forefront in developing middle-level technical skills among small-scale forestry businesses in South Africa. Nonetheless, the colleges have been affected by the schism between the DAFF and DHET over their control in the period 2002 and 2011. As elaborated by Mr B27, the Head of the Department of Forestry Studies at Fort Cox,

> There is a problem because the Department of Agriculture, Forestry, and Fisheries (DAFF) is claiming these colleges to be under them whereas the Department Higher Education was indicating that the mandate for education falls under their jurisdiction. DAFF says these are agricultural colleges, whatever they are training is subordinated specifically to needs of DAFF, so they do not want to give these colleges away.[376]

This schism resulted in the agricultural colleges being neglected between 2002 and 2011. As a result of the conflict over their control, the agricultural colleges have been poorly funded and

[376] Mr B27. Head of Forestry Department- Fort Cox, interviewed by Mushangai, Fort Cox, Eastern Cape, 06/11/2017

unable to apply for NRF research funding because they are not registered under Higher Education.[377] This affected the scope of their operations as to what they could or could not do, thereby limiting outcomes in terms of skilled manpower development. This problem was also highlighted by the AgriSETA SSP (2016), which noted that agricultural colleges were not financially catered for between 2002 and 2011, because of the conflict between DHET and DAFF. The problem partly explains the current shortage of forestry extension officers in South Africa.

The neglect of the colleges emanating from the conflict between DAFF and DHET brought about the uncertainties affecting the tenure of the lecturers, hence their work commitment. The impact of these challenges on the development of forestry skills was highlighted by Mr B27, when he stressed that,

> When you are operating in a state where you are not sure of the department you belong to, it affects your work in trying to forge the way forward. There will always be a limitation to what you can do and how far you can go. That could be in terms of resources available, be they financial or infrastructural resources. When someone has a budget or is fully budgeted for, that person can do a lot of things because s/he is able to budget for what is required for the training.[378]

One possible result of this lack of alignment is that a government department may end up neglecting a duty that it assumes another department would perform.

In a similar fashion, the lack of understanding between DAFF and DRDLR as to who was responsible for the resettled farmers delayed the provision of post-settlement support, resulting in the failure of many land reform projects in South Africa (Hall, 2007). The lack of alignment between government departments is a common feature in the South African NSI.

Further, the disjuncture between government departments may also lead to resource wastage by preventing cross-departmental synergies in skills development, transfer, and application. As an example, the lack of interactive capabilities between government departments has resulted in some departments producing excess skills, but with other government departments experiencing

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[377] Ibid

[378] Mr B27. Head of Forestry Department- Fort Cox, interviewed by Mushangai, Fort Cox, Eastern Cape, 06/11/2017

a critical shortage of the same skills. This is the case with the Department of Correctional Services (DCS) that is producing an excess number of people with technical expertise in cabinet making but with the Department of Environmental Affairs (DEA) having a shortage of cabinet makers in its eco-furniture industries.[379] The lack of cross-departmental interactive capabilities has prevented the channelling of excess capacity in cabinet making being produced by DCS to DEA's eco-furniture industries where such skills are highly demanded. As noted by Mr B49,

> We have got so many government departments but not one of them is working together. At DCS they have got centres that are accredited to train people to qualify them. We have got people inside the prison working being trained. Some of them get qualifications but what happens the moment they go outside, where do they start? Now for DEA to get its factories to be accredited to qualify people is a lot of work. It is good for us to sit down with DCS to say we are also a government department (DEA), we can take them in and work together. We can negotiate and bring that knowledge immediately to be transferred to the other people.[380]

The lack of alignment between government departments as blocking mechanisms in the NSI has resulted in some departments producing skills that are not immediately channelled into production for the benefit of the economy as a whole. This is also the case with the SETAs. There is a need for an alignment between the SETAs and government departments in their approach to small business development. Evidence points to instances whereby SETAs have been able to facilitate skills development among small businesses but some government departments have not been able to augment this by providing the necessary financial and technological support to small businesses to start producing. As indicated by Mr B21,

[379] Mr B49. Technical Manager- DEA Eco-Furniture Industries, interviewed by Mushangai, 27/06/2017

[380] Ibid

> Some people have acquired this skill, but the support for production is lacking. As AgriSETA we do not provide support for production. The Department of Agriculture, for instance, must provide money for production, money for equipment, which is not forthcoming. I have trained 10 people, but they cannot be productive because they do not have the means of production. Where are the skills going, down the drain?[381]

This is a case of resources wastage as one of the aims of skills production is to enable people to aid in economic development. This points to the fact that skills development, knowledge generation and application is not only impacted on by the lack of resources but the misalignment of government departments.

The lack of alignment between government departments exacerbates transaction costs, which are disincentives for the small-scale players wanting to join the sector. This is exemplified by the challenges involved in obtaining planting and water permits. The locus of the information required in obtaining water and planting permits is scattered across different government departments which increases transaction costs in relation to finances and the time spend on visiting different departments, if one wants to join the sector. Mr B15 noted that the information required for such permits is scattered across different departments with,

> ...One sitting at the Department of Environmental Affairs, one sitting at the Department of Water, another sitting with KZN - Ezemelo and another sitting with KZN Amafa Heritage information. Why cannot you put all this information into one screen and when somebody applies, you just look through this screen and say the area you would like to plant trees is good.[382]

The lack of alignment between different departments and the accompanying transaction costs implies interactional challenges with regard to the ease of doing business in the forestry sector. This may have the effect of scaring away investments.[383]

While government departments may share the same policy goals and objectives related to economic inclusion, there has not been much cooperation within the forestry SSI in designing

[381] Mr B21. Implementation Manager- AgriSeta, interviewed by Mushangai, AgriSETA, Pretoria, 27/06/2017

[382] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[383] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

cooperative strategies in implementing policies at local levels across the system. The lack of such joined-up governance systems as indicated above in the struggle between DAFF and DHET over the control of agriculture colleges or the schism between DAFF and DRDLR over responsibility to the beneficiaries of the land reform, and in the failure by DCS to channel trained artisans to DEA's eco-furniture factories make it difficult to achieve the set goals of the DST strategy on inclusive

> [i]nnovation that addresses the triple challenge of inequality, poverty, and unemployment and enables all sectors of society, particularly the marginalised poor, informal sector actors and indigenous knowledge holders to participate in creating and actualising innovation opportunities as well as equitable sharing in the benefits of development (DST, 2016, p. 11).

It was partly for these reasons that the SETAs were created, to enhance alignment in the development and application of innovation in their respective sectors.

6.10 The role of the SETAs in SME skills development and the employment of R&D

In their role, the SETAs are supposed to initiate innovative projects, to provide labour market intelligence, to support the development of technical, business, and high-level R&D skills through learnerships, apprenticeships and the provision of bursaries (DHET, NSDS III, 2011).

In facilitating the development of business skills among SMEs in the forestry sector, the AgriSETA and the FPM SETA have undertaken a number of development programmes. An example of these programmes is the International Leadership Development Programme (ILDP). The ILDP attempts to address the business side of small enterprises by equipping the trainers in the forestry sector with financial and managerial skills.[384] Those trained would in turn transfer the skills to the small entrepreneurs in the sector. The ILDP is facilitated by senior faculty staff members at the Gordon Institute of Business Science (GIBS-UP) and the European School of Management and Technology in Germany.[385] This programme is pitched at National Qualification Framework (NQF) level 7/8.[386] The FPM SETA set aside a budget of R8, 1 million

[384] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[385] Ibid

[386] Ibid

for the programme for the 2016 financial year (FPM SETA, SSP, 2016). According to one of the beneficiaries, Mr B15, the Small Business Manager at FSA, the ILDP programme has capacitated them to identify the challenges of small growers and to provide them with business skills, which the big firms are incapable of transferring in their out-grower schemes.[387] Mr B15 noted that the ILDP programme is still ongoing, hence the difficulties in assessing its impact on the transfer of business skills to small businesses in the sector. This is normal when we consider Kuhlmann and Shapira's (2010) observation that successful innovation systems develop their special competitiveness and strength gradually over long periods.

The FPM SETA has also entered into various arrangements with FSA and the big firms in the sector to improve the operational capabilities of small businesses in areas such as chainsaw operations, fire prevention, and firefighting. As a result of the partnerships, the FPM SETA was able to provide R3.06 million for training interventions in 2016 and a further R2.7 million for 2017 (FSA Annual Report, 2016, p. 29). This intervention enabled the training of 165 people in firefighting, 100 in silviculture, and 50 in advanced chainsaw operations (FSA Annual Report, 2016, p. 29). The remaining balance was used for training SMEs in business courses and forestry management operations in 2017 (FSA Annual Report, 2016, p. 29).

The cooperation between the FPM SETA and the industry (FSA) has enabled the industry to provide training venues and sites for practical demonstrations in chainsaw operations, firefighting and basic farm management. Examples of these training venues and sites offered by the industry to enable the capacitation of SMEs include Inkanyezi yamaHhobe CPA plantation, Mondi's Twin-Streams Forestry Academy and SAPPI's Richmond Training Centre (FSA Annual Report, 2016, p. 29). As a result of the fire training interventions, 'for the first time in eight years, the small-scale grower subsector recorded the least damage due to fire during 2016 despite the fact that the sector as a whole had experienced a harsh fire season' (FSA Annual Report, 2016, p. 29). Nonetheless, the FSA Annual Report (2016) noted that there is still a considerable need for training with an emphasis on business venture creation among community-based forestry contractors to enable them to meet the demand for 'quality forestry operations'.

As noted in the previous sections, the effectiveness of agricultural colleges had been affected between 2002 and 2011 by the struggle between the Department of Agriculture (DOA) and

[387] Ibid

DHET over their control.[388] The schism between the two departments over the control of these colleges led to a lack of direction, guidance, and financial investments in the colleges from 2002 to 2011.[389] This left many of the colleges with reduced institutional capacity, diminishing morale, diminishing standards and deteriorating infrastructure (DAFF, 2008). However, because of 'talk', the differences were resolved and the colleges were left under the Department of Agriculture in 2010.[390] Since then, the AgriSETA has been actively involved in rebuilding the capacity of the agricultural colleges. According to Mr B21,

> We are doing what we call, 'capacity development' of the agricultural colleges. We are capacitating the lecturing staff through funding and training, funding the training of the lecturers.[391]

To remedy the deteriorating infrastructure emanating from the neglect of the colleges between 2002 and 2011, the AgriSETA allocated a sum of R6 million for the funding of 12 agricultural colleges in South Africa (AgriSETA Annual Report, 2013/14, p. 38). This fund was aimed at capacity building, curriculum or learning programme development, lecturer training and development, and infrastructure. For the financial year ending 2016, the amount was increased to R28 million to facilitate capacity development in the agriculture training organisations (formerly agricultural colleges) for three years from 2017 to 2019 (AgriSETA, SSP, 2016). This was effectuated in 2016 with the signing of a memorandum of agreement between the AgriSETA and the agricultural colleges for increased funding as a way of strengthening the role of the colleges in skills development (AgriSETA, SSP, 2016). All of this was deemed necessary to ensure the development of R&D capabilities in the sector. The continued shortage of forestry extension officers despite these efforts is a result of the fact that the funding schemes by DAFF and the AgriSETA are skewed in favour of training agricultural extension officers as opposed to forestry extension officers.[392]

Important to consider is that small businesses are different in their configuration, hence the demand customised skills to improve their efficiency. For example, cooperatives demand many

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[388] Mr B27. Head of Forestry Department- Fort Cox, interviewed by Mushangai, Fort Cox, Eastern Cape, 06/11/2017

[389] Ibid

[390] Ibid

[391] Mr B21. Implementation Manager- AgriSeta, interviewed by Mushangai, AgriSETA-Pretoria, 27/06/2017

[392] Ibid

soft skills to resolve conflicts among the various participants, if their sustainability is to be guaranteed. Mr B21, the Implementation Manager at AgriSETA, observed that,

> In their Farm Together Co-operative, there are always conflicts. The aim of 'Farm Together' is to train the existing co-operatives to farm as a collective because they are a collective. We want to enhance cohesion for them to understand that they are not individual farmers but they are farming as a collective and the vision must be a collective vision and their approach to work must be a collective work.[393]

It is therefore imperative to develop conflict resolution skills for the sustainability of small businesses, especially the cooperatives involving people of diverse backgrounds and interests. Some of the skills needed would include communication skills on how to conduct meetings in making resolutions.[394] The lack of soft skills in forestry cooperatives and the impact thereof on business development was expounded by Mr B15, regarding a case of a community plantation in KwaZulu-Natal. As explained by Mr B15,

> There are always conflicts. I can take you to a plantation where in 6-months people had over R1 million in their bank account. They have a plantation in rotation, and a portion of it matured. The plantation was planned in a way that they have work and portions to harvest and make money every day of the year. It was planned properly and in the area of 400 hectares. They could harvest 40 hectares a year and the rotations were normalised. They had people employed and a good business going. I worked with them for 6-months; they paid their workers, and re-invested some of the proceeds from the sale of timber. Everybody was happy. But there was a conflict and the business stopped. Nobody was working, and they were not making the money from selling the trees and the plantation was going out of shape just because there was a conflict, and did not know how to resolve it.[395]

In a bid to resolve some of these challenges, the FPM SETA and the FSA have been working with training providers in the sector, such as Skills Unlimited, Dibanisa Learning Solutions, NOSA Agricultural Services, and Mearnsii Training Centre, to upgrade SMEs and people's skills

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[393] Mr B21. Implementation Manager- AgriSeta, interviewed by Mushangai, AgriSETA-Pretoria, 27/06/2017.

[394] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR, UKZN 27/10/2017

[395] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

in rural areas.[396] The impact of these interventions is not yet clear. Nonetheless, the SETAs face a number of challenges in working with the private skills providers. Mr B21, the Implementation Manager at AgriSETA, noted that many of the service providers are too theoretical, whereas technical skills in operations are predominantly practical.[397] The failure by service providers to deliver practical knowledge limits the ability by SMEs to apply the technical skills required in upgrading their production functions. This is worsened by the fact that the SETAs lack the legal basis to monitor and supervise training processes by the contracted service providers (this is done by the QCTOs).

In trying to understand the R&D challenges and to forecast skills development in the forestry sector, the AgriSETA and the FPM SETA have also established a number of partnerships and research chairs at universities. This was partly in response to the demand by the NSDS III (2011) for partnerships in achieving R&D capabilities for high-level vocational education and training. This was critical for South Africa did not have research chairs in the academic field of skills development before 2011 (Kraak, 2018a). The VET post-school system as a distinctive academic field was not much supported before 2011, as South African universities focused on the public schooling system.[398] Kraak (2018a) noted that, between 2011 and 2018, over 20 SETA-funded research chairs were established at universities. The SETA research chairs have made strategic interventions in relation to financing and human capacity development in resolving some of the problems in the skills system.[399] Despite the interventions in integrating skills formation in the forestry sector, the SETAs are confronted with a myriad challenges.

A number of interactional challenges have been noted that affects the work of the SETA research chairs. First, the SETAs' officials have a limited understanding of academic processes. This makes interactions with their partners at universities difficult. For example, Mr B23, the Research Manager at FPM SETA, wrongly assumed that the PhD and masters students funded by the SETA would be experts in understanding the issues limiting the application of R&D in the forestry sector, within months of starting their research degrees.[400] This outcome is impossible,

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[396] Ibid

[397] Mr B21. Implementation Manager- AgriSeta, interviewed by Mushangai, AgriSETA-Pretoria, 27/06/2017.

[398] Prof B45. Wits-FPM SETA Research Chair, conversation with Mushangai, Wits-Real, Parktown, Johannesburg, 23/04/2018

[399] Ibid

[400] Mr B23. Research Manager- FPM SETA, interviewed by Mushangai, Wits University 24/09/2017

for the PhD study is a process that may extend to over six years. The lack of understanding of PhD academic processes caused Mr B23 to complain that their partnership with the University of the Witwatersrand's Center for Researching Education and Labour (Wits-REAL) was slow in producing solutions required in setting up innovative projects that could employ more people.[401]

Moreover, while the masters and PhD students sponsored by the FPM SETA had been focusing on the dynamics that have allowed for industrialisation of the forestry sectors internationally and on issues hindering industrialisation in South Africa, the FPM SETA envisaged that the students would intervene directly by setting up development projects.[402] This was despite the signed contracts having been silent on the need for the students to intervene directly in the industry by setting up innovative projects. This challenge partly emanated from the pressure being exerted on the SETAs by the political environment and their political departments to see to it that different sectors of the economy generate employment for young people. Further, the challenge can also be traced to the lack of clarity on the role of the research chairs, whereby the SETAs expected them to provide a variety of support interventions from sector skills plans, to understanding the sectors, and to initiating projects directly linked to employment creation, activities that had not been stipulated in the original contracts.[403]

Moreover, the University of the Witwatersrand's Center for Researching Education and Labour and FPM SETA Research Chair, Prof B45, criticised the short-term nature of the contracts.[404] This is directly linked to the regulations governing the SETAs. The SETAs are licensed on short-term bases, normally one to two years (National Skills Authority, NSDS III Review, 2018). As was noted in Chapter 2 in relation to the dismissal of Tom Sim at Cedara College during the colonial era and in Chapter 5 with regard to the continuity of impactful R&D projects, short-termism impacts negatively on the completion of projects and hinders the continuity of long-term projects. Short-termism may result in research projects being abandoned halfway or in the lack of commitment to long-term projects that may revolutionise production in the long term. This has a negative impact on the application of R&D in the sector. With regard to PhD training, the short-term focus of the SETA projects has resulted in a situation whereby funding is ended

[401] ibid

[402] Ms B40. PhD Student, Wits- Real, conversation with Mushangai, Wits University, Parktown, Johannesburg, 12/03/2019

[403] Ibid

[404] Prof B45. Wits-FPM SETA Research Chair, conversation with Mushangai, Wits-Real, Parktown, Johannesburg, 23/04/2018

before the students could complete their projects.[405] Mr M, a student in the Wits-REAL- FPM Research Chair Programme indicated that he was left without funding to complete his PhD project in 2018 because the contract had ended.[406] This brings in a challenge whereby resources are wasted when students are abandoned halfway, for those who fail to complete their programmes as a result of the lack of funding may end up being unable to apply the knowledge they would have gained for the benefit of the sector. It is highly unlikely the PhD process will be completed in two or three year's time. Short-term contracts are therefore not providing sufficient space for the development of long-term academic careers.

Further, short-term employment contracts also negatively affect the ability of the SETAs to build their research capabilities. As noted by Ms B33, a former administrator at FPM SETA,

> Workers are moving in and out of SETAs. The short-term contracts do not facilitate the building of research capacity. This is supposed to be long term. I think the University of the Witwatersrand or any university partnership that happens with the SETA should be grounded on expecting long-term outcomes that would spread from internal SETA staff getting capacity through the university links as well as the university expanding the reach of skills planning as a field of study for future.[407]

However, the indispensability of partnerships was acknowledged by Ms B33, when she noted that the partnership between the University of the Witwatersrand and the FPM SETA had been a strong learning curve to the partners because of 'how different institutions with different ways of doing things that have strong roots in history are finding each together'.[408] It is important to note that the role of SETAs in the skills system was originally administrative, but with access to many companies in their respective sectors. The FPM SETA's partnership with the internationally acclaimed University of the Witwatersrand was a milestone in facilitating sectoral skills development and the employment of R&D in the forestry sector. The University of the Witwatersrand provided the expertise in the form of high-level 'professors to delve deep into a specific subsector of the economy and try to determine or resolve whatever problems'.[409] For the

[405] Prof B45. Wits-FPM SETA Research Chair, conversation with Mushangai, Wits-Real, Parktown, Johannesburg, 23/04/2018

[406] Ms B40. PhD Student, Wits- Real, conversation with Mushangai, Wits University, Parktown, Johannesburg, 12/03/19

[407] Ms B33. Former Administrator- FPM SETA, interviewed by Mushangai, SEDA, Pretoria, 07/06/2017

[408] Ibid

[409] Ibid

improvement of efficiency and effectiveness of partnerships, it is, however, crucial to develop monitoring and evaluation mechanisms to pick up lessons about ‘what gets in the way, and how the administration can be made easier in the future’.[410] All of this demands extended time to enable integration and the development of trust as the glue that binds partners for the sustainability a partnership.

The SETAs also lack the R&D capabilities required for them to perform their roles in the economy effectively. The Department of Higher Education and Training (DHET 2011) recognised that ‘’no research or skills planning expertise existed in the Skills Branch. It (SETA) relied mainly on external capacity’’. As a result of this, no ‘systematic evaluation of the SSPs could be done internally’ (DHET, 2011). As such, the NSDS III (2011) emphasised the need for the SETAs to build their R&D capabilities. As noted by Ms B33,

> The NSDS is saying that SETAs must have research capacity. It is creating this emphasis so that we can build a group of people who have studied and understands skills planning. This requires pumping money into creating a new profession. It means that you need to invest in curricular and in building a culture of people who know that skills planning is not just ad hoc.[411]

This requires long-term planning but is necessary in building the capacity of the organisations within the forestry SSI. The current shortage of R&D capabilities within the SETAs negatively affects their ability to generate the necessary knowledge pertaining to their respective sectors’ needs and the ability to execute their functions in relation to the production of sector skills plans (SSPs), strategic plans, annual performance plans (APPs), annual reports, and in conducting graduate tracer studies.

Many documents of the AgriSETA and the FPM SETA show a lack of comprehensive understanding of the complex interactions between the SETAS and their external environments. This understanding is important for the SETAs in building their R&D capabilities and in facilitating the adoption and application of new technologies in their respective sectors. The SETA documents are not articulate on the importance of interactions between the national

[410] Ibid

[411] Ms B33. Former Administrator- FPM SETA, interviewed by Mushangai, SEDA, Pretoria, 07/06/2017

systems and the international systems in R&D and technological developments in their sectors. An understanding of interactions and the sustained management of the points of linkage with the external environment is crucial and requires a thorough understanding of the factors affecting their industrial sectors. This is an undertaking that requires strategic thinking, composite knowledge, and experience, and management skills normally produced at masters and PhD levels. Both the FPM SETA and the AgriSETA lack these skills, which are critical in the application of R&D in the forestry sector.

From the analysis of the AgriSETA and FPM SETA documents (SSPs, Strategic Plans, APPs, and Annual reports 2009 -2016) and of the interview data, this study discovered that the information management systems of the AgriSETA and the FPM SETA are not up to date with developments in their sectors. For example, the two SETAs could not readily make available the information pertaining to students supported, whether they are in employment as a result of skills development or whether they failed to secure employment and what firms are saying in relation to the capacity of these students to improve production at firm level. Thus, poor information on learners, throughput rate, graduation, and employment has continued to be a problem for the FPM SETA and the AgriSETA.[412] This emanates from the lack of R&D capabilities within the SETAs themselves to perform these functions. SETAs are required to strengthen their research capacity in order to improve their performance.

Important to consider is that the challenges in the employment of R&D do not lie only at the point of production for what happens at the point of production is a result of concerted interactions within the broader NSI. Once the interactional challenges in the broader system have been resolved, the flow of knowledge and technologies and their adoption could be facilitated. However, worthy of note is that systems' interaction is continuous, a process always changing and adapting to changing environments and circumstances.

6.11 Conclusion

Despite the existence of a number of policy frameworks and funding schemes designed for small businesses (ISBDS, NIFP ASGI-SA, BNG, Nibus, etc) and financial schemes (SEDA, Khula,

[412] Ms B33. Former Administrator- FPM SETA, interviewed by Mushangai, SEDA, Pretoria, 07/06/2017

Samef) within the South African NSI, funding is still a challenge for many SMEs. This has been a result of the failure to implement policies, mainly emanating from the lack of integration in the NSI and the forestry SSI. As such, the NCR (2013) noted that risk assessments about the SMEs in South Africa have not changed in relation to the policies and funding schemes introduced by the democratic governments. Without the necessary financial resources, it will remain difficult for SMEs to employ economies of speed, scale, and scope. This will mean continued difficulties for small businesses to venture into product diversification to capture new markets as old ones close. The adaptability of the businesses to changing environments is compromised without funding and this partly explains the collapse of many small businesses in South Africa during their formative stages (Chimucheka & Rungani, 2011).

The chapter noted that there are still interactional challenges faced by the AgriSETA and the FPM SETA in facilitating skills formation and the employment of R&D by firms in the forestry sector. Some of the challenges are internal to the SETAs, while others relate to the broader skills and political environment. The internal challenges include the lack of R&D capabilities, the lack of clarity on the work and responsibilities of the SETAs and short-termism in relation to their projects and employment contracts. Further, the SETAs have to interact with organisations of various capabilities ranging from universities, technikons, private skills providers, and political departments to big and small firms, which make coordination difficult.

Nonetheless, the SETAs have realised successes in the resuscitation of agricultural colleges, the provision of bursaries, and in facilitating the development of small business technologies, such as the timber winch. However, more could have been achieved had the South African SI been more integrated. The lack of integration has resulted in instances in which skills are facilitated for SMEs by the SETAs with the responsible government departments doing nothing in supporting them financially so that they can own the means of production. The lack of integration has also led to situations in which there are plenty of skilled people in one sector but with the same skills in shortage in another sector or in a mismatch of skills facilitated by the SETAs with those demanded by the firms in the sector. All of these factors are challenges hindering the employment of R&D in the forestry sector.

The forestry sector requires a skills regime that caters for enterprises of various sizes. There is a need for a multi-pronged strategy in supporting all post-school organisations (colleges, UoT, universities, and research institutes) to produce a mix of skills from intermediate to high-level R&D skills, which caters for firms of all sizes in the sector. This would require universities to have greater links with TVETs and agricultural colleges in the alignment of skills production in the sector. The links are important, especially in boosting intermediate organisations within the skills system, enabling them to render important extension services required at the firm level for innovative activities. However, for this to happen, there is a need for capacity across departments in coordinating this multi-pronged strategy. This is an important missing link within the South African SI.

A common error has persisted for some time and needs to be challenged. R&D skills are not the domain of universities alone. Though university R&D is required for radical and revolutionary innovations, most of the courses and programmes offered at agricultural colleges and TVETs are crucial for incremental innovations. The many vocational progression pathways (South African Technology Network, Mail & Guardian, 15- 17 September, 2017, p. 7) from a diploma up to the doctoral level in South Africa have blurred the differences between the technical applied studies from academic studies. Thus, a technical masters' degree and an academic degree within the same field allow for both the technical and the academic student to perform research activities. There is therefore a need for integration if interactional challenges within the NSI and the forestry SSI hindering the formation of skills and the application of R&D in the forestry sector are to be resolved.

Chapter 7: Institutions and their role in forestry R&D in South Africa

7.1 Introduction

Institutions constitute one of the three main building blocks of an SI. Defined as ‘’rules of the game in a society or … humanly devised constraints that shape human interactions’’ (North, 1990, p. 3), institutions are crucial in shaping innovation, for ‘’they structure incentives in human exchange, whether political, social or economic’’ (North, 1990, p. 3). Institutions regulate the relations and interactions between individuals, groups, and organisations (Edquist, 2006). Institutions may be formal or informal. With regard to innovation, formal institutions would include government policies and laws on innovation, policies, and laws defining the context in which innovation takes place, or policies and laws aimed at participation or economic inclusion. Informal institutions are usually unwritten social norms, customs, or traditions that shape behaviour (Leftwich & Sen, 2013). The existence of formal and informal regulations points to the fact that innovation may be a result of informal collaboration between participants or it may be stimulated through government policies. This chapter focuses on the interaction between innovation policies and forestry stakeholders and the challenges in driving innovation in the forestry sector. Some of the institutions analysed include the national policies encouraging collaborative research, land reform policies, labour policies, policies aimed at protecting resources, such as environment and water policies, institutions focusing on traditional authorities, and institutions governing competition in the economy. Recognising that South Africa is a member of the global community, the chapter also investigates how forestry systems are influenced by international institutions, such as the ISO and FSC regulations. The chapter endeavours to answer the question: *How have institutions and policy frameworks been facilitative of partnerships, collaboration, and networks in the employment of R&D by firms in the forestry sector of South Africa?* The core aim of the chapter is to understand whether institutions have been responsible for the lack of integration (OECD, 2007) or ‘weak coordination, weak linkages, and limited capability’ (Greenberg, 2010) in the South African forestry SSI. Such an understanding is important as the basis for building institutions that foster innovation. The chapter draws on 19 interviews with personnel from universities and research organisations, government departments and NGOs, firms and workers.

7.2 Landscape innovation policies and impact on collaboration

Landscape policies are policies that regulate interactions in innovation across all sectors of the economy.[413] These policies are different from sectoral policies, which are framed with a focus on a specific sector within an economy. The landscape policies are framed in a way that considers the history of development in a country. In South Africa these policies have been framed taking into consideration the effect of colonial and apartheid systems on economic development. The policies were framed taking into consideration the importance of peace and security, nation-building and the need to link growth, development, reconstruction, redistribution and reconciliation. The goal of these policies is partly to address the colonial and apartheid legacies of skewed development through innovation that partly advocates for economic inclusion of formerly excluded groups. It is expected that these policies would lead to the democratisation of the economy to end minority 'control and privilege'.

The landscape policies in South Africa emanate mainly from the Department of Trade and Industry (DTI) as the department mandated to oversee the country's industrialisation. They also emanate from the Department of Science and Technology (DST) as the national department overseeing the development and application of science to advance the economy. Since the political transition of 1994, the DTI and the DST have designed nationally focused innovation policies aimed at driving innovation and inclusive development in South Africa. A common feature of their innovation policies has been the emphasis on R&D driven through collaboration by the partners within the system of innovation, as opposed to supporting individual studies. Thus, the White Paper on Science and Technology (DACST, 1996) which assimilated Gibbons' Mode 2 to knowledge production encourages collaboration between universities, industry, government, and other agencies in the NSI. The DST's Ten-Year Innovation Plan (2008-2018) aims at, ''improving access to finance, creating an innovation-friendly regulatory environment and strengthening the NSI'' (p. v).

One way of promoting collaboration between universities and the industry that result in commercialised products has been the provision of financial support to strengthen the NSI. It is because of this that organs such as the Technology and Human Resources for Industry Programme (THRIP) and the Innovation Fund came into existence. THRIP was launched in 1991

[413] Defined so in this study

and is managed by the National Research Foundation (NRF) on behalf of the DTI (Petersen & Rumbelow, 2008). THRIP aims at promoting R&D collaboration between higher education and industry in human resources development as the backdrop to the acquisition of skills important in understanding, adopting and adapting new knowledge, and technologies, for the benefit of the economy (Petersen & Rumbelow, 2008). The DST initiated the Innovation Fund in 1999, which is managed by the NRF. According to Letseka (2005), the Innovation Fund aims to ‘’promote technological innovation and trans-disciplinary collaboration within the research community by encouraging and supporting longer-term, large-scale, collaborative innovation projects in the higher education sector, government science councils, civil society, and the private sector’’. As of now, South Africa has a compact set of innovation policies that encourage collaborative research with clear regulatory frameworks, strategies, and funding mechanisms. However, these policies are always adjusting to changing circumstances within the NSI. The landscape innovation policies influence the practice of research in forestry research in South Africa.

The impact of the new approach to R&D emanating from the policies by the DTI and the DST with a focus on collaborative research on the forestry sector is well summed by Dr B4, the Research Director at FSA,

> The Innovation Fund should be commended and is beneficial to forestry. The DST does not work with standalone researchers but with associations. Instead of saying, we work with a researcher because he is excellent and has a very good CV as was traditionally, the DST now work with the industry association. They want the research agenda to be driven by an association which makes it more relevant to the industry. They are pushing to get the industry to make sure that the research being done improves international and national competitiveness, job creation, and skills development. For the forestry sector, they want to see that research increases productivity, sustainability, student education, and employment. They give you the money and you spend it in a way that you can quantify the value of the investment back to the DST. That is one of the big differences that DST has had. DTI is following suit now with THRIP funding. It is at the same level and they work with industry associations. There is a big push to make the research expenditure from government to be driven by an industry association which has a collective view and

> sets the priority for the entire sector. On the small growers' side, this fund has doubled the government expenditure into forestry.[414]

The above explanation points to the entrenchment of Gibbons' Mode 2 or the multi-pronged approach to R&D as explained in Chapter 3.

Initiatives encouraging collaborative research, such as the Innovation Fund and THRIP, have been customised to cater for the needs of the forestry sector. Thus, in December 2013, the DST approved Forestry South Africa's application for the establishment of a Forestry Sector Specific Innovation Fund (FSA Annual Report, 2013). Since then, a number of collaborative research projects have been completed, funded by either THRIP or the Innovation Fund. For example, it was noted that in the Cryphonectria Cubensis Research Project (Appendix 1, Box 3) that the TPCP received funding from the THRIP. Further, Dr B1 from SAPPI noted that in the genomics collaborative research (Appendix 1, Box 5) the DST, later on, supported with funding.

The small-scale enterprises are also benefitting from collaborative research projects funded by the DST and the DTI. The Timber Winch project in Appendix 1, Box 7 is an example of a project funded by the Innovation Fund for the development of low-level technology aimed at boosting the capabilities of SMEs in the forestry sector.

The Timber Winch project is discussed in this chapter under institutions to demonstrate how the changing 'rules of the game', as in the approach by the DST and the DTI, has impacted the research landscape, especially in motivating collaboration in forestry-sector R&D. The Timber Winch project (Appendix 1, Box 7) demonstrates the advantages of collaborative research in the development of customised technologies for SMEs in the sector. The project allowed small enterprises in the sector to benefit from the expertise of the big and established firms. The chainsaw experts from Mondi and SAPPI cooperated with the experts from the biggest chainsaw company in South Africa, Stihl and Husqvarna, and with researchers from the University of KwaZulu-Natal and the University of Stellenbosch in designing and manufacturing the small-scale timber winch for the SMEs in the sector.[415] The machine helps in lessening the burden of harvesting and extracting timber from harvesting sites. The machine is suited for small-scale

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[414] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

[415] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

growers for ‘it is small, portable, practical, and affordable’.[416] It can therefore be seen that the policies informing funding models such as THRIP and the Innovation Fund in South Africa have to some extent been encouraging a move towards more collaborative forms of R&D. However, other regulations, such as the IPR and the Competition law, also have an impact on the employment of R&D in the sector.

7.3 Intellectual property regulations, competition law and forestry innovations

The other policies by the DST and the DTI articulated at national level but with a bearing on forestry sectoral innovation have been the Intellectual Property Rights of Publicly Funded Research and Development Act (5) of 2008 and the Competition Act of 1998. The nature of interactions and transfer of knowledge between public research institutes and organisations in South Africa are governed by the Intellectual Property Rights of Publicly Funded Research and Development Act (5) of 2008.

The Act has been linked to current changes in research organisations and funding. The challenge of the IPR Act in relation to knowledge transfers is that it enables the big firms with capabilities to buy and monopolise the IPR of innovations formerly produced at government research organisations. This has led to knowledge monopolisation which denies other players, especially small-scale businesses, access to highly valued production knowledge and technologies required to upgrade their activities. For example, the CSIR was formerly funded by the government to provide DEEM support activities to all firms, but, partly as a result of the 2008 IPR Act, it now operates in most cases as a consultancy whereby knowledge is largely produced for those who pay.[417] Traditionally work on tree improvement, classical breeding and biotechnology in South Africa was done by the CSIR.[418] The work involved classical quantitative genetics in transforming planting material using genetics knowledge for improved timber. This work was done in partnership with major firms, such as Merensky Timber. As explained by Dr B3,

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[416] Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017

[417] Prof B44. Forest Ecologist, UP, interviewed by Mushangai, UP, 29/05/2017

[418] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

> Traditionally a lot of the planting material was developed by the CSIR and it was their intellectual property. We had a strategic partnership with them. But over time we have purchased that from the CSIR. We now have our own intellectual capital in terms of plant material.[419]

The fact that Merensky managed to buy IPR formerly meant for public consumption entails that such knowledge is no longer freely accessible to other firms. This kind of monopoly disadvantages those firms lacking the capabilities to purchase intellectual property from government research organisations. It can therefore be seen that the technological needs of the SMEs with limited financial capabilities are usually neglected in the framing of legislation governing the production and transfer of knowledge and technologies. Prof B44 at the University of Pretoria observed that,

> CSIR now runs like a business, they are essentially a highly paid consultancy company. Because they have to do things for money, I think they have slightly changed away from producing knowledge as a public good.[420]

This development affects systems integration and the employment of R&D by some sections of the forestry SSI, for when knowledge producers are linked to the profit-generation motive and the ability to consume, knowledge ceases to be a public good (David, 2006).

The other challenge with the Intellectual Property Rights of Publicly Funded Research and Development Act (5) of 2008 is that it has increased transaction costs for collaborative research between the universities and firms in the industry. Mr B12 at Mondi Forests stressed that,

> The Intellectual Property Rights Act governs the funding of any institution that receives funding from the government. The Act talks about intellectual property ownership and commercialisation. The main aim of the legislation is to make sure that the intellectual property that is developed gets to commercialisation. The Act wants you to think about research outcomes before you do the research. This is difficult for you have to anticipate the outcomes and to think about the commercialisation process before you launch the investigation whether there is any merit in it at all. This is

[419] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[420] Prof B44. Forest Ecologist, UP, interviewed by Mushangai, UP, 29/05/2017

> difficult and as a private company you have to have a legal framework in place that talks to the intellectual property, and how they could be commercialised if you want to do work with the university.[421]

It is because of these complex requirements that Dr B8, the Research Manager at the Sappi Technological Hub in Pretoria, concluded,

> IPR is costly, cumbersome, and very complex. It involves IP Lawyers, university lawyers and company lawyers, and it is a very difficult space to navigate. So, the transactional cost of doing research at a university has become quite difficult from a legal point of view.[422]

The good intentions of the IPR Act to have research products commercialised seem to have had the unintended negative consequences of making industry-university collaboration costly. However, evidence from the Cryphonectria Cubensis Project (Appendix 1, Box 3); the Genomic case study (Appendix 1, Box 5); and the Timber Winch project (Appendix 1, Box 7) points to the fact that, despite the challenges, collaboration is still happening in the forestry sector.

Despite the R&D challenges of navigating the legal space, the IPR Act has provided a framework governing the ownership of intellectual property. The importance of this was underscored by Prof B46, the Head of the Genomics Project at the University of Pretoria. The Genomics Project deals with genetic plant material, where IP is a major issue. According to Prof B46,

> All of the research is being done under the South African IPR Act. The IPR Act governs how the IP is dealt with. There should not be problems with the IP because university-industry collaborations are long-term relationships. We are not going to do things that will anger our industry partners. There are also long-term benefits for the industry to work with academic researchers because we also bring in money.[423]

The IPR Act has therefore been able to fulfil one of the main aims of institutions in a system of innovation that of managing conflicts in research collaboration, as identified by Edquist (2007).

[421] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[422] Dr B8. General Manager- SAPPI Technology Centre, interviewed by Mushangai, Pretoria, 02/03/2018

[423] Prof B46. Genomics Programme- FABI, UP, interviewed by Mushangai, UP, 19/09/2017

In the Genomics Case (Appendix 1, Box 5), issues of IPR and building a relationship based on trust were resolved through the signing of contractual agreements between the collaborating partners. As Dr B1 noted, 'This was done contractually and committees comprising three people from the companies and three breeders, and then three staff and students from the universities were involved'.[424] There has not been a reported case of disputed IPR in industry-university collaboration in the forestry sector of South Africa.[425] This may be one of the positive outcomes of the IPR Act of 2008.

With regard to the complexities of the sharing of IPR, Prof B47 emphasised that, in the field of pests and pathogens, their concern is to make knowledge accessible to all for the benefit of the whole sector.[426] As she elaborated,

> Our directors said there will be no IP in our field. They noted that we can only win the battle against pests and diseases if we share information, because these things move from plantation to plantation. In our aspect, everything is open, there are no IP issues. Other programmes dealing with genetic material and clones have IP issues.[427]

Nevertheless, in cases where issues of IPR arise, Prof B47 noted that these may make it difficult for students wanting to publish their work or to present it at conferences. As such, students may have to wait for a long time before making their work public. Dr B5 observed that this

> can impact on student publishing and completion of their projects, because some of our students work on company projects. When there is a certain discovery made, this may be a mark to collect a trait, there are often significant delays for the student to publish.[428]

According to Dr B5, ownership problems usually arise because 'industry essentially wants to own most of the intellectual property while at the same time the University of Pretoria owns all the intellectual property that we as academics produce'.[429] The university policy demanding all

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[424] Dr B1. Former Genomics Researcher, SAPPI (2009), interviewed by Mushangai, Pretoria, 24/10/2017

[425] Dr B5. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

[426] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[427] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

[428] Dr B5. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

[429] Dr B5. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

the intellectual property to be owned by the university may thus makes it difficult for collaboration, especially when funding is committed by firms. However, the extent of such an occurrence has not been corroborated by evidence in the South African forestry sector.

The problem of shared IPR may be made complex when there are multiple funding schemes and much of it is private. Nevertheless, all of those interviewed agreed that conflicts pertaining to ownership of IPR between the university and industry could be avoided through 'talk' within the framework provided by the IPR Act (2008). It was noted that the partners have memoranda of understanding, which involve a discussion between the university's department of research and innovation and the company involved, before the commencement of a research project.[430] This points to the importance of communication, as emphasised by Storper (2006). Despite the burden imposed by state regulations in R&D activities, some kind of regulation remains necessary, especially in curtailing the development of cartels and monopolies that clogs the market and hinders competition. In South Africa, this is the function of the Competition Act of 1998.

7.3.1 The Competition Act of 1998

The importance of regulating competition in South Africa was underscored by the former Deputy Minister of Finance, Mcebisi Jonas, when he noted that,

> The problems of concentration in certain sectors … is that (they) … block the entrance of new entrants - in particular, black entrants are being blocked by concentration and the monopolisation of the economy (Feketha, 2018).

The Competition Act 89 of 1998 was designed to stimulate competition by the lowering of entry barriers for new and small businesses. The Act was partly designed to avoid collusion by big firms, which can have the effect of pushing less established firms out of the market. The Act forbids cooperation in product development to prevent collusion by the big firms in monopolising the market. However, by so doing, the Act prevents the distribution of R&D transaction costs in product development by the big firms involved. Mr B12 noted that,

[430] Ibid

> The competition law exercises some influence in collaborative research. For example, if our self (Mondi) and Sappi as the two main producers of pulp in the country want to work on a common problem, the competition law will probably prohibit us from doing that, even though it may be for the benefit of the country. Research becomes more costly because we have to do it on our own and them on their own. We cannot do it together because the competition law is not conducive to us.[431]

At times rules and regulations meant to ensure inclusive development hinder cooperation in R&D. Despite other things, regulation in a country like South Africa is important for dismantling the economic legacies of apartheid. Regulation is important in curbing unscrupulous activities, such as collusion by big firms, which tends to push small businesses out of the market. Stiglitz (2009) noted the importance of regulations by pointing to collapsing financial organisations in the USA at the time of the 2008 financial crisis. He argues that this was largely a result of the lack of state regulation to avert such consequences. What is important, is the institution of mechanisms to ensure that the extent of regulation does not have disrupting effects on innovative enterprises.

7.4 Land reform, land tenure, and impact on forestry investment and production

Apart from the national policies that influence innovation dynamics, forestry innovation is also impacted by policies that focus on rural development, such as land reform in South Africa. The Financial Mail noted that 'the issue of land redistribution is a thorny subject in South Africa, and the forestry industry is not immune' (XIV World Forestry Congress, Financial Mail, 10 September, 2015).

The land reform programme is necessary in South Africa ''to address … the injustices of forced removals and the historical denials of access to land … to ensure security of tenure for rural dwellers'' (RDP, 1994, p. 20). The White Paper on South African Land Policy acknowledges that ''forced removals in support of racial segregation have caused enormous suffering and hardships in South Africa and no settlement of land issues can be reached without addressing such historical injustices'' (DLA, 1997,, p. 28). As a result of these concerns, South Africa in the

[431] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

1990s embarked on a three-pronged land-reform programme hinged on the levers of restitution, redistribution, and land tenure reform.

The land restitution programme is a 'rights' based programme catered for in Section 25 (7) of the 1996 South African Constitution. Section 25(7) offers redress for a person or community dispossessed of property as a result of racially discriminatory laws or practices after 19 June 1913, to the extent provided by an Act of Parliament. Section 25(7) was put into effect by the Restitution of Land Rights Act 22 of 1994, allowing for the return of the land expropriated from African communities after 1913 on the basis of past discriminatory laws and practices (Rangan & Gilmartin 2002). The Restitution Act of 1994 and the Amendment Act of 2004 gave the Minister the powers to expropriate land for the purpose of settling land claims (Wegeriff, 2005). The restitution programme disquieted many white farmers who thought that black people staying on their farms made them vulnerable to expropriation. Many farmers responded by evicting black people from their lands (Weigriff, 2005).

By the time of the land claims deadline of December 1998, 63 455 claims had been lodged (Hall 2004). However, there is much confusion pertaining to the number of rural land claims that have been settled, the number of hectares transferred, the amount of money disbursed for comparable redress and the number of people who benefitted to date. For example, in December 2002, the official data indicated that 10 836 rural claims had been settled but the 2004 figures show that the number had dropped to 5833 (CRLR,[432] 2002b, cited in Hall, 2004).

The need to cater for those who have failed to lodge their claims by December 1998 led to the reopening of the claims process in 2014. These dynamics cause anxiety pertaining to the finalisation of the programme, hence creating an environment in which property rights are not guaranteed. This threatens forestry investments and innovation, which is mostly driven by the availability of investments in the sector.

While the restitution programme is rights-based, the land redistribution programme is discretionary. The land redistribution programme emerged to cater to the needs of landless people who did not qualify for restitution (Hall, 2004). The redistribution programme aims to redress existing racial imbalances in rural land ownership by facilitating the transfer of 30% of

[432] Commission of the Restitution of Land Rights

agricultural land to black people by 2015 within the Willing-Seller-Willing-Buyer (WSWB) framework (Kariuki, 2010). The government provides a Settlement Land Grant (SLAG) of R16 000 for previously disadvantaged Africans to buy land belonging to white South Africans (Rangan & Gilmartin, 2002). The Community Property Associations (CPA) Act 1996 which allows for households to pool their grants together to acquire, hold and manage land as a collective partly explains the emergence of many SMEs in the agriculture and forestry sector of South Africa. In the forestry sector, land reforms led to the emergence of 24 190 small scale growers by 2012 (XIV World Forestry Congress, September 10, 2012). The new small-scale growers require resettlement support, start-up grants, tools, and equipment, training, and advisory services (Binswanger-Mkize, Bourguignon, & Van den Brink, 2009). Their lack of capabilities is partially linked to the reduction in government support as a result of 1999-2000 policy changes. The changes resulted in the replacement of SLAG focused on land reform for poverty reduction by the Land Redistribution for Agricultural Development (LRAD), aimed at creating a black middle class through commercial farming (Wegeriff, 2005). LRAD is elitist, requiring the beneficiary to contribute huge sums to be supported by the government in order to make land productive.

The land tenure reform programme as the third leg of the land reform processes has two components. These are to provide legally secure tenure for people living on communal land and to secure the security of tenure of people living on land belonging to other people, such as farm dwellers. The tenure programme is catered for in Section 25(6) of the 1996 Constitution, which requires the drafting of legislation to give secure tenure or comparable redress to those whose land tenure is insecure as ‘’a result of past racially discriminatory laws or practices’’. Again Section 26 of the constitution asserted that no person ‘’may be evicted from their home …without an order of court’’ and that no ‘‘legislation may permit arbitrary evictions’’.

The tenure reforms with a focus on guaranteeing the security of tenure to farm workers and farm dwellers were effected through the Extension of Security of Tenure Act 62 of 1997 (ESTA) (Wegeriff, 2005). The Act worsened relations between the employers and workers. The employers responded pre-emptively by evicting employees and labour tenants from their farms to prevent them from claiming the newly won tenure rights (Wegeriff, 2005). For example, in

2004, the Rural Legal Trust dealt with 607 cases of threatened evictions and 282 cases of actual evictions (Wegeriff, 2005, p. 39).

Further, tenure reform, as informed by the Communal Land Rights Act of 2004 in the homelands, brought about constitutional contradictions in relation to the democratic rights of the people living in the former homelands and the customary law powers of the traditional authorities (Ntsebeza, 2006). This brought about challenges with regard to ownership and management of land in former homelands, which affect production on communally owned plantations, especially when mechanisms for the appropriation of benefits are not clearly defined.

The three levers of the land reform programme have experienced distinctive implementation challenges. As a result of these challenges, the land reform programme failed to transfer the targeted 30% of white-owned agricultural land to black South Africans by 2015. According to Kariuki (2010), by 2009 the land reform programme had managed to transfer only 6.7% of the envisaged 30%. Minister Nkwinti, in his presentation to Parliament in 2017, indicated that a total of 4 850 100 hectares have been redistributed and that, for a total of 2 774 570 hectares, financial compensation was chosen by the beneficiaries (Sihlobo & Kapuya, 2018). This makes 9.2 % of the envisaged 30% of 82 759 000 hectares targeted for redistribution by 2015.

The slow pace of land reform processes, as indicated by the failure to meet the 30% redistribution target by 2015, has invigorated the shift from the WSWB approach towards expropriation without compensation. This shift is reflected in the 27th February 2018 National Assembly decision to review Section 25 of the Constitution to enable the expropriation of land without compensation (Sihlobo & Kapuya, 2018). This radicalisation coupled with the threat of the expropriation of corporate land ignited by the reopening of the land claims effected by the Restitution of Land Rights Amendment Act of 2014 has generated tenure uncertainties, thereby undermining investments in the forestry sector. The FSA Annual Report (2016) regards the Restitution of Land Rights Amendment Act of 2014, which allowed for the lodging of land claims by those who failed to do so by the time of the December 1998 deadline, as a political gimmick aimed at garnering short-term political gains by the ANC. The Forestry Scientific Services (DAFF) Research Manager refused to talk about the timing of this radicalisation as ‘it is a sensitive issue’.[433] The rural constituent in South Africa has been advocating for the reopening

[433] Mr B9. Manager- DAFF, Forestry Scientific Services, interviewed by Mushangai, Pretoria, 25/10/2017

of the land claims process, hence the FSA sees the amendment as a populist move to placate the demands of rural people in a bid to win their votes in elections.

Generally, the land reform process generated uncertainties with regard to the land tenure of the corporates and the protection of investments in the forestry sector.[434] These challenges hinder collaboration between DAFF and the industry to spur innovation in the sector, as the big firms are suspicious about the intention of government policies. The effects of the land reform on forestry production and innovation are discussed in detail in the sections below in relation to land rights, asset stripping, traditional governance systems, uncertainties generated by the flux in land policies and the emergence of speculative investments in land markets.

7.4.1 Land reform and land rights

In line with the Restitution of Land Rights Act of 1994 and the Amendment Act of 2014, a number of claims have been lodged on land under corporate plantations. In relation to this, Ms B32, the Transformation Manager at SAFCOL, had this to say,

> For us at SAFCOL, more than fifty-seven percent of our land is under land claims. The land belongs to DAFF. We pay rentals to DAFF. The communities have claimed the land from the government and not SAFCOL.[435]

The fact that SAFCOL has 57% of its land being claimed and the fear of losing its land may cause SAFCOL to hesitate to invest in land improvements. The FSA (2016) indicated that some of the land claims in the sector had been resolved but some are still outstanding. The long time it takes to resolve the land claims affects the security of tenure of the big plantation firms, hence their commitment to long-term investments. In this way, production suffers, as tree growing is a long-term investment that can take 15 to 25 years before returns are realised (XIV World Forestry Congress, Financial Mail, 10 September, 2015). The previous Deputy Minister of DAFF, Bheki Cele, observed that land claims continue to cause uncertainty in the forestry plantation industry (FIC presentation, Transnet Esselen Park, Kempton Park, 5 October, 2017). Sender (2014) also observed that the outstanding land claims had delayed production on the underutilised lands in communal and other areas where claims have been lodged. This according,

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[434] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

[435] Ms B32. Senior Manager- Transformation, SAFCOL, interviewed by Mushangai, Nelspruit, Mpumalanga, 26/10/2017

to Mr B13, has generated 'uncertainty of tenure', which consequently is scaring away investments in the forestry sector.[436] Good institutions should reduce uncertainty in the economy and, as noted by De Soto (2002), without tenure security, it is very difficult for any enterprise whether big or small to invest in the future. Moreover, it has been argued that the more advanced the institutions in a society are, the greater the level of trust and social capital in that society (Schrempf, Kaplan, & Schroeder, 2013). Trust has a positive influence on innovation, since it reduces the risk that accompanies investment in innovation (Soete et al, 2010). The reopening of the land-claims process in 2014 coupled with the growing voices clamouring for expropriation without compensation generates uncertainties with regard to land tenure, all with a negative impact on forestry investments. One of the immediate consequences of the reopening of the land claims process in 2014 has been a reduction in forestry investments. As noted by Dr B4,

> There are areas where people are not re-investing in their piece of land because they do not know what will happen tomorrow. The land has been claimed; will it be taken away?[437]

Uncertainties because of policy fluctuations prevent investments in long-term R&D activities and this has negative consequences on the future of plantation productivity. Property rights as institutions governing relationships between individuals have to be clearly defined, understood and enforced for it is the institutional clarity that brings about certainty, and this in turn attracts investments. This cannot be said to be the case in the South African forestry sector.

Nonetheless, the firms in the forestry sector have been proactive in countering the negative impact of land claims on production by getting into partnerships with the land claimant communities, whereby they keep the land in return for paying rentals to communities. According to Dr B4,

> In dealing with the land claims, forestry is probably the most successful of all the sectors that have been affected. Forestry has a few innovative models. In some instances, corporates pay the new land owner an annual lease to continue exercising forestry on that land. Others would provide the claimants with the skills, training, and

[436] Mr B13. Forestry Technology Manager- NCT Forests, telephonically interviewed by Mushangai, Johannesburg, 26/06/2018

[437] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

> equipment and the best genetic planting material to continue practicing forestry on the land and buy the timber at the end. A lot do that for two rotations and then leave the landowner to do what he likes; either continue with forestry and sells his timber wherever he wants. Most of the plantation lands that have been transferred back to the rightful owners are still in a plantation region. This shows the success of the models and the pro-activeness of the forestry sector to drive land restitution.[438]

Since the beginning of the land reform in South Africa in the 1990s, forestry production has been partly maintained by entering into innovative partnerships between the corporates and the new landowners. Thus, process innovation that affects the organisation of production activities may be induced or incentivised by institutions.

The major companies in the sector, such as Mondi, SAPPI, and Merensky, have schemes, which foster partnerships with small emerging businesses resulting from land-reform processes. Mondi has the Khulinathi scheme; SAPPI has project Grow; while Merensky is involving communities in enterprise development (XIV World Forestry Congress, Financial Mail, 10 September, 2015). The CEO of SAFCOL, Nomkhita Mona, believes that, despite 57-61% of their land being claimed, SAFCOL will be able to continue with its planting and harvesting by partnering with the claimant communities (XIV World Forestry Congress, Financial Mail, 10 September 2015). Ms B32 elaborated on this approach,

> If a community gets back its land and because of the lack of skills, resources, and capabilities decides they want SAFCOL to continue to manage the plantations on their behalf, we make sure that the community benefits from SAFCOL's forestry value chain. We are saying we want to be a partner of choice for land claimants.[439]

Accordingly, the partnerships between corporates and claimant communities provide the context, allowing for the transfer of skills from the corporates with the experience and expertise to the communities and small businesses. As noted in the preceding chapter, these partnerships have proved to be one of the most effective ways of transferring business and technical skills to SMEs outside the skills system. As a result of these partnerships, SAFCOL has been facilitating

[438] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

[439] Ms B32. Senior Manager- Transformation, SAFCOL, interviewed by Mushangai, Nelspruit, Mpumalanga, 26/10/2017

empowerment in communities surrounding its forest plantations by involving the youth in skills development activities, such as furniture production.[440] As a consequence of the pro-activity of the big firms in the sector, Michael Peter, the Executive Director of FSA noted that '90% of our claims have succeeded because, after transfer, industry has stayed involved' (XIV World Forestry Congress, Financial Mail, 10 September 2015). Despite some of the negative effects, the land reform policies have compelled the big firms in the sector to embark on innovative partnerships, which have so far managed to maintain the resource base in the sector and to facilitate skills transfer to SMEs joining the sector.

7.4.2 Land reform and asset stripping

Mr Q, a participant at the Forestry Industrialisation Conference (FIC, Transnet Esselen Park, Kempton Park, 4 October 2017), noted that corrupt practices, mainly at managerial levels in SAFCOL have been delaying the immediate transfer of successfully claimed land to the beneficiary communities (FIC, Esselen Park, Kempton Park, 4 October, 2017). Mr Q linked this to the asset-stripping conundrum accompanying the settlement of land claims under SAFCOL plantations. With regard to forestry production, Mr B12, the Research Manager at Mondi Forests, observed that asset stripping happens when 'you are changing the age class or when you physically degrade the area'.[441] Asset stripping in cases of land reform has not been a feature in South Africa alone. In Zimbabwe, several presidential commissions found that the 'expropriation of land and other capital was carried out poorly, leading to asset stripping' (Binswanger-Mkhize, Bourguignon, & Van den Brink, 2009, p. 24). In some instances, asset stripping occurs when the transfer of land to claimant communities is intentionally delayed by a temporary lease to a third party.[442] In his explanation of this challenge in relation to sustainable forestry production in South Africa, Mr B15 elaborated,

> You would find that small portions of land were claimed by a group of people. Fortunately, or unfortunately the Department of Rural Development and Land Reform bought that piece of land from the previous owner. However, the transfer of that land to the claimant community is intentionally delayed. It stays there for 10 years being

[440] Ibid

[441] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[442] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

> leased to someone else before it gets transferred. Whilst on leasehold, the guy in charge is dilapidating the plantation. He is basically creaming the crop and not investing into planting. Eventually, when the claimants receive the plantation, there is poor productivity, it is almost dead. It would have 50% of the area unplanted because the conditions that were attached to this person were not very strict.[443]

The above statement points to the need for a speedy resolution of land claims and the institutionalisation and enforcement of new ownership rights. Without that, Von Mises (1949) noted the resource

> ...is used without any regard to the disadvantages resulting. Those who are in a position to appropriate returns … do not bother about the later effects of the mode of exploitation. For the erosion, depletion of soil, and depletion of the exhaustible resources and other impairments of the future utilisation are external costs not entering into their calculation of input and output. They cut trees down without regard for fresh shoots or reforestation.

The land and agrarian reforms in South Africa have been riddled with corrupt activities, allowing corrupt officials to benefit unnecessarily from the claimed land before it is handed over to claimant communities. With regard to this issue, Hall (1998) concluded that there is a need, ‘’to build systemic checks into policy to mitigate the tendency for the powerful to use power to resist and subvert a policy which aims to bring about a changed distribution of power and wealth in society’’ (p. 460). The government departments responsible for the land and agrarian reform processes should institute monitoring mechanisms in land transfers to avoid the deliberate degradation of plantations where land is transferred (Binswanger-Mkhize, Bourguignon, & Van den Brink, 2009). The failure to monitor issues pertaining to asset stripping where land is transferred is affecting the sustainability of the plantation economy in South Africa. The problem of asset stripping has also been observed in communal plantations where those who work the land are denied the fruits of their labour by traditional authorities.

[443] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

7.4.3 Traditional authorities, land tenure, and plantation forest production

There have been various, often confusing and inconclusive debates on the superiority of individualised property rights over communal landholding under traditional authorities. Hardin (1968), De Soto (2002) and Acemoglu et al (2004) have been on record championing the eradication of the communal land rights regimes, considering them an anathema, an antithesis to development, economic growth and poverty eradication. These scholars have tried to demonstrate the superiority of land titling in relation to tenure security, investment, and creditworthiness, among others. However, some scholars (Boserup, 1981; Migot-Adholla, 1993; Migot-Adholla et al, 1991; Cousins 2005) have emerged in response to their postulations and through empirical studies have demonstrated that in some cases communal land tenure regimes can guarantee security and economic development. These scholars regard arguments for the efficiency of individualised tenure regimes in comparison to communal tenure as platitudinous, meant to advance western developmental ideologies and to see to it that even the remotest areas of the world are connected to global capitalism to enhance capitalist exploitation. These debates over tenure systems have influenced the land reform discourse in South Africa with regard to land ownership and the role of traditional authorities in the governance of communally owned land. The Communal Land Rights Bill (2004) reflects the ambition of the South African government to placate both groups, those in support of communal land rights and those who support tenure individuation. On the one hand, the bill reflects De Soto’s (2001) concern with the formalisation of community property aimed at giving legal recognition to land tenure in communal lands including the rights to own, occupy, use, alienate, or bequeath communal land. According to Kariuki (2004), the Communal Land Rights Bill is a modernising project informed by western jurisprudential and development experience, which failed to note that the conditions in South Africa are vastly different from those obtaining in Europe. As such, Kariuki (2004) describes the Bill as ‘ideological captive’ demonstrating the poverty of ideas among the African elite. On the other hand, the Communal land rights Bill retained some residual elements of the customary system in relation to the role of traditional authorities in the governance of land in communal areas. It created the traditional councils with the powers to allocate and administer land in communal areas (Ntsebeza, 2006). This was buttressed by the Traditional Leadership and Governance Framework Act (2003) which asserted the role of traditional councils as the most important organ in the administration of land in communal areas (Ntsebeza, 2006). However, the defect of the traditional councils is that most of the traditional council members are not democratically elected but appointed by the chiefs (Ntsebeza, 2006; Kariuki, 2004).

Cousins (2005), in his study on the virtues of communal tenure with regard to housing in Joe Slovo Park in South Africa, discovered that the individuation of tenure did not result in any significant improvements on land but instead led to the disenfranchisement of many poor families as they were duped into selling their assets at negligible prices. He discovered that within a space of five years, 30% of houses belonging to the poor in Joe Slovo Park, houses whose tenure had been individualised, had all been sold. This evidence accordingly disputes that individualised tenure is more secure than communal tenure, especially in relation to poor communities. Also, in Kenya, evidence shows that in the 1950s agriculture did not respond much to tenure individuation but to improvements in communication, transport infrastructure, and the establishment of extension and credit services (Migot-Adholla, 1991). This, according to Migot-Adhola (1991), disputes the argument that individualised tenure regimes are more developmental than communal tenure regimes.

Nevertheless, in South Africa evidence points to the effect that communal tenure systems under traditional authorities may hinder plantation forestry productivity. Evidence shows that production on communal forestry plantations in South Africa is negatively affected by the dictatorial tendencies of traditional authorities. With regard to communal plantations in KwaZulu-Natal, Mr B15, explains,

> Locally most of these people are in chiefdoms led by Inkosi in KZN - Langa. In the Eastern Cape, they also say Nkosi or Amakhosi. I spoke to some men and said, 'why are you not taking care of the plantation?' It was a community plantation. The men said, 'you do not understand our chief, we work very hard fighting fires and when the plantation gets to maturity, our chief takes over and say this is my plantation, it is in my area.[444]

The inviolability of property rights is therefore not guaranteed in former homelands because of the lack of tenure clarity. As noted by Mr B15,

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[444] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

> The thing that is missing is clarity around land tenure. If there was clarity around land tenure, if there was clarity around some kind of social facilitation, clarity as to who owns what and who is going to benefit, that will make life easier.[445]

The lack of tenure clarity and of equitable profit-sharing mechanisms in communally owned plantations under traditional authorities are disincentives that have resulted in the neglect and degradation of community plantations. The former president of South Africa, Kgalema Motlanthe, reporting on the High-level Panel on the Assessment of Key Legislation and the Acceleration of Fundamental Change on 19 May 2018, noted with regard to land reform that traditional leaders have usurped the tenure rights of people in the former homelands, who are now required to pay exorbitant levies. He noted that the ''majority of them are acting as village tin-pot dictators to the people in the villages'' (Motlanthe, 2018). The lack of clarity of on issues of land tenure in the former homelands is also one the disincentivies for the private investors to partner with homeland communities in fostering forestry resource development in these areas. With the dictorial tendencies of some traditional authorities, the security of investments is not guaranteed and this scares away the ptivate actors who are mostly interested in recouping returns on investments.

Nonetheless, an analysis of the South African situation does not indicate the lack of mechanisms or legal instruments defining tenure or the management of common resources but to the lack of capacity in implementing legal provisions. The Communal Property Rights Act of 1994 defines tenure in former homelands while the Communal Property Associations Act (CPA) of 1996 provide communities with a legal framework by which they ''may acquire, hold and manage a common property''. The CPA Act of 1996 gave effect to community property as, institutions ''established and managed in a manner that is non-discriminatory, equitable and democratic and that such institutions are accountable to their members''. The absence of such relationships or interactions in former homelands in relation to the management of the common property, as established by the Motlanthe high-level land assessment report of May 2018 and as indicated by the interviewee statements above, point towards the usurpation of the rights of people in communal lands by the chiefs and kings. This usurpation reflects tenure insecurities acting as disincentives in working the communally owned plantations. It is because of these developments

[445] Ibid

that Ntsebeza (2006) regarded the retention of traditional authorities in democratic South Africa as a 'retreat of democracy'. Since it is the common people who work the community-owned plantations and not the kings, efficiency is affected when incentives to work the plantations are appropriated by the kings from the people. Consequently, efficiency in forestry production is affected by political issues, such as the failure by the traditional authorities to observe and uphold the rights of those living under them in the former homelands, as is provided by the CPA Act of 1996. However, this case also reflects a lack of institutional alignment as the Traditional Leadership and Governance Framework Act (2003) asserted the role of traditional councils as the most important organ in the administration of land in communal areas while the CPA Act of 1996 gave effect to democratic governance of common properties. There is, therefore, a need for institutional alignment in South Africa to avoid institutional contradictions which affect production on forestry plantations in areas under traditional authorities. This case points to the fact that individualised tenure systems may be more efficient than communal tenure, especially in the forestry sector, and it is reflective of the fact that some types of institutions may hinder productivity on plantations.

Despite the above criticism of the customary law and the rule of traditional authorities in relation plantation forestry development in communal areas, this should not, however, be taken to mean that communal tenure is completely antithetical to development. As discovered by Cousins (2005) on Joe Slovo Farm, communal tenure may be the best system to guarantee the security of tenure to poor communities. Since not all of the land reform projects are geared towards forestry resource development, communal and individual tenure systems should be allowed to co-exist, taking into consideration the type of land use and the capabilities of the people involved. In some instances, the poor people should be protected through communal tenure to avoid instances of them being tricked by unscrupulous entities into selling their properties at negligible prices. However, the rights of the poor under traditional authorities should be protected through democratic governance and the democratic election of representatives to traditional councils.

7.4.4 Flux in land policy and legislation

Land policies that are exposed to constant policy changes bring uncertainties that scare away long-term R&D investments. Binswanger-Mkhize, Bourguignon, and Van den Brink (2009) observed that, land rights that are subjected to ''chronic redistribution are likely to conflict the objective of ensuring land users' tenure security'' (p. 29). Perpetual changes affect the building of long-term relationships, as the basis of trust, bringing about positive interactions between the government, investors and other stakeholders. The Restitution of Land Rights Act of 1994 and the lodging of land claims brought about tenure insecurities to plantation owners. The reopening of the land claims after the cut-off date of 31 December 1998, through the institution of the Restitution of Land Rights Amendment Act of 2014 to facilitate the lodging of claims by those who had failed to do so previously, sent shock waves throughout the forestry sector which was in the process of finalising the claims lodged before 1998. As a result of the amendment of 2014, over 200 000 new claims were lodged. In a legal battle that ensued between the Department of Rural Development and Land Reform (DRDLR) on the one hand and the industry (the FSA and AgriSA) on the other, the Constitutional Court ruled that the 2014 amendment Act which enabled the lodging of the last 200 000 claims was invalid.[446] The Court further prohibited the DRDLR from addressing the new claims and recommended that priority should be given to the settlement of claims lodged before 2014[447].

Further, confusion was brought in the sector by the DRDLR's inconsistency with regard to interactions between stakeholders pertaining to ownership rights. For example, the DRDLR established the Workstream as the forum through which AgriSA, FSA, the government, and the workers could meet and resolve issues pertaining to ownership (FSA Annual Report 2016:24). Through interactions in the Workstream, AgriSA and FSA successfully challenged the Department's 50/50 ownership policy with regard to the rights of farm workers as aligned to the Land Expropriation Bill (from 2014-2016).[448] Instead, they devised models, which were adopted as preferred policy by the Workstream. However, in June 2016, the DRDLR called for a Workstream meeting but avoided the FSA and the AgriSA (FSA Annual Report 2016:24). The meeting was called to test their old ownership models as opposed to those that have been crafted with the participation of the FSA and AgriSA and had been adopted by the Workstream as the preferred model (FSA Annual Report, 2016).

Further, the National Empowerment Fund supported the funding of the old models opted for by the DRDLR instead of the new ones, which had been prepared together with the involvement of

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[446] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

[447] Ibid

[448] Ibid

AgriSA and FSA as affected stakeholders (FSA Annual Report, 2016). Later on, the DRDLR advised that they were not tied to the resoulutions and models crafted by the Workstream, meaning to say that AgriSA and FSA had wasted their resources in terms of time and money by serving in the Workstream (FSA Annual Report, 2016). In response, AgriSA and FSA made it clear that there was no precedent in a democtratic country where land had been expropriated without compensation, as was implied in the 50/50 policy by the DRDLR (FSA Annual Report, 2016). This fission between the government and the commercial farmers, as represented by FSA and AgriSA, did not stop with the passing of the Expropriation Bill by Parliament in 2016, which the then President Jacob Zuma did not sign. As noted above, on the 27th of February 2018, the National Assembly made a landmark decision to review Section 25 of the Constitution of the Republic of South Africa in order to expedite the principle of land expropriation without compensation. All these fissures indicate that, although the land reform institutions have in some instances incentivised the government and the industry to work together in resolving challenges, the disagreements between the government and the industry are worsening relations. This has led the DRDLR to stop consultations with the industry in the Workstream meetings. Collaboration is therefore made difficult in the forestry SSI by the fact that government departments such as the DRDLR rarely consider the views of important stakeholders such as the FSA and AgriSA. This impacts trust, hence the relationship between the government and industry is shrouded with suspicion.

The disagreements between the government and the industry in relation to land reform approaches are affecting forestry production. As noted by Dr B4,

> In the forestry sector the big corporates drive the land claim process and they want to finalise it. When the land claims reopened in 2014, a lot of people were unhappy because all land claims had to stop until the new window got closed again. We were so busy settling a large number of land claims and then it had stopped.[449]

There is, therefore, policy confusion in South Africa, which affects long-term investments in plantation production. This confusion with regard to land ownership has led to speculative tendencies, with some pension fund organisations speculatively buying land and selling it at

[449] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

exorbitant prices.[450] Though this point was highlighted by two interviewees, it is an important issue bound to affect the approach to R&D in the forestry SSI. Landholding by those not involved in forestry plantation production is likely to affect investment in R&D as the new landholders will not derive their profit from participating in the production process. Hence, they have no imperative to invest in R&D. There is a general fear among the stakeholders that, if this trend continues, it will impact negatively on forestry production.[451] As a result of these developments, investment trends in the sector have been changing with an increase in short-term pension fund investments in land ownership rather than investments in land by those owning production, i.e. plantation firms. In relation to the trend, Dr B1, a former Researcher at SAPPI explains,

> We have seen pension funds that are buying some land with the view of owning it for a few years, escalating the value of the land over time, and getting that as a return and then exiting again. There is something to be learned from that because it changes one's view on the long-term investment into research. You know you are not going to be in it for the long-term but only for 5 or 10-years, then you exit, so, you are not driving the success of the forestry business, but you are driving the escalation of the land value over time.[452]

Pertaining to the growth of speculative investments, Mr B12, the Research and Development Manager at Mondi Forests, noted that,

> Some years ago, Global Environment Fund (GEF) bought about 80 000 hectares of Mondi's saw timber holdings from Global Forest Products (GFP). Then after a number of years they sold that to York. What York Timbers owns today used to belong to a pension fund, so there is already a chain there. We have sold one of our other areas to a group of the American pension fund. There are a number of transactions that have happened in that space. In terms of the ownership of land, the pattern is changing. I am not sure that the land owner is necessarily going to be participating in driving research in that sectoral industry in the long run. It would

[450] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[451] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[452] Dr B1. Research Manager, Genomics, 4Sight Futures, interviewed by Mushangai, Pretoria, 24/10/2017

> probably be the users of the land that will be driving that and not the owner because the owners may be changing more frequently than in the past.[453]

The growth of pension funds in the sector seems to be an important change pointing to new interactions with regard to investments in forestry production. This is a new phenomenon the impact of which is not yet fully known, caused by changes related to land-tenure institutions. It is likely to impact negatively on investments in R&D as the owners of land will be concerned more with financialisation than improving production processes. The challenges in the implementation of R&D in the forestry sector are made worse by water and environment regulations.

7.5 Water and environmental regulations and impact on forestry production

The Jonkershoek catchment experiment discussed in Chapter 2 discovered that plantation forestry is a streamflow reduction activity that affects water available for irrigation agriculture and other uses. A recent assessment by Le Maitre et al (2013) indicated that plantation species categorised as invasive alien plants (IAPS) have a total of 1444 million m^3 per annum water flow reduction in South Africa (cited in Mander, 2017). This makes 2.9% of the country's naturalised mean annual runoff (Mander, 2017). The fact that the forestry industry uses significant amounts of water has been used by the government to restrict planting in order to save water. In the 1930s, a policy was adopted which recommended plantations to be established 20 metres away from riparian zones (Scott, 2013). Later on, the Forest Act (1941) was promulgated and amended in 1972 to introduce an Afforestation Permit System (APS) to curb uncontrolled plantings (Tewari, 2001; Scott, 2013). Moreover, the 1970 Mountain Catchment Areas Act emphasised land conservation and demarcated the extent of catchment areas under the joint management of landowners and the Forestry Department (Bennett & Kruger, 2015). Recently, the National Water Act (1998) requires plantations to avoid areas with serious water shortages (Chamshama & Nwonwu, 2004). The Conservation of Agricultural Resources Act (CARA 1983), as amended in 2001, requires ''reasonable steps to be taken to curtail the spread of plants outside the demarcated areas'' (Van Wilgen & Richardson, 2012, p. 63). Moreover, the National Environmental Management Biodiversity Act (NEMBA) 10 of 2004 categorised some plantation species, such as pines (Pinus) and wattle (Acacia), as IAPs to be controlled (Van Wilgen & Richardson, 2012). Further, government organisations such as the South African National

[453] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

Biodiversity Institute (SANBI), taking into account existing legislation, have mapped and listed threatened ecosystems and devised a planning tool to ensure that even limited afforestation in the future avoids sensitive habitats (Van der Merwe, 2011).

The above policies have led to conflicts between the forestry industry and the government with regard to rain water and the conservation of the environment. The source of conflicts stems from the labelling of the plantation forestry industry as 'water hungry' and a source of invasive species. The conflicts have extended to government departments leading to the dismantling of DWAF, giving birth to the Department of Agriculture, Forestry and Fisheries (DAFF) and the Department of Water and Sanitation (DWS) as separate departments to avoid conflicts of interest. However, conflicts in government departments did not end with the dismantling of DWAF but persisted between DAFF and DWS in connection with forestry development. This was emphasised by Mr B9 (DAFF) when he noted that,

> Our department wants to promote the development of commercial forestry, whereas the Department of Water Affairs would not want to see any more trees planted. That is a difficult one. There is demand for more forestry resources to be generated, but water is scarce in South Africa. How does the government then make up its mind on how much resources are allocated for that purpose? These are the threats to sustaining the forestry resource further worsened by population pressure. There are some very serious looming pressures impacting on the forestry resources coming from population growth.[454]

As a result of the challenges involved in navigating the policy space, there are people in the industry who are of the opinion that the apartheid government had mechanisms to resolve the water challenges in a way that allowed for the expansion of plantation forestry. As noted by Mr B12,

[454] Mr B9. Manager- DAFF, Forestry Scientific Services, interviewed by Mushangai, Pretoria, 25/10/2017

> There have been a number of institutional arrangements in the past up to the 1990s when the industry was growing faster. There was conducive policy for growing the industry but lately because of certain directions the industry has been shrinking and is in a declining phase.[455]

The institutional changes introduced by the democratic governments in South Africa to accommodate issues related to population growth and pressures on water, people's rights of access to natural resources, to deal with the increasing menace of invasive species on biodiversity, and to safeguard other land uses, such as agriculture and tourism, disrupted the status quo with the resultant effect of reducing the land formerly allocated for plantation forestry.

7.5.1 The impact of legislation on plantation forestry productivity

The water laws and the demand for planting licences by the DWS and DAFF are inhibiting the growth of forestry plantations. The effect of the Water Act of 1998 has been the reduction of afforestation to less than 70% of the available area in some cases. In the case of Mondi, about 200 000 hectares will never be planted again (Chamshama & Nwonwu, 2004). Dr B3 regards the water licence as a great disincentive for the growth of plantations, noting that,

> The water use licence is more of a hindrance than an enabler. There is a fee that you need to pay to have a license to plant in a plantation area, whereas for any other crops or industries that is not a requirement. The forestry sector is the only sector in the country that needs to pay for rainwater as it is not water used for irrigation. It is a bit unfair on the forestry sector.[456]

The processes of applying for the water licences are onerous and cumbersome with huge costs involved. Compounded to this are the requirements for soil surveys and environmental impact assessments (EIAs) to be conducted before planting (Chamshama & Nwonwu, 2004). As noted by Dr B4,

[455] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[456] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

> There is no other stream flow reduction activity registered by law, forestry is the only one. We are the only one that needs a water license when you want to forest a new piece of land. We are the only ones who need an Environment Impact Assessment. Water is not big a problem, but the legislation around water is inhibiting the growth of the sector.[457]

For the year 2012/13, the Department of Water Affairs (DWA) proposed a Stream Flow Reduction Activity (SFRA) water tariff that was above inflation, between 10% and 382% (FSA Annual Report, Dec 2013:18). Though the Director General (DG) at DWA invited the FSA in 2012 to propose tariff increases which the industry could sustain, when the FSA proposed inflation-related increases, DWA ignored the proposal and went on to implement increases averaged at 30% across all water management areas (WMA) in the forestry sector (FSA Annual Report, Dec 2013:18). This provides a similar case to the Forestry Workstream case alluded to above, whereby DRDLR disregarded recommendations by stakeholders in the sector. The effect is also similar in that collaboration in the SSI is affected when the government chooses to disregard the voice of the industry. This generates an atmosphere of mistrust between the partners in the sector. When the views of an important stakeholder are disregarded in government consultations, the stakeholders might not see the need for participation in future consultations. This has a negative impact on collective approaches to R&D and to dispute resolutions in the forestry SSI.

However, the 30% levy increases by DWS (2012/2013) in all water management areas, though disaggregated and dictated by the government, was an improvement from previous instances when increases of 300% to 400% used to be levied on forestry (FSA Annual Report, December, 2013). Further, for the year 2013/14, the DWS consulted with FSA on a Water Pricing Strategy (FSA Annual Report, December, 2013). In these consultations, the FSA strongly objected to the idea of a standard tariff for all water users. They argued that forestry could not pay for the cost of dams, infrastructure and personnel as ‘’none of those costs are incurred in the provision of water to the primary side of the forestry industry’’ (FSA Annual Report, December, 2013, p. 18). On the contrary, in its presentation to DAFF, in November 2013, DWS overlooked most of the recommendations FSA gave during consultations (FSA Annual Report, December, 2013). Only

[457] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

one area was considered and this was a concession that forestry would not pay towards dam safety (FSA Annual Report, December, 2013). People in the industry are therefore offended when their views are not considered.

In most cases, plantation forestry is already practised in marginal areas compared to agriculture, which gets the prime areas. Considering this fact, it is not water *per se* that is inhibiting growth but the perception emanating from the water legislation. This makes sense, particularly considering that other countries, which are deserts, such as Israel, are exporting figs (Prof C, FIC, Transnet Esselen Park, Kempton Park, 4 October, 2017). The water legislation has had the effect of scaring away investments and of limiting the employment of R&D in the forestry sector.

Moreover, the delays encountered in the process of obtaining water licences and EIAs impact negatively on economies of speed. This was elaborated by a member of the Licensing Assessment Advisory Committee member Mr B15. According to Mr B15,

> The water use license is a great disincentive. For you to be able to get that license, it might take an average of 5 years. I know of a man who applied to grow timber in 2008 and we are in 2017 now but the man has not received authorisation. That is one thing, but just meeting the requirements is costly. For the small-scale timber grower, he might not have enough money to meet the requirements for the water use license.[458]

The water and environmental laws have not reflected the benefits of plantations. These benefits would include rural job creation, tree growing as a superior land-use technology in terms of efficiency of water conversion to biomass and as a superior carbon (CO_2) sinking technology. The superiority of plantations in economic terms in relation to sustainable development was spelled out clearly by Dr B3 when he explained that,

[458] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

> You might plant something else which uses less water for every tree, but you may not be producing the same volume but a product with less value to the rural economy and does not create jobs. The industry is seen in a negative light environmentally whereas it is hugely positive in terms of carbon fixing. Through photosynthesis, you take the CO_2 from the atmosphere, you bind that in the trees, and you release oxygen.[459]

The legislation meant to conserve the environment and to preserve water for other uses by limiting the extent of plantations through afforestation permits have slowed down the pace of afforestation (Chamshama & Nwonwu, 2004) The legislation has had the effect of scaring away investors. Dr B4 observed that,

> Because of the impending legislation requiring one to obtain a planting permit for genus exchange from pines to eucalyptus a company pulled a five-billion-rand investment into the country. They said with that legislation we not putting that investment.[460]

The legislation is despite scientific evidence proving that the there is no basic difference between pines and eucalyptus in relation to water usage. As such, interactions in forestry innovation are made difficult when the government delays in resolving issues even when the industry is supported by scientific evidence. The previous Deputy Minister of DAFF, General Cele, attended the World Forestry Conference in 2015 and held an indaba with forestry stakeholders where issues with regard to water licences and the need to extend the areas under plantation were discussed, but the government has not yet responded.[461]

The government policies that label plantation forestry as the source of invasive species fail to consider technological advances that have been realised in the sector over time. These advances have resulted in the industry planting improved germplasm that does not seed and cannot easily escape into the natural environment as compared to old varieties planted during the colonial and apartheid times, when the government was the main owner of plantations.[462] The industry is of the opinion that it is not the only source of IAPs but also the government which was the main

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[459] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[460] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

[461] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[462] Ibid

owner of plantations in the 1960s.[463] As such, the industry is of the view that it is paying for the government's previous mistakes.

The narrative from leaders in the forestry firms is very clear: they are unfairly taxed for rainwater whereas other activities using harvested water are exempted. This has imposed unnecessary production bottlenecks. Nonetheless, these challenges have compelled some governments departments to come to the aid of forestry firms, especially in assisting the small players in obtaining water and planting licences. For example, the DTI chipped in by funding environmental impact assessment processes required before establishing a timber plantation.[464] Also, DAFF has been assisting the small growers in obtaining water-use licences (XIV World Forestry Congress, Financial Mail, 10 September, 2015).

Moreover, the forestry industry has also been proactive in removing plantations from riparian zones. For example, Mondi Forests initiated the Mondi Wetland Programme, whose model in resuscitating the catchment areas has been adopted by other companies (Lindley, 2014). Under the programme, plantations that have been in wetland areas have been removed and the wetlands restored (Lindley, 2014).

Further, the legislation has incentivised the government and the industry to work together in fighting the spread of IAPs throughout the country. Such collaboration points out what North (1990) meant when he said institutions are crucial in innovation, for ''they structure incentives in human exchange'' (p. 3). Cooperation between the industry and the government is important in building the profile of the industry, so that it continues to stand in good stead with regard to accessing international markets, as required by international regulation institutions, such as the Forest Stewardship Council. Thus, innovation scholars such as Storper (2006) emphasise the importance of 'talk' in resolving differences in the process of production. This was important in this case in moving away from the polemical arguments whereby the government accused the industry as a source of IAPS and the industry in turn accused of the government of being unfair. Production by firms in the forestry sector is also partly affected by labour regulations.

[463] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

[464] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017

7.6 Labour regulations

The labour policy continued in the Labour Tenant Act (LTA) of 1996, the Basic Conditions of Employment Act (75 of 1997), the Employment Equity Act (55 of 1998), and the Extension of Security of Tenure Act (ESTA 62 of 1997) has had an impact on the dynamic capabilities of the forestry firms in South Africa. The Department of Labour introduced sectoral determination to regulate employment conditions in 2003 and imposed a minimum wage for the agriculture and forestry sector in South Africa (Wegeriff, 2005). The sectoral determination also stipulated the maximum working hours and minimum safety standards for the sector. These changes, coupled with trade union action advocating for the protection of the rights of farmworkers, caused forestry firms to embark on processes of casualisation and labour retrenchment (DOL 2015, Pons-Vignon, 2014). The regulations encouraged the big firms in the sector to embark on process innovation to reduce the cost of labour through mechanisation. Labour regulations are therefore pushing innovation towards capital intensive, labour-replacing solutions. The labour laws have also brought about challenges in the collaboration between the government and the industry in forestry resource development because of their different objectives. The industry is more concerned about improving efficiency and returns on investments through the replacement of human labour by machines, whilst the government is mainly interested in the generation of employment and the retention of the labour force. This has created tensions as the firms try to evade government regulations.

The big firms have managed to evade the demands of both local and international labour regulations because of mechanisation and the emergence of the contracting system. The contracting system caused the big firms to outsource most of their former activities. Outsourcing has compelled the big firms to concentrate on their core production activities. As a result of FSC requirements for labour rights to be respected coupled with the international drive to mechanise forestry production processes to reduce injuries at work and the trade union activities within the local environment, many people will lose their jobs, as already happened with big firms, such as Mondi and SAPPI (DOL, 2015). Mondi Forests retrenched over 10 000 workers between 1997 and 2002 (DOL, 2015). However, in relation to innovation, the labour regulations have incentivised the big companies to become more capital intensive so as to reduce the cost of labour. As noted by Nattrass (2014), labour regulations have incentivised ‘’firms to substitute machinery for workers and to have a smaller, better-skilled, better-paid, and more manageable workforce'' (p. 16). Mr B12, the Research and Development Manager, noted that, at Mondi Forests, they had mechanised most of their production activities to reduce the management costs of dealing with labour issues.[465]

The resultant growth of outsourcing, as firms try to evade labour legislation related to the minimum wage and the ESTA regulations demanding the entrenchment of farmworkers tenure rights on corporate plantations, has worsened relations between the employers and the workers (Pons-Vignon, 2014). It is this that partly explains the emergence of innovative but exploitative ways of organising production, such as task jobs. The introduction of task jobs, resulted in workers' wages being calculated not in relation to the hours worked but in relation to whether the task as prescribed by the employer has been completed (Pons-Vignon, 2014). The task job system is completely controlled by the employers and the workers have little room to manoeuvre. These developments on the farms have engendered conflicts based on a different understanding of tasks between the employers and the workers. For example, if a worker fails to meet the production target because of environmental conditions but has worked hard enough, the expectation is to receive full payment (Pons-Vignon, 2014). On another hand, the employers stick to their production targets as a way of maximising profits (Pons-Vignon, 2014).

Labour regulations in the main affected the small-scale firms without the capabilities to rapidly change their production systems to adjust to changing circumstances. As a result of the lack of capabilities, small firms consider labour costs resulting from the institution of the minimum wage an anathema in their quest to accumulate and upgrade their systems. Labour regulations thus limit accumulation by SMEs, which is necessary to save to buy the machinery required in process and product innovation. The start-ups in the forestry sector would like the local labour regulations to be relaxed until such a time as they can stand on their feet. Ms M, the owner of a Dry Mill operation in Mpumalanga, complained that the minimum wage regulations do not consider the plight of small businesses.[466] Consequently, the lack of capabilities by the small-scale enterprises prevents them from meeting the requirements of labour legislation. It is partly the burden of labour regulation that dissuades small businesses from operating in the legal sphere, as noted by De Soto (2002).

[465] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[466] Ms B38, Small Dry Mill Business Contractor, interviewed by Mushangai, Mpumalanga, 30/06/2017

The labour and tenure legislation affected firms in different ways. Some firms at the top of the value chain are in a better position to comply with labour laws and minimum wage requirements, but SMEs operating at the bottom of the value chain find it difficult to comply with minimum wage requirements. The Eastern Cape Agriculture Research Project discovered that farmers only comply with minimum wage by paying the core male workers the minima, and atypical and sub-minima wages for women (Naidoo, 2010). The differentiation of wages on farms had a fracturing effect on the unity of workers, leading to rising inequalities in income distribution and access to services, such as housing on farms. These inequalities were further encouraged by the segmentation of agriculture and forestry labour markets between male and female workers, full time and part-time, and atypical and the different minima in different areas. This factor is important, for it affects worker motivation, for Thu Ngan (2015) noted that motivation is one of the aspects determining the level of innovation by workers in a firm.

The labour laws (LTA 1996 and ESTA 1997), with reference to labour tenants, farm workers, and farm dwellers, have not been effective enough in changing the relations of production, as they were intended. ESTA (1997) contributed to the worsening of relations on farms. In most cases, the white farmers responded pre-emptively by dismissing the workers to prevent them from claiming their newly won tenure rights. Hall (2004) discovered that most of the government workers involved with implementation were not empowered enough to deal with violations in relation to the enforcement of LTA and ESTA rights. This points to the fact that policy implementation should fit in the institutional, human and financial resources at the disposal of the state. If this is not aligned, it results in a situation in which good policies exist on paper but without the capacity to achieve the objectives through implementation. Despite the good intentions of the labour legislation to improve the workers' conditions on farms and plantations, the labour laws have bought little benefits to farmworkers. Linked to innovation and worker productivity, the worsening relations between employers and workers on farms affects motivation and worker productivity. This may also be another cause of the unaccounted for fire outbreaks that have been destroying plantations in South Africa.

However, it is worth considering that the demand for the relaxation of labour regulations is complex. If granted, it may lead to moral hazards. Moral hazards may emanate from deliberate unfair practices by firms. While recognising the challenges of small businesses is important, it is also necessary to enforce regulations to incentivise them to scale-up their activities. Thus, labour regulations have to balance both the welfare of the owner and the worker. Mr B31, a worker at a small wet mill in Mpumalanga, complained bitterly about the lack of timeous payment by small businesses. With regard to the small business that he works for, Mr B31 noted that,

> There are problems with payment. I have been here since 2013 and was not being paid on time. The money eventually came. Things like that reduce motivation and delay production. I do wish something could be done at least for people to know that they will be paid.[467]

This was also noted by Mr B29, a machine operator at a milling business in Heidelberg, Mpumalanga, who points out that they staged a protest in 2016 because of extended non-payment. Mr B29 explains,

> Our contract says we must work for 3 months but that year it was almost 6 months. For the whole year (2016), I only was paid four times. It was not only me but all the people.[468]

Generally, employers along the forestry value chain employ a number of mechanisms to exploit their workers. For example, employees in small-scale furniture manufacturing enterprises in the Orlando Industrial Park resented their payments having to be handed to them in cash but prefer a payment system whereby their wages are deposited into bank accounts. Ms G and Ms B19, who are responsible for the marketing of Mr B20's cabinets, whose business is located in the Orlando Industrial Park, indicated that they alerted the owner that they would like to have their payment through the bank to avoid the dangers of losing the money to robbers.[469] [470] However, the owner has not responded and 'we are afraid to keep on reminding him in case you lose your job'.[471] Mr B20's cabinet-making business is registered and employs 15 people.[472] However, the employees are not registered and, according to Ms G, this is a great disadvantage because 'you cannot even

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467 Mr B31. Machine Operator- employed by a Small Dry Mill contractor in Mpumalanga, interviewed by Mushangai, Mpumalanga, 30/06/2017

468 Mr B29. Machine Operator- employed by a Small Dry Mill contractor in Mpumalanga, interviewed by Mushangai, Mpumalanga, 30/06/2017

469 Ms G. Employee (Marketer), L Cabinet Manufacturer, Orlando Industrial Park, Soweto, 28/06/2019

470 Ms B19. Employee (Marketer), L Cabinet Manufacturer, Orlando Industrial Park, Soweto, 28/06/2019

471 Ibid

472 Ibid

claim for benefits, for UIF even when you are injured at work'.[473] The problem of not receiving payment via the banking system was also noted by the seven employees of an informal SME owned by Mr B30 in the Orlando Industrial Park.[474] The seven employees indicated that they are not registered as employees but their case is different from Ms G and Ms B19. The seven employees of Mr B30 are foreigners who do not have the required documents to stay and work in South Africa.[475] This is an important issue, which demands monitoring mechanisms to ensure that the rights of the workers are respected by the owners of the SMEs. The failure by the small business owners in the Orlando Industrial Park to pay their workers via the banking system is a deliberate ploy to evade taxation and being tracked as to whether they are complying with labour regulations.

Labour regulations should thus be enforced to avoid the exploitation of workers by business owners. Monitoring mechanisms should be strengthened, as the above workers' testimonies seem to highlight the lack of government monitoring to ensure fair play in economic enterprises. Stiglitz, in his article Regulation and Failure (Moss & Cisternino, 2009), noted that state intervention is always necessary for protecting the public from the unscrupulous actions of business. Similarly, Meagher (1995) noted that the regulation of small businesses is necessary for the protection of labour from exploitation and that of consumers from the marketing of adulterated, contaminated, and expired goods. Also, North et al (2007) argued that innovation and economic growth could also occur if the state is able to provide resources to devise monitoring mechanisms to reduce moral hazards. Regulation is therefore imperative to compel small businesses to be ethical in their practices and strive to improve the quality of their production. Regulation is critical in ensuring that capital accumulation does not endanger public wellbeing and that the benefits of development are enjoyed by all in an economy.

7.7 International institutions

Over the past decades, global capitalism has been driven by international institutions in establishing global rules of the game. The World Bank, the International Monetary Fund (IMF), the World Trade Organisation (WTO) and other international organisations, such as the United

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[473] Ibid

[474] Mr B16. Worker (Cabinet maker), Y Cabinet Manufacturer, Orlando Industrial Park. Soweto, 28/06/2019

[475] Ibid

Nations (UN) and the International Labour Organisation (ILO), have been defining the conceptualisation of capitalist development anchored on the notions of globalisation. Their interaction ‘’generates consensual guidelines, underpinned by an ideology of globalisation that is transmitted into national governments and big corporations’’ (Cox, 1994, cited in Satgar, 2014, p. 11). South Africa joined the WTO in 1996 and has been an active participant in the processes of generating international consensus on conceptions of capitalist development. South Africa actively participates in the UN, IMF, World Bank, World Economic Forum, and the WTO (Mushangai, 2015). According to Satgar (2014), South Africa is a vital recipient and participant in a transnational consensus rooted in global development institutions. As such, the South African forestry SSI is also influenced by international standards emanating from the FSC and the ISO.

International organisations compel local forestry firms to comply with international standards related to environmental protection and labour rights, if they are to access the lucrative markets of Europe and America. With most of its wood products destined for export markets, South Africa complies with the international forestry certification requirements and now stands out as one of the few African countries that have been able to fulfil these requirements (Chamshama & Nwonwu, 2004). According to Mr B12, 80% of South Africa’s plantations have been certified by the FSC.[476] Moreover, the R&D Manager of TWK cooperative, Mr B24, noted that they adhere to highly strict international labour practices as defined by the FSC and the Programme for the Endorsement of Forest Certification (PEFC).[477] These organisations, according to Mr B24, dictate that, ‘you will follow this route or we are not going to purchase your product’.[478] Mr B24 noted that,

> Japanese inspectors come here twice a year to do inspections in our plantations. When we export, we invite them come and do due diligence to give proof that we are not exploiting labour and respect environmental laws.[479]

[476] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[477] Mr B24. Manager, Research and Development, TWK Agri (Pty) Ltd, telephonically interviewed by Mushangai, 13/11/2017

[478] Ibid

[479] Ibid

The important point to note here is that both international and local institutions push innovation towards capital intensive, labour replacing solutions, in a country with a massive, and growing, labour surplus. In relation of forestry research systems, international institutions have been facilitative of collaborative approaches to forestry resource development for the local firms have to work with representative of international organisations such as the ISO who have to come and inspect their activities to align them with international standards.

As a result of international standards, the forestry value chain has come to be buyer-driven, with international buyers having to inspect local forestry production systems. However, the challenge is that these international-standard systems were designed with a focus on the European environment, 'where they want to implement highly skilled operations because they have a shortage in labour and then they want to force that on to South Africa that has a labour surplus'.[480] It is bound to happen that, with these FSC requirements, many more people will lose their jobs, as has already happened with big firms, such as Mondi and SAPPI (DOL, 2015). This will happen as the local production processes become mechanised in line with international standards to reduce labour costs and the incidences of workers being injured at work. The local companies have to adjust because, without the FSC certification, it will be difficult to access profitable European and American markets.

Environmental protection is at the centre of the FSC certification. In compliance with international regulations, Dr B3 noted that plantations in South Africa have been retreating from riparian zones.[481] He noted that, in the 1990s, the plantation estate stood at 1.5 million hectares but now stands at 1.25 million hectares, because of this retreat.[482] Further, Dr B3 observed that stringent measures are being applied to reduce the use of chemicals in curbing the spread of invasive species to protect biodiversity and the environment. These issues were also raised by R&D managers from NCT, TWK, Mondi, Sappi, and FSA. According to the Dr B4, the regulatory requirements have led to a number of innovations, including the introduction of physical and biological control mechanisms of controlling the spread of invasive species; in

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[480] Ibid

[481] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017

[482] Ibid

removing plantations from riparian; in reducing of the use of chemicals in forestry production and in producing non-seeding tree species to curb the spread of invasive species.[483]

Participation in international forestry governance systems is important to encourage local innovation, but this has, however, led to a reduction of the area formerly under plantations in South Africa. The reduction in the size of plantation estate is somewhat necessary to protect the environment in an age of global warming and climate change. Moreover, another challenge with the FSC regulations pertains to the inability by small players to have their plantations certified. In countries like Gabon, the failure to meet the FSC standards by the Gabonese firms has limited these firms to supplying the less lucrative markets of China, Malaysia, and Asia (Terheggen, 2011). This is because, in China, Malaysia, and other Asian countries, environmental protection is not much considered in their trading activities, whereas in Europe the firms need to comply with the FSC standards for them to participate.

Plantation certification processes are too expensive and beyond the reach of small-scale players, thus limiting their participation in lucrative international markets. This challenge was raised by the research managers of cooperatives, such as NCT and TWK. According to Mr B24,

> ...approximately it costs about R1.7 million to get small growers to be certified. We have tried everything but could not certify 360 hectares with R1.7 million. It is not economically viable to do an FSC certification. That is why we joined the Programme for the Endorsement of Forest Certification (PECF) system. The programme is another international certification and we hope that it will be implemented during the course of next year.[484].

This challenge has resulted in some small-scale growers getting into out-grower schemes with big firms, such as Mondi and Sappi, on unequal terms, to enable the certification of their plantations. The impact of the different types of partnerships and out-grower schemes on innovation by small businesses was discussed in Chapter 6.

Even though the PECF might be a certification system of choice by small-scale growers, allowing them to participate in international forestry product markets, the fact that it promotes

[483] Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017

[484] Mr B24. Manager, Research and Development, TWK Agri (Pty) Ltd, telephonically interviewed by Mushangai, 13/11/2017

participation through independent third-party certification puts small-scale growers at a disadvantage by compelling them to enter into unfavourable partnerships[485] in global value chains. However, it is only through this way, as noted by Mr B49, that 'small growers will be able to be certified and to trade internationally'.[486]

The other presumed negative impact of the FSC is that it may disincentivise the planting of advanced genetically modified tree species, which have already revolutionised forestry production in China and Brazil.[487] This will delay South Africa's catch-up process with leading forestry sectors in the world.

The forestry SSI is made up of complex interactions cutting across national and international boundaries. The scale and scope of these interactions place huge challenges on the capacity of those involved to coordinate and collaborate in forestry R&D. It is because of this that evolutionary economists, such as Nelson and Winter (1977), believe in the development of capabilities over time. This is normal when we consider SI scholars Kuhlmann and Shapira's (2010) observation that successful systems of innovation develop their special competitiveness and strength slowly over time. Facilitation, coordination, and institutional alignment are crucial in developing countries like South Africa because innovation policy needs to be multi-faceted, with effective networks and collaboration between government departments and between the private sector and the government (Goedhuys et al 2015:85).

7.8 Conclusion

Kruger and Bennett (2015) have argued that,

[485] The unfavourable partnerships were discussed in Chapter 5

[486] Ibid

[487] Dr B5. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018

> The policy frameworks and institutional arrangements prior to the 1990s utilised an integrated approach that brought together researchers, industry leaders, and government agencies in order to harmonise economic development and nature protection at national and provincial scales. … This model attempted to integrate diverse scientific perspectives into policy and planning in order to direct afforestation to suitable sites while using knowledge gained from forestry research to protect the nation's catchments and ecosystems (p. Xviii).

Bennett and Kruger's (2015) assessment is true to some extent, but tends to glamourise colonial/apartheid approaches and to discount the efforts by the democratic governments to provide a compact approach to forestry R&D. Their assessment fails to consider the ways in which colonial and apartheid accumulation was based on dispossession and the neglect of forestry R&D in the homelands. Integration cannot be achieved through the economic exclusion of certain segments of society. Despite some defects and implementation challenges, the R&D institutions governing forestry development by democratic governments in South Africa have been to some extent integrative, encouraging linkages between the components of the NSI and the SSI and between the first and the second economies in the forestry sector. The Innovation Fund and THRIP encourage cooperation in forestry R&D by funding collaborative research projects.

Other policies, such as the Competition Act, are hinged on the need to transform the skewed apartheid accumulation structure by lessening entry barriers for new firms in the economy. The implementation of the Competition Act has made it difficult and costly for collaborative research in the forestry sector. However, the Competition Act has been important in preventing monopolies in a way that opens space for the participation of small players in the sector. The Act has been framed in the spirit of encouraging competition in technology and product development for the benefit of the economy as a whole. What is required is an assessment to make it possible for big firms to collaborate in product development, especially in areas where small-scale businesses, because of the lack of technological capabilities, are less likely to participate. The IPR Act of 2008 has to some extent resulted in the monopoly of knowledge by those with financial capabilities to buy the new knowledge and technologies emanating from research councils. The Act has, however, provided a framework for the sharing of IPR in cases of collaborative research in a way that prevents conflicts which discourage the implementation of R&D. It is the implementation of the policies rather than the premise upon which they are based that is faulty.

The land reform policies are premised on the need to address colonial and apartheid inequalities to integrate South Africa as a way of achieving sustainable development. However, the land and agrarian reform policies seem to have impacted negatively on collaborative research and investments in the forestry sector. The fluctuations in land reform policies have affected the security of tenure, which disincentivised those involved in forestry production from embarking on long-term R&D investments. Though the South African government's democratic approaches to conflict resolution are hinged on the participation of stakeholders, government departments have displayed a tendency to ignore the views of the industry, as shown in the DRDLR's approach to land claims in the Workstream. The tenure reforms have also failed to resolve the issues pertaining to the rights of the people working the communally owned plantations with regards to benefit-sharing mechanisms. This has in some cases led to the neglect and deterioration of communally owned plantations in the former homelands under traditional authorities. Nonetheless, the land policies have also encouraged the formation of innovative partnerships between the big and small players in order to maintain the resource base. These partnerships, despite some of them being exploitative, have been important in the transfer of knowledge and technologies from the big players to the small-scale firms in the sector. The partnerships have provided the market required by SMEs and enabled some of the small grower's plantations to gain international certification.

Labour institutions and the resultant increased cost of labour have affected productivity in the forestry sector. The labour institutions have worsened relations between employers and workers. The employers have responded to the sectoral minimum wage through mechanisation, casualisation, and retrenchment of workers. These processes affected worker motivation and, to some extent, innovation. Thu Ngan (2013) is of the view that innovation is partly a result of worker motivation. The lack of worker motivation and the worsening relations between the workers and their employers on farms as a result of labour institutions may be a cause of some unexplained fire outbreaks in the forestry sector, though there is a lack of evidence to support this.

The international regulatory institutions have incentivised the established firms in the sector to implement sustainable forestry management systems with regard to environment protection and the observance of labour rights. Thus, most of the big firms have had their plantations and production processes certified in accordance with the international standards. The international and local labour regulatory institutions have tended to push process and organisational innovation by the big firms, such as Mondi and SAPPI, towards capital intensive, labour-replacing solutions, in a country with a massive and growing labour surplus.

The environment and water regulations have had the effect of driving away investments from the sector and have increased the entry barriers for small businesses wanting to join the business of growing trees. However, these regulations have also incentivised the industry to collaborate with the government in working out solutions to the threat of invasive species to agriculture, water, and biodiversity. It can, therefore, be seen that the regulatory institutions impacting on forestry resource development encourage collaboration among the stakeholders but their implementation has not been rosy, mainly because of conflicting interests that are difficult to resolve. The disagreements in policy orientation and implementation have to some extent hindered or delayed the application of R&D in the sector.

As it stands now, the forestry SSI is not yet integrated (OECD, 2007) and suffers from weak coordination, linkages, and limited capabilities (Greenberg, 2010). The integration of the forestry SSI is a complex exercise, which demands time. The forestry SSI interacts with regulations at national and international levels, hence the need for good coordination. The existence of the two economies in the forestry sector, mainly a result of the colonial and apartheid patterns of accumulation, is important in making sense of the challenges in coordination and collaboration, for the two economies implies a differentiation of interests between stakeholders. Centuries of a skewed colonial and apartheid accumulation structure cannot be dismantled in the space of 25 years of democracy in South Africa.

Chapter 8: Conclusions

8.1 Introduction

The aim of the research has been to contribute towards an understanding of the challenges in the interaction of forestry-related institutions in the employment of R&D in the South African forestry sector. To this end the thesis adopted a qualitative research design, employing a number of qualitative research techniques such as interviews, observations, and case studies. It is argued that the challenges in the interaction of forestry-related institutions in the forestry sector of South Africa are a result of a convergence of factors interacting in varying degrees at various scales of the system of innovation.

The chapter concludes the research effort by summarising the findings of the study and analysing its methodological, educational and conceptual and theoretical contributions.

8.2 Summary of findings

Chapters 5, 6, and 7 analysed a number of factors impacting negatively on the application of R&D in the South African forestry sector. Chapter 5 was focused on the big firms in the sector and the systemic failures and blocking mechanisms bringing about interactional challenges in the application of R&D. These factors were analysed in relation to the concept of social interaction, from which the idea of social capacity emanates. Among these factors are failure by firms to apply new knowledge and technologies resulting from the work of researchers; the disjuncture in the research needs and focus of the industry and research organisations; funding challenges and the problem of short-termism; firm diversity and coordination challenges in directing R&D activities; regional climatic differences and impact on international collaboration; and the shortage of high-level R&D skills in genomics, systems analytics and product development. It is the effect of a combination of these factors interacting in varying degrees at various scales that brings about the lack of integration, the lack of coordination and limited resources, linkages and capacity in the forestry sector of South Africa.

However, a number of nuances exist, which tend to work against a general or abstract understanding of our conception of the lack of integration and the interactional challenges limiting the application of R&D in the South African forestry SSI. For example, the Cryphonectria Cubensis Project (Appendix 1, Box 3); the Cirex Research Project (Appendix 1, Box 4); the Genomics Research Project (Appendix 1, Box 5); the Eco-Furniture School Desk

Project (Appendix 1, Box 6); and the Timber Winch Project (Appendix 1, Box 7), all of which demonstrate the existence of collaboration, cooperation and a variety of partnerships underlying the concept of social capacity in the South African forestry SSI. In these projects, the private sector, the government, and academia have been able to link up and collaborate with each other in addressing challenges related to pests and diseases, small-scale enterprise technology development, forestry management systems, growth cycles, cloning technologies and forestry product development. Nevertheless, the challenges in these partnerships have been mainly related to the lack of funding and short-termism, due to limitations in the private sector's and government's funding models. Despite the problems with regard to the short-term nature of the funding models, collaboration in the above-mentioned research projects demonstrated that, although the challenges of funding and skills shortages have persisted, these challenges can be greatly reduced by pooling resources. Further, it was also realised in the TPCP Programme that the government and the private sector could be persuaded to continue funding projects through 'talk'. The TPCP was started at the University of Free State (South Africa) in 1989 and was transferred to the University of Pretoria in 1997. Through 'talk', academia has been able to convince the industry and the government on the importance of long-term research on pests and pathogens, hence continued funding of the programme by the government and the private sector to this very day. However, 'talk' with regard to productivity has to be convincing and for this to happen it has to be based on evidence that supports effective predictions. Taking into consideration these nuances related to collaboration and partnerships, it would be more apt to consider the South African forestry SSI as less integrated in line with the OECD (2007) but also to note that it is becoming integrated.

Chapter 6 focused mainly on the factors impacting innovation by SMEs in the South African forestry sector. Among these factors was a lack of funding in technological upgrading by small firms; a lack of funding as a result of the lack of business skills; a shortage of extension services in knowledge and technology transfers; a lack of social capital by SMEs; power dynamics in the value chains and a lack of trust between big and small firms; and the lack of alignment in government departments. Most of these factors are historically informed and emanate from the colonial and apartheid patterns of accumulation. The lack of skills among the SMEs impact negatively on their ability to link up with financial organisations, with skills development organisations, and with the big firms important in the capitalisation of their businesses, and in the transfer of knowledge and technologies enabling them to embark on process, product and functional innovations. The lack of skills and knowledge among the SMEs is partly related to the ‘development of underdevelopment’ in the second economy in the South African forestry sector underpinned by the philosophy of separate development adopted by the colonial and apartheid governments in South Africa. This philosophy underlies the colonial and apartheid education and economic policies that were focused on developing production and innovation capabilities in white segments of the economy while negating the importance of forestry knowledge and skills in propelling industrialisation in the homelands. This also touches on the processes of accumulation by dispossession in relation to land ownership under colonial and apartheid governments.

The lack of innovation by the SMEs has, however, been aggravated by weaknesses in the sub-systems set up by the democratic governments to facilitate skills transfer to small businesses to enable innovation. The support schemes by the democratic governments have been isolated and not provided in a compact manner, hence the limited impact on SMEs development. The FPM SETA and the AgriSETA, as intermediaries mandated by the democratic governments to facilitate linkages and skills transfer between the stakeholders in the forestry sector, have not been able to perform optimally. This has been mainly a result of the lack of R&D capacity in the SETAs and the lack of a clear understanding as to their role in the economy. However, this does not mean that nothing has been achieved. The timber winch project (Appendix 1, Box 7) testifies to this.

Further, Chapter 7 focused on institutions and realised that some institutions may hinder or encourage innovation. Some of the institutions that were analysed included the competition law, intellectual property regulations, land reform policies, water and environmental regulations, labour regulations, and international forestry regulatory institutions. It was realised that though institutions may hinder innovation, they are necessary to prevent moral hazards and that in some instances they incentivise innovation. For example, environmental and water regulations have been blamed for imposing heavy costs on forestry productivity but the same regulations have in some ways incentivised innovation, with the big firms retreating from riparian zones and cooperating with the government in the Working for Water Programme in funding the removal of alien tree species from wetlands. These regulations have also incentivised the big firms in the sector to certify their plantations with international standardisation bodies to gain access to the lucrative markets of Europe.

The factors having an impact on the integration of the South African forestry SSI are many and interact in varying degrees in bringing about the lack of coordination, limited capacity and limited linkages, which impact negatively on the application of R&D in the sector. However, the factors are linked together and should be considered holistically to prevent putting an emphasis on a single factor. The notion of interaction is hinged on the ability to influence and to be influenced. Interactions are social processes and this understanding brings in the importance of social capital as an important vector in the alignment of the South African forestry SSI for effective and efficient application of R&D. This understanding is crucial, for it takes into consideration the concept of embeddedness, which regards the economy not as a distinctive unit, but as part of broader social, cultural, and political processes, with the government playing an important regulatory function. In this mould, the challenges bringing about the lack of integration and coordination in the forestry sector of South Africa are not only of a technical nature, linked to one or two of the factors discussed in Chapters 5, 6 and 7, but are a result of a complex convergence of factors mediated through social processes whose relevance is greatly reduced when the focus is placed on a single factor. Thus, 'talk' according to Storper (2006) becomes important in integrating components across the regional, national, and sectoral levels.

The thesis also exposed the criticality of institutional alignment if the South African forestry economy is to excel. Reflexive governance is crucial and requires the government and the partners to continuously monitor the impact of a variety of regulations to map as to how they can be improved in a way that promotes forestry innovation and productivity without compromising issues relating to the public good, such as environmental protection, regulating monopolies, and the empowerment of the historically disempowered. Since the policies impacting on forestry productivity emanate from various government departments, there is a need for cross-departmental cooperation in aligning policies and legal provisions and in building broad-based consensus considering the virtues of participatory approaches. Cross-departmental cooperation is crucial in limiting resource wastage by preventing the duplication of programmes, by channelling access to resources in a department to other departments where they are needed and by preventing conflicts with the effect of limiting forestry productivity that may ensue when there is a lack of alignment. The achievement of this hinges on human interactions for departments, components, and structures are made up of people whom they influence but are also influenced and changed by them in reverse.

8.3 Conceptual and theoretical contributions

While the thesis does not contribute to a revision of the theory and conceptual framework, it does illustrate, through the case of forestry and the nested case studies of R&D, new ways of thinking about this literature that takes account of South Africa's complexity. In this way the thesis has contributed to a reinterpretation of the literature on innovation and the evolution of the South African forestry research system. While agreeing with the OECD (2007) prognosis that the South African NSI is less integrated when compared to that of China, the thesis basing on evidence from case studies and from a historical analysis of the South African forestry R&D rejects the OECD (2007) conclusion that the benefits of the NSI for the economy are not known. The OECD's argument is an ahistorical position, which fails to discern the importance of change, continuities, and discontinuities in development. The OECD (2007) takes its stance from a realisation that South Africa adopted the NSI concept in 1996. It failed to realise that the forestry SSI, which is heavily influenced by the NSI but also with some influence on the NSI, was a culmination of the developments that have been taking place in South Africa since the early stages of forestry R&D in the 18th century. By adopting a historical approach, the thesis noted that many achievements have been realised because of the application of R&D in the South African forestry sector, since the 18th century. Chapter 2 noted that afforestation was something that was introduced to South Africa. As a result of R&D, foreign tree species, such as pines, eucalyptus and wattle, were introduced and adapted to the South African environment. The interaction between the government and the private sector ensured that the area under plantation had reached 1.4 million hectares by 1994 (Mayers et al, 2001). The application of R&D in adapting foreign tree species in plantations was a process of creative destruction, a result of human-assisted ecological colonisation. The success of this process is partly realised in the current challenges with regard to the problem of naturalised exotic tree species, which are invading wetlands in South Africa.

As a result of the advances in R&D, Bethlehem and Dlomo (2003) noted that in the 1960s ''the private sector companies became more experienced and developed tremendous expertise in the manufacture of pulp, paper, and packaging, as well as certain solid wood applications'' (p. 4). Currently, because of R&D capabilities gained over time, the big firms in the sector are venturing into new processes to improve proficiency and to widen their product range. Some of the processes include conversion of sludge at pulp and paper mills into bricks, the production of pine oils, the conversion of hemicellulose sugars to xylose and then xylitol, a replacement for sugar for people living with diabetes. New systems have also been put in place to reduce the ecological footprint of the forestry sector in line with international standards. These developments define both radical and incremental innovations in the sector.

Other important benefits of R&D were elucidated in the Jonkershoek catchment experiment, the Fynbos research project, the silviculture studies by O'Conner and Craib and the studies by Phillips, as was demonstrated in Chapter 2. All of these studies generated valuable knowledge in understanding the relationship between plantation forestry and water resources, environmental and biological conservation, the importance of fire in forestry management, and the role of exotic species in undermining species diversity in natural ecosystems.

Further, after the adoption of the concept of the NSI in 1996, a number of benefits emanating from the application of R&D have also been realised. Research projects such as the Cryphonectria Cubensis Project (Appendix 1, Box 3) the Genomics Research Project (Appendix 1, Box 5), Cirex Research Project (Appendix 1, Box 4), and the Timber Winch Project (Appendix 1, Box 7) advanced knowledge in areas important to forestry productivity. These studies generated knowledge and technologies in the production of clones and hybrids which are fast-growing, resistant to pests and diseases, and adaptable to climate change. These studies also generated knowledge important in the preservation of provenances, conservation and forestry systems management which reduced plantation forestry environmental impact. Further, research such as the Timber Winch Project generated technologies customised to SME production activities. Some of these studies, especially in tree protection, started in the 1980s before the collapse of the apartheid regime and have continued under democracy.

All of the advances that have been made provide evidence that the forestry SSI in South Africa has been beneficial with regard to productivity improvement through the introduction of new processes and the production of new products. Though South Africa is still far from the advances made in Europe, for instance in the application of root technologies, some advances have been realised in other areas, where people with advanced R&D skills at masters and PhD levels are employed. This is not, however, to say that they were no interactional challenges. During the colonial era, the refusal to renew De Vasselot's contract in 1893 and the dismissal of Tom Sim in 1906 as the Conservator of Natal as a result the short-term approaches to R&D and of the lack of financial resources were interactional challenges with a negative impact on the application of R&D. These challenges are still existing and impacting the performance of R&D in South Africa. Moreover, South Africa is yet to optimise wood resources in the construction of buildings and bridges, as has been achieved in developed forestry economies, such as that of Sweden. SAFCOL has initiated a project in timber construction, but the project has not yet achieved much, as it has not been fully marketed.[488]

The thesis also brought about a reinterpretation of Bennett and Kruger (2015)'s notion that the apartheid forestry research system was more integrated than the current South African forestry research system. The argument by Bennett and Kruger (2015) is reductionist and is a result of a poor understanding of two important issues defining forestry R&D and its history in South Africa. These are the lack of understanding of the historical origins of the 'development of underdevelopment' in the South African forestry sector and the lack of understanding of Douglas North's concept of 'path dependence'. The history of forestry R&D in South Africa, as elaborated on in Chapter 2, shows that partnerships, collaboration and networks of a triple or even of quadruple helix kind started in South Africa before the adoption of the NSI concept in 1996. The adoption of the concept of NSI was a formalisation of the processes that had started to emerge in the South African context before 1996. As such, assessing the benefits of the forestry SSI starting from 1996 leads us to pitfalls of an epistemology that seeks to deconstruct the importance of history and with it the importance of change and continuities in history and fails to appreciate that the achievements and failures after 1996 are also partly informed by the R&D activities before 1996. This epistemology is dangerous, for it whitewashes the nuances in the forestry sector and avoids questions as to why partnerships, collaboration, and networks during the colonial and apartheid periods were more developed in the white segment of the forestry sector and did not develop in homeland community forestry. Without an understanding of change and continuities, the origins and impact of the current duality in the forestry sector, whereby we

[488] Ms B32, Senior Manager- Transformation, SAFCOL, interviewed by Mushangai, Nelspruit, Mpumalanga, 26/10/2017

have the big firms, such as Mondi and Sappi, having their own laboratories and applying the most up-to-date technologies, existing in juxtaposition to underdeveloped SMEs, mostly in the hands of black people, cannot be comprehended. Such a history is important in understanding, for example, De Soto’s position on the extra-legal sphere (informal sector) and Shapira (2010) on what needs to be done to prop up small businesses. Thus, historicising enables us to understand the challenges with regard to the historical roots of the emergence of the second economy in the forestry sector, the lack of financing, the lack of technologies, the lack of social capital (as in partnerships, networks), and the lack of operational, interactional and managerial capabilities, among the SMEs in the forestry sector. It is these dynamics that enables us to comprehend the virtues informing affirmative action strategies as in BBBEE, the land and agrarian reforms and the emergence of various support and financial schemes by the democratic governments aimed at building the capabilities of small businesses. The argument by Bennett and Kruger (2015) is thus a result of a selective appropriation of history, whereby their knowledge was built mainly by studying the white segments of the forestry sector and failing to realise that the development of the white segments of the economy and underdevelopment in the homelands are two sides of the same coin and should never be explained separately. The problem of selective appropriation of history has caused Bennett and Kruger (2015) to present a fallacious argument that the current South African forestry system is not integrated compared to the apartheid system. The apartheid forestry system can never be said to have been integrated for it excluded other racial groups in South Africa.

Further thesis also contributed in mainstreaming the importance contextual and historical considerations in understanding the research dynamics in the forestry sector of South Africa. The thesis argues that comparison between South Africa with any other country’s system of innovation should take into consideration these historical and contextual dynamics [489]. For example, it is crucial to consider that apartheid was a special kind of societal organisation within the South African capitalist system not experienced in any other country and the democratic South African constitution informing innovation policies adopted by the democratic governments

[489] The historical analysis of the South African Forestry research system in Chapter 2 shows that the system was not static but evolved in relation to time, local and international developments within the capitalism system itself. Thus comparisons can also be made of the system itself through time. The differences through time may indicate the changing contexts and research dynamics. These historical dynamics and contexts defining a system of innovation within a capitalist system differentiate national systems from each other. This idea links to Soskice and Hall (2001)’s idea of ‘Varieties of Capitalism’ hence the notion of ‘varieties of systems of innovation’.

have been concerned with redressing the apartheid patterns of accumulation and the attendant inequalities with a focus partly on social innovation. Comparisons of systems of innovation should thus be able to measure what they claim to measure or may end up distorting the reality which we are seeking to comprehend, by neglecting important variables with explanatory power as to why a system may be ineffective or disintegrated or may disintegrate. When comparing China and South Africa, we have to historicise to understand if the Chinese and South African historical development trajectories are similar and, if they are, then we may ask what strategies were put in place by China to propel innovation and industrialisation in its forestry sector. Without this understanding, we may distort the reality which we are seeking to comprehend, and South Africa may end up mimicking the Chinese policies that may unintentionally further skew the economy by failing to consider contextual and historical realities as the basis for addressing the roots of the ‘development of underdevelopment’ in the second economy of the South African forestry sector.

Moreover, thesis further contributed to a radical reinterpretation of the the history of the evolution of the South African research system. In doing this the thesis discarded Bennett and Kruger’s (2015) argument that the South African forestry system developed in contradistinction to European and Indian forestry traditions. It argues that their argument emanates from a lack of understanding of epistemic cultures (discussed in Chapter 2 and Chapter 3) and the international dimensions of a forestry SSI in knowledge generation and application. The naturalisation of alien tree species in South Africa can be explained within the framework of epistemic cultures. Through the application of European and Indian forestry traditions, early foresters at the Cape were able to learn through experiments and to develop models such as the bio-climatic models in adapting exotic tree species to the South African environment. It was because of the success of the bio-climatic modelling that the Cape foresters thought that their practices were different from those of Europe and India. However, the epistemic cultures concede that knowledge production precedes in reverse, opposites, and contradictions, hence the Hegelian/Marxian tradition of thesis-antithesis-synthesis criteria in knowledge development, implying the continuous testing and verification of the hypothesis. This is also implied in the ‘conjectures and refutations’ of Popper (1989), which implies the continuous testing of hypothesis to determine their validity and explanatory power. The fundamental feature of epistemic cultures is the continuous questioning of the knowledge one has in order to improve it or to refute it. This is important to move from a particular position to a general understanding with universal application. The claim by the Cape foresters that their practices were different from those in Europe and India was soon disputed by officials in Transvaal in 1907, based on the need for the interaction of the South African forestry system with European knowledge systems by employing a European-qualified forester as the head of the Tokai School of Forestry. Thus, the government of Transvaal was bemused by the failure of the Cape foresters after spending 30 years of research in classifying the Eucalyptus genera. These dynamics point to the fact that the practice of scientific forestry in South Africa from the earliest years was a fusion of both locally produced knowledge and universal knowledge based on scientific principles, hence the European, American, and Indian influences.

In addition, it should be understood that a forestry SSI may also have researchers from different countries who work together in generating knowledge and developing technologies to address forestry problems. In the Cryphonectria Cubensis Project, the Cirex Research Project, and the Genomics Research Project, it was realised that South African researchers interacted with researchers from other parts of the world and adopted technologies from other countries, such as the PCR technology developed in America. These interactions in an SSI are crucial if nations are to tap into international knowledge systems in building their research capabilities. A lack of the understanding of the operation of epistemic cultures and of the knowledge base of an SSI puts a country at a disadvantage in the knowledge economy of the globalised era. Further, the fact that most of the early professional foresters and scientists in the South African forestry sector were trained at leading European schools means that forestry knowledge production was somewhat influenced by the knowledge these professionals had acquired at European and American schools.

The thesis has also contributed to a reinterpretation of the Sachs and Warner (1995) hypothesis which states that natural resource rich countries suffer from dependency 'curse', hence the inability to achieve high growth rates. The South Africa case informing this study provided evidence contrary to the Sachs-Warner resource curse hypothesis. It demonstrated the possibility of a country to derive development from its own natural resources. Evidence from the South African forestry sector demonstrated that natural resource-based economies can capitalise on their natural resources to propel diversification and industrialisation through resource beneficiation and the export of semi-finished and finished products. This, according to Calatan

(2002), can happen ‘’...as long as learning and innovation reach higher levels and technology creation, absorption, adaptation and diffusion occur’’ (p. 2-3). Countries such as China, Canada, and Sweden were able to industrialise their natural resources because of their strong systems of innovation, which allowed for ‘’learning and innovation to reach higher levels and technology creation, absorption, adaptation and diffusion’’ to occur. A common thread tying these countries together was the cooperation between their governments with the higher institutes of education and the private sector in stimulating innovation and technology application as the basis for forestry industrialisation.

South Africa did not have any natural forests except for some patches of lands with a few valuable stinkwood and yellowwood trees when Van Riebeeck arrived at the Cape in 1652 (Briton 2006). However, its development from the earliest phases of colonisation was hinged on the exploitation of natural resources. According to Fine and Rustomjee (1996), South Africa’s industrialisation trajectory revolved around what they have termed the ‘minerals-energy complex’ (MEC). All other sectors of the economy failed to optimise and diversify because they were linked in a state of servitude, servicing the interests of a few monopolies involved in mineral extraction and energy production, especially after the discovery of diamonds at Kimberly in the 1860s and that of gold on the Witwatersrand in the 1880s. Though the plantation forestry economy in South Africa grew in subordination to the dictates of the mining and energy sectors, it is crucial to note that the plantation economy in the white segment was somewhat able to diversify and industrialise, mainly emanating from the application of R&D, as elaborated on in Chapter 2. The achievements of the South African forestry SSI from the colonial through the Apartheid period to the democratic era become much clearer when we compare the level of diversification and deepening of the South African plantation forestry economy with other countries endowed with rich natural resources, such as Gabon. The first remarkable achievement was the establishment of plantations on a remarkable scale. This was only made possible through the application of R&D. In 1800, South Africa did not have any plantation forests but, by 1999, the area under planted forests had reached 1.5 million hectares, supplying the timbers needs of the mining industry, the construction industry, the furniture industry, the sawing milling industry, the pulp and paper manufacturing enterprises, and in exporting wood chips, among others. Unlike countries such as Gabon, which relies on the exploitation of natural forest timber

(Terheggen, 2011), South Africa exploits plantation timber in fostering forestry-sector industrialisation.

Further, South Africa's value chain is much more diversified and deepened compared to countries like Gabon. South Africa supplies products from mining props, veneer and plywood, pulp and paper, solid wood for trusses, rail sleepers, timber for the furniture sector, wood chips, chemical products, and concrete additives. South Africa is further heavily investing in emerging bio-manufacturing technologies, as was noted in Chapter 5. Although South Africa is far from the technological frontier in comparison to the forestry economies of Sweden and China, possibilities of a catch-up are high, especially if the alignment is achieved in its SI. Evidence shows that South Africa is already leading in new frontiers of forestry innovation, such as the application of genomics and quantitative genetics in tree breeding, forestry management, conservation and the production of new products (Genomics Case Study, Appendix 1, Box 5). To a greater extent, South Africa has managed to overcome the resource curse, despite the subordination of the plantation economy to the dictates of the mining and the energy sectors. Contextual considerations will determine whether South Africa catches up or remains behind countries such as Sweden and China in relation to forestry innovation and development. South Africa has to address issues related to land reform and sustainable development, equal access to education, access to financing by SMEs, and others, which are working against the integration of the NSI and the forestry SSI.

Moreso, the thesis demonstrated the importance of the partnerships between the leading firms and the SMEs in building the operational capabilities of the small firms that are joining the sector. Despite the criticism that the out-grower schemes are exploitative[490] and best at the transferring technical skills, evidence also points to the fact that some schemes, such as the Mondi-Zimele scheme, have been good in the transfer of both operational and business skills. Based on the Mondi-Zimele scheme, the study rejects the notion that the big companies established during apartheid times are always exploitative of small upcoming businesses in value chains and demonstrated that, if anything and at times, these big firms and their partnership schemes have offered the most effective way of transferring skills and technologies to SMEs

[490] Prof B43, SAFCOL Research Chair, Interviewed by Mushangai, University of Pretoria, 13/07/2016

outside the skills system. What is important is for the government to support and extend these schemes with a focus on strengthening the provision of business skills. In addition, the government should oversee the levelling of the power asymmetries in these partnerships to ensure that the benefits accrue to both parties in the forestry value chain.

In South Africa, the truism is that the big companies have the knowledge and technologies because of historically acquired advantages. As a result of these advantages, the big firms are more innovative and able to create employment rather than the small-scale enterprises mostly in the hands of black people. Therefore, to address the employment challenge while promoting redress through black empowerment programmes, there is a need for a mix of policies that supports the top-down approaches to sustain the big firms so as to maintain productivity and create employment and the bottom-up approaches to support small-scale firms and link them to the big firms to ensure skills and technological transfers, allowing them to upgrade their businesses.

The thesis rejects as a half-truth the high skills thesis with regard to the future of forestry resource production in South Africa. High-level R&D capabilities are crucial for the advancement of the South African forestry sector. The cases such as the Cryphonectria Cubensis Project (Appendix 1, Box 3); Cirex Research Project (Appendix 1, Box 4); the Genomics Research Project (Appendix 1, Box 5); and the Eco-Furniture School Desk Project (Appendix 1, Box 6) demonstrated the necessity for the production of high-level scientific skills mostly at masters and PhD levels required in the generation of new knowledge, skills, processes and products. Further, bio-manufacturing, which the South African forestry sector is now focusing on, requires high-level skills. However, much of the production activities by the SMEs in the sector require low to intermediate skills, mostly produced at agricultural colleges. Some of the skills required by the SMEs, such as management and operations, can be acquired through linkages with the big firms in the forestry sector in schemes such as the Mondi-Zimele scheme. These skills are crucial to SMEs because most of their innovation activities are a result of imitation, adoption, and adaptation of technologies already in existence.

The existence of firms of different sizes requiring different skills in the sector calls for a multi-pronged strategy in supporting all post-school knowledge organisations across the intermediate education organisations and higher education organisations in South Africa. This would allow the production of a mix of skills catering for the requirements of both the big and small firms in the sector. The university should have links with the agricultural colleges involved in applied research. The links are important for such intermediary organisations as agricultural colleges render important extension services required at the firm level for innovative activities. This is an important missing link in the South African System of Innovation.

8.4 Methodological contributions

Methodologically, the thesis contributed in demonstrating the potential for a deeper understanding of systems of innovation by employing a variety of qualitative techniques (from interviews, case studies, observations, documentary material, and desktop research) within an appropriate theory. This enables a synthesis of perspectives from various sources bringing about a nuanced understanding of systems of innovation as opposed to generalistic survey data. The focus of the study of interactions gave qualitative techniques a priority for they enable the researcher to understand reality from the participant's point of view.

Further methodologically, the contribution of the thesis lies in the emphasis placed on the interaction between macro-dynamics and micro-dynamics in skills development and the promotion of innovation. Most of the literature on skills development tend to separate the two and to ignore the interactions. Researching these levels in isolation tends to limit our understanding of the ramifications of macro-dynamics at an international level on local skills formation processes and the impact on innovation. Globalisation and information technologies have blurred the nation-state bounderies, making it difficult to understand local systems as isolated from the international systems. The focus of the thesis interactions is critical if the South Africa is to account for the factors affecting the competitiveness of its firms in local and international contexts.

8.5 Contribution to Education studies

The focus of the thesis is on interactions in a system of innovation (SI) that enables the comprehension of how new knowledge moves between research organisations, sectoral actors such as firms, and the processes of mediating these through education and training. This is where the education part of the thesis lies. The thesis contributed in showing that knowledge production processes are changing in a fundamental way. The focus is nolonger on isolated individuals working in isolation within their disciplines but on the interplay of different actors within a system of innovation in skills formation, knowledge generation, transfer, and application. Knowledge production is nolonger the prerogative of individual researchers working in isolation within their disciplines but is shifting with focus multi/trans/inter-disciplinary ways of generating knowledge. Linked to this is the importance of collaboration, partnerships, and knowledge networks. The advantage these forms of cooperation in knowledge production, transfers and application is that they reduce transactional costs in knowledge generation, transfer and application. Also cooperation between the knowledge producers and the end-users reduces the knowledge-practice gap. These forms of cooperation are a new reality mainly made possible by the proliferation of information technologies which are lessening the challenges in the interaction between collaborators in different regions of the world.

The framing of the study within the critical research paradigm allowed the study to critically interrogate the nature of interactions focusing on power relations and the inter/multi-disciplinarity nature of the issues bringing about the lack of integration (OECD, 2007), 'weak coordination', 'weak linkages', and 'limited capacity' (Greenburg, 2010) in the South African Forestry SSI as a backdrop ''to address missing components or missing connections'' (Metcalfe, 2004) important in improving the efficiency of the system in the employment of R&D. However, development is not a one-way process and nations have to juggle with all available paradigms, taking into consideration their own environments and historical realities in crafting development strategies.

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Appendix 1, Box 2: The fire research project

Introduction

This aim of the fire research was to understand the fire flow patterns in the landscape so as to minimise the fire menace on plantations. The understanding of fire pathways is important minimising loses due to fire by preventing the establishment of plantations in fire pathways. The study was a result of the realisation that many plantation firms were losing a lot of money due to fire damage because their plantations were wrongly placed in fire pathways. The knowledge of fire pathways is also important in determining the areas to concentrate on in firefighting during fire outbreaks. To this study the fire research is important in demonstrating that the reluctance by some firms to consider and implement the results of scientific studies have been behind some of loses by plantation firms due to fire damages.

The study

The study by Prof B44 was based on systematic scientific observations of fire flow patterns in planted and natural forest areas throughout South Africa.[491]. This followed the fire damages in 2007. The 2007 fire damages to plantation forestry in South Africa had led Peter Briscoe to suggest the planting of natural forests as fire breaks (Geldenhuys 2007:4). Peter Briscoe considered indigenous forests as 'fire resistant and adapted to fire regimes over time' (Geldenhuys 2007:4). However, following a careful and systematic observation of the scars left in the landscape by these fires, Prof B44 concluded that the fire flow patterns in the landscape and the spatial patterns of natural vegetation were important in giving clues as to where plantations should be located to prevent fire damages[492]. Prof B44 observed that the high-rainfall areas of South Africa are made up of grasslands, woodland, and patches of forest[493]. He concluded that the spatial patterns these types of vegetation are related to fire frequency[494]. From his systematic observations he noted that where fires are frequent, the common vegetation available would be grassland whilst in areas where fires are sporadic the common vegetation is made up of woodlands and evergreen forests (Geldenhuys 2007:4). Prof B44 further observed that fire moves along with the flow of air around and over barriers causing a fire pathway[495]. This movement of fire is directed by the fact that hot air moves up and strong wind cannot suddenly change direction and blow down a steep slope[496].

According to Prof B44, the loss incurred by the plantation firms from 2007 to 2017 due to incidences of wild fires was a result of the lack of knowledge on fire flow patterns by firms[497]. From his observations, Prof B44 concluded that the plantation damages and the resulting loses due to fire could have been prevented had the forestry firms understood the fire behaviour at the landscape level and had these firms been able to read the spatial patterns of the natural vegetation in the landscape as guides when establishing their plantations[498]. The patterns of natural forests on the landscape are a result of a long history of interaction between these forests and fires (Geldenhuys 2007:5). As such natural forests on the South African landscape are found outside natural fire pathways[499].

[491] Prof B44. Forest Ecologist, UP, interviewed by Mushangai, UP, 29/05/2017
[492] Ibid
[493] Ibid
[494] Ibid
[495] Ibid
[496] Ibid
[497] Ibid
[498] Ibid
[499] Ibid

Results

From his study Prof B44 drew three main conclusions worth noting and these are: (1) in most cases the fires stop at the boundary of natural forests in all forestry areas throughout South Africa, (2) large areas were being burnt in total but with the natural forests within the same regions left intact, or with some scars where natural forest had expanded into the plantation area, (3) Natural forests are as vulnerable to fire as other vegetation formations and plantation stands and nothing would be gained by planting fire breaks of indigenous forest species – just effort and costs (Geldenhuys 2007:4). As such Prof B44 concluded that natural forests survive fire in most instances in South Africa not because they are fire resistant but because they happen to occur in 'wind shadow' areas, not along fire pathways[500].

From these observation Prof B44 realised the importance of (1) the need to understand wildfire history at regional and at the landscape level and to identify hazardous areas through the region or landscape specific fire hazard classification (2) The need for fire simulation through wind flow dynamic studies with consideration of the topography of the terrain (Geldenhuys 2007:4).

Challenges

The challenge in South Africa with regard to the employment of R&D is that most plantations are established in grassland and fynbos areas which are located in fire pathways. This challenge is exacerbated by the fact that most forest firms do not cooperate with researchers in applying certain basic rules pertaining to fire flow patterns at the landscape level as their focus is at local levels[501]. Prof B44 noted that he has been advising forest firms about the fire flow patterns in the landscape but some firms have not been taking his advice, which makes it difficult for the employment of R&D in the forestry sector[502].

[500] Prof B44. Forest Ecologist, UP, interviewed by Mushangai, UP, 29/05/2017
[501] Ibid
[502] Ibid

Appendix 1, Box 3: Cryphonectria Research: A case study by Prof B47 (FABI-University of Pretoria)

Origins of the research project

The *Cryphonectria cubensis* research was conducted by is the Tree Protection Cooperative Programme (TPCP) based at the University of Pretoria. The TPCP Programme started in 1989/90 at the University of Free State and was transferred to the University of Pretoria in 1997[503]. The TPCP is now 27 years old. The programme was started because in the 1980s commercial forestry started shifting from planting pure species to planting clones[504]. Firms selected the clones based only on two characteristics, that is, the timber quality and growth. The firms did not consider the threat of pests or pathogens at that stage[505]. The clones performed wonderfully in the first few years after planting but then started dying in the Zululand, in KwaMbonambi area[506]. The cause of death was two fungal diseases. The industry then approached, Prof Wingfield who was at that stage the only forest pathologist in South Africa wanting to understand what was killing their trees and how to manage this and they started this TPCP programme[507]. The study has had several breakthroughs because of the interaction and funding from private forestry firms, the government, and international collaboration. Prof B47 noted that though the funding is in not enough, the TPCP has received funding from the Industry (FSA), NRF, DST, and THRIP[508] and DAFF. The FSA Annual Review (2016:16) noted that the Technology and Human Resources for Industry Programme (THRIP) 'had been funding for the sector and its partners for some time'. THRIP does not fund individuals but encourages collaboration through funding collaborative research projects[509].

The study

The research focus was the identification of new problems on trees, understanding the pests and pathogens, how they interact with their environment and with the host[510]. This was to help companies to select resistant or tolerant material, help government, and their agencies to establish appropriate quarantine and management guidelines to deal with pests and pathogens and to train the students in the process[511].

When the forestry firms approached the TPCP they only wanted a solution, that is applied research and were not interested in the basic functions of research which in this case would have involved research into where the pest is coming from, how diverse it was, and the name of the pests[512]. The industry said, 'where it's from…we don't care, just solve the problem' As such there was a conflict pertaining to the focus of the research as the university researchers were also focused on broad issues in order to generate a broad understanding with regard to the pest whilst the funders- firms, were only concerned about cutting costs by limiting the study to functional aspects of research. As a result of 'talk', the firms were compelled to

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503 Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
504 Ibid
505 Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017
506 Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
507 Ibid
508 Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
509 Dr B4. Research Director- Forestry South Africa (FSA), interviewed by Mushangai, Illovo, Johannesburg, 16/10/2017
510 Ibid
511 Ibid
512 Ibid

compromise to allow the researchers to focus on both the basic and applied functions of research. Thus, the study evolved to understanding the biology of the pests and pathogens through sequencing of the genome[513].

The research confirmed that the clones were dying from fungal infection. *Cryphonectria cubensis* was the name of the fungus at the time. The fungus is now called Chrysoporthe cubensis (Roux et al 2005:411). It was first identified in the 1990s (Wingfield, Swart and Abear 1989:311-313). At first, it was believed that the fungi were foreign to South Africa and was introduced with the introduction of the exotic tree in the country[514]. However, as a result of research, the original understanding has undergone several changes. It is now understood that fungus is native to Africa and originated from native species[515]. It did not cause diseases in native species because it was in the balance but then it jumped onto exotic eucalyptus, which is closely related to some of the native species[516]. The exotic eucalyptus does not have the natural resistance and it started killing it[517]. The research discovered that *Cryphonectria cubensis* was not only a single fungus as was believed at first but a family made up of more than 50 species of fungi[518].

The new knowledge that the fungus was native to Africa and that it was a family of more than 50 species compelled the researchers to go further to generate the understanding important in knowing the true identity of this fungus[519]. That understanding was regarded by researchers as important from a quarantine perspective and from breeding perspectives[520]. The knowledge is important in developing disease resistant planting material for the industry and in generating technologies to screen the planting material[521]. The firms become more lenient and patient with regards to understanding that 'we have got to have this longer-term more academic research because it does feed into our needs and demands also at the end'[522].

The study also benefited from international collaboration with various international universities and research organisations, and the US Department of Forestry[523]. Collaboration with government departments and, research organisations in other parts of the world were important because when working with pests and pathogens, is not only a South African problem because 'these things move around all the time'[524]. Through those collaboration technologies developed in other countries were brought in and adapted to the South African context. For example, the PCR was developed in the US and with international collaboration and learning, the technology was brought to South Africa[525]. The PCR is a molecular technique to multiply the DNA so that you can sequence the genome, get that barcode[526]. The technique originated in the field of human medicine but is now also employed in the field of plant biology and plant protection. These collaborations have been enhanced with the development of general ICT technologies[527]. In the 1980s international collaborations was via telephone or letters, sharing

[513] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
[513] Ibid
[514] Ibid
[515] Ibid
[516] Ibid
[517] Ibid
[518] Ibid
[519] Ibid
[520] Ibid
[521] Ibid
[522] Ibid
[523] Ibid
[524] Ibid
[525] Ibid
[526] Dr B5. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018
[527] Ibid

information that allowed the diffusion of these technologies to South Africa[528]. With the development of modern communication technologies such as Skype, the internet, and e-mailing interactions, the exchange of knowledge and technologies is now quicker[529]. The researchers in the TPCP Programme at the University of Pretoria were the first in the country to apply the technique in understanding the biology micro-organisms and plants[530].

The technologies at the time when the programme started (the 1990s) were not very much efficient and 'started off with planting trees, waiting 6 months, going to put the fungus in there, waiting another 6 months before you get a result'[531]. This has now evolved as the modern technologies have shortened the time before you can say what is resistant, and what is tolerant[532]. The Molecular-breeding project at FABI- University of Pretoria built upon the pest and pathogens research, up-scaling it and making the processes quicker[533]. Thus, the *Cryphonectria cubensis* project benefitted also from local collaboration especially the Molecular-breeding project at FABI, University of Pretoria.

Importance of collaboration and challenges involved

The project benefited from the collaboration between the TPCP –University of Pretoria, firms, and the government. The firms and the government provided funding whilst the universities provided the expertise required to carry out the research to provide solutions with regard to breeding and quarantine mechanisms. However, relationships are not always smooth because the different collaborating partners have different interests. In this case, the conflict emanated from the fact that the firms wanted to limit expenses by compelling the researchers to focus only on providing solutions related to the applied functions of research[534]. However, the researchers noted that this was not possible without generating a much more basic understanding of the pest with regard to its origin, diversity, and biology. Through continuous negotiations, the industry was made to realise the importance of basic research[535]. This process took place with contracts being signed between the partners. Prof B47 noted that the relationship with industry was not always easy but now the industry has been supporting to research on other pests and pathogens that are threatening plantation forestry for the past 27 years[536]. The continuity of this relationship is because the firms can now see the benefits of long-term academic research. Thus, research should be able to produce evidence that supports effectiveness predictions. Compelling evidence is important to incentivise the funders to continue funding an organisation's research project. This was the case with TPCP's *Cryphonectria cubensis* study.

Collaboration between research groups was also important for the success of this research project. The molecular breeding project assisted in quickening the breeding processes, and the growth of the fungi in plants under laboratory conditions and in understanding the biology of the organisms[537].

However, the major challenge was that collaboration and interaction 'is not always easy, it is not always positive, sometimes there are some very strong disagreements as to what is a priority or not, …they are still an industry, they still need to make money, so they still… need to have a solution tomorrow or next week, which does not exist in forest protection, so it is not always a smooth plane sailing interaction, but we have over the years cultivated a trust and that understanding, that yes, there

528 Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
529 Ibid
530 Ibid
531 Ibid
532 Ibid
533 Ibid
534 Ibid
535 Ibid
536 Ibid
537 Ibid

will not always be an agreement in everything but we can speak openly, we can disagree, but we continue the collaboration and for 27 years that has continued'[538].

The study was also limited by the shortage of skilled experts in the field of pests and pathogens. South Africa starting from the late 1980s has been losing its professionals to developing countries such as Indonesia, Brazil, and China[539].

The other problem pertains to the lack of resources for bursaries to build the critical mass needed for research in this area of forestry production.

Results

The programme has had several breakthroughs because of collaboration with the private companies, the government, and international partners. Funding has been coming from private companies, government, and the international collaborators and this facilitated a longer-term vision related to pests and pathogens research. The project has brought in new technologies (e.g. PCR) and has been at the forefront of a lot of the new developments for South Africa and the African continent. It has improved knowledge of biodiversity in the country and has helped in developing disease resistant planting material for industry and in generating technologies to screen the planting material[540]. There has been a revolution in forestry commercial production in SA as a result of these achievements[541]. The firms have accumulated benefits especially from, 'having trees that do not die, so having the stems in the ground, then the quality of the product that comes out, you do not want things with spots and cracks'[542].

Creative destruction has occurred with regard to understanding tree breeding. When the firms shifted to planting clones in the 1980s they were mostly concerned with two characteristics, that is timber quality and growth but 'now pest and pathogens and resistance or tolerance to pest and pathogens is number 1 or 2 on all of their lists for when they do their evaluation and selection for new material that they will be planting'[543]. That is one of the impacts of the research in making a complete mind shift as to what they consider important when doing selection for breeding purposes.

More than 50 species of fungi, 'which nobody knew they existed, they did not have names, have been described'[544]. It is now known that *Cryphonectria cubensis* is not a single fungi species but a family of fungi species of African origin. It is not of foreign origin as was previously assumed at the beginning of the study. All of discoveries are improvements to the knowledge of biodiversity in South Africa. As a result of this knowledge, scientists have helped in developing disease resistant planting material for industry and the technologies to screen this material.

Further and as a result of this research, the University of Pretoria now runs a world-class biological control facility that produces biological control agents (FSA Annual Report 2013:11). This is something usually done by a commercial company but now FABI- University of Pretoria is mixing that with doing academic research but being 'very carefully to plan our research so that we can maintain that commercial side without it impacting on our academic and scientific side and keeping both bosses happy in that sense'[545].

The research also reflected on the importance of collaboration in knowledge production and application. International collaboration was important in making available foreign generated technologies such as the PRC and in adapting these

[538] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
[539] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
[540] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017
[541] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
[542] Ibid
[543] Ibid
[544] Ibid
[545] Ibid

technologies to local contexts.

Further, many students were trained in the process of researching. Student training is important on part of the university as universities are assessed partly in terms of the number of students they would have trained. Developing a large skills base was also important in the development of the critical mass required in monitoring and surveillance of pest and pathogens and in the implementation of tree protection mechanisms. The relationship that developed between the industry and academia in the process compelled the firms to offer bursaries to students in forestry-related studies[546]. Also, the industry is assisting in the training of students by providing access to their properties, giving their time to 'interact with us and our students' allowing the students to see things happening in practice[547]. This also helps in forestry awareness on the importance of trees and saving the environment.

[546] Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

[547] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

Appendix 1, box 4: The Sirex Wood Wasp (Sirex noctilio) research: A case study

Sirex Research Programme

The Sirex Control Programme started in 2002. Traditionally in terms of forestry production, not so much attention was paid to pests and diseases[548]. According to Dr B3 before the Cirex programme (2002) in the 1990s, many of the players in the sector including the managers in the big companies like in Sappi and Mondi were interested in investing in productivity improvement and did not buy the idea of investing in forestry research focused on pests and diseases. However, a lot of reviews which were conducted in the early 2000s revealed that the quantified losses due to pests and pathogens on forestry production runs into hundreds of millions of rands and in some cases billions[549]. These discoveries changed the approach of the industry in relation to investments in pest and diseases.

When the Cirex Programme started, it adopted a stakeholder inclusive approach to research[550]. The programme is funded through a private-public partnership between DAFF and FSA (ICFR Annual Report 2016:40). FABI and the ICFR support the programme through research and the provison of the necessary technology[551]. FABI supplies the biological control nematode (*Deladenus siricidicola*) for deployment in plantations in South Africa and Swaziland and determines the rate of parasitism by the nematode (ICFR Annual Report 2016:40). The operational aspect of the project is managed by the ICFR (ICFR Annual Report 2016:40). The ICFR, monitors the levels of parasitism by Sirex noctilio and releases the contro agent *Deladenus siricidicola* when appropriate (ICFR Annual Report 2016:40)

The project involves four main aspects which are: the operational control of the Sirex wasp (*Sirex noctilio*) through the deployment of *Deladenus siricidicola;* monitoring the spread of Sirex in South Africa; Research to support the Control programme; and Communication of information to stakeholders. The whole project is managed by a steering committee made up of forestry companies, DAFF, FSA and research staff from FABI and the ICFR.

The study

The Sirex Control Programme was only focused on the pines. The Sirex wasp targets pine trees. *Sirex noctilio* is a wood wasp that is attracted to trees that are stressed[552]. When trees are stressed from drought, they release plant volatiles which are referred to as chroma[553]. The insects (Sirex) can detect those chemicals and are then they are directed towards those trees. According to Dr B3, this is a natural occurrence like a natural selection (survival of the fittest) in that the weaker trees are targeted by the wasp[554]. The wasp would lay their eggs in the stressed trees. *Sirex noctilio* has got a life cycle which starts with the egg and the egg would hatch into larvae, the larvae would complete its development into pupae, and the pupae would then develop into a new wasp[555]. In this process, the pine tree would die and the firm will effectively lose that tree. The tree affected cannot be used for sawmills, for pulp and paper or for any other application that you want to use it for[556].

However, through research and international collaboration with researchers in Australia, the researchers in South Africa got to know that the Cirex wasp can be controlled biologically through the introduction of biological agents that infect and kill the wasp[557]. The biological agent, in this case, is a nematode- *Deladenus siricidicola* found in Australia. Since the nematode is not native to South Africa and the South African researchers had to import it from Australia.

The researchers first had to understand how it works to develop control mechanisms. The nematode controls the spread of the wasps by

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548 Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
549 Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017
550 Ibid
551 Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
552 Ibid
553 Ibid
554 Ibid
555 Ibid
556 Ibid
557 Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016

infecting infect the Sirex wasps. The researchers had to inoculate the trees and the female wasp would go there and lay her egg but, in the process, pick up this nematode[558]. The nematode would then start multiplying inside her body and actually kill her[559]. However, over time, from 2002, the researchers started a breeding process of these nematodes in South Africa[560]. Since the program started in 2002, researchers inoculated trees in the field, and every year the program would have trap trees where they actually catch some of these Sirex wasps. They would then dissect them and from that, they would culture the nematode[561]. The process isolated the nematode from these wasps, and then the researchers will multiply them[562]. Thus, the nematode is now reared in South Africa and that comes with to intellectual capital, something developed in South Africa which was not there before and which the researchers did not have the skills or the ability to do[563].

Results

According to Dr GD, 'great advances have been made, we are busy at the moment with the strategic review to show what benefits we have realised, and it's positive in terms of the improvement that we have made in terms of area that are infected by this wasp and the contribution that has been made since we started the program'[564].

One of the results was intellectual property realised from the rearing of the nematode (*Deladenus siricidicola*) that infects and kills the Sirex Wasp. With that, were processes of learning that led to the development of the ability to rear the nematode that was not available before in South Africa[565]. Further, numerous papers and a textbooks were published and numerous conferences were held. Also, in terms of academic advancement, many Ph.Ds graduated and that was a big benefit from the program[566]. As a result of the research, the University of Pretoria now runs a world-class biological control facility at their University campus in Pretoria (FSA Annual Report 2013).

The Cirex Control Programme has led to the development of other projects aiming at tree protection. Beside the nematode, the researchers involved also discovered another wasp in the process of research, the Ibalia wasp (Ibalia leucospoides), but of a different species that would actually kill the Sirex Wasp and can also be introduced to plantations as a biological control mechanism[567].

Recently, there has been a growth in the demand of Eucalyptus (especially saligna eucalyptus) as hardwood and a replacement of the indigenous and now protected hardwood species. The Integrated Forest Protection Strategy was compelled to realise that they cannot only focus on pines and Cirex wasp, as the problem is much greater, especially with the introduction of many new pests over the last 10-years, but most of them also focused on Eucalyptus[568]. The Sirex project was thus also extended to find protection mechanisms for the eucalyptus species threatened by the Eucalyptus Gall Wasp (*Leptocybe invasa*) in South Africa. The Gall wasp attacks eucalyptus species especially younger Eucalyptus. The wasps lay their eggs on the plants and that would result in their larvae starts to emerge and feed on the plant. The plant would respond by producing a gall. The photosynthesis processes are impacted on negatively and the tree would not grow in a normal way[569]. In this process, if there are a lot of these insects around the trees, the trees would almost grow into something that looks like a bonsai tree[570]. The researchers have therefore been trying to encapsulate that infestation.

The concern about tree protection led to the development of an Integrated Forest Protection Strategy and with it the national pest and disease committee. This led to the development of Working Groups focusing on the protection of different plantation species[571]. The Letsabi

558 Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg, 10/11/2017
559 Ibid
560 Ibid
561 Ibid
562 Ibid
563 Ibid
564 Dr B5. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018
565 Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg,
566 Ibid
567 Ibid
568 Ibid
569 Ibid
570 Mr B12. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017
570 Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017
571 Ibid

Working Group focuses on eucalyptus, and then there is the group that focuses on wattle species, and then another focusing on the pine species but all governed by a national pest and disease committee[572]. DAFF is also represented on the committee. However, with different groups working on the protection of different species, there have been conflicts as each group feels their priority should be the greatest in terms of funding[573].

The Sirex Control Programme is still in existence today. There was an expansion, which spread through the whole of the country whereas it was only focused originally in the Cape Province. However, there has been a decline in the number of infected trees and this has resulted in a lot of economic benefits to the industry. The nematodes are now in the system and the infected wasps are transferring this into the trees, which will be infecting the next wasp that will go there. This is already is reducing the risk that the firms had from the pest[574]. As such, the focus of the project has now shifted to monitoring.

The benefits of the research have also accrued to the firms. There had been a reduction in terms of the infection rate of trees. There is, therefore, a direct economic benefit. In an unpublished paper, an economist calculated the benefit to the industry to be about R400 million. In terms of the investment cost in 2016 monitory terms about R80 million was invested and the return was about R400 million rand[575]. In terms of 'reducing losses and in terms of investment of what we had to invest, so that is without the leverage through the universities and so forth, but a direct investment that was made, so that R400 million benefit is in 2016 monitory terms'[576]. The cost-benefit is hugely positive and actually translating that research into something that the industry uses and that contributes to the economy of South Africa[577].

The Sirex Programme communication and awareness has ensured a high level of awareness of Sirex and its control among stakeholders. This was achieved through field days and a control website by ICFR and through progress reporting to stakeholders (ICFR Annual Review 2016:41). Also, FABI has a technical information system established for the dissemination of this kind of information (ICFR Annual Review 2016:41).

Collaboration and challenges

The collaboration between the industry, the university, and the government was crucial in Sirex Research Programme. DAFF and the industry were able to provide funding for the research. This was important for research cannot be conducted without funding. The university was important in providing the expertise needed to conduct research and provide a solution to the Sirex wasp threat.

Also, collaboration between research institutes enabled the accumulation of the benefits of both the basic and applied functions of research in the project. More so, collaboration allowed the division of labour between the collaborating partners. The Tree Protection and Cooperative Programme at FABI-University of Pretoria was involved in rearing and production of the nematodes and development of technologies whilst the ICFR was mostly involved in applied research and innovations by deploying the biological control agents in the field and in monitoring the trends in terms of trees dying, surviving, affected areas and so on. The project was, therefore, a success because of interactions and collaborations between many partners.

Prof B47 noted that their major challenge pertains to short-termism with regard to government and industry's approach to research funding. Thus, the continuity of the project is threatened by short-term funding whose renewability is not guaranteed[578]. The researchers involved noted that with pests and pathogens, effectivity requires a lot of long-term research as these pests and pathogens change because nature is dynamic[579]. The problems of 20 years ago whose solutions have been devised will no longer be problems today as many new pests and pathogens are continuously coming into the country. This calls for better understanding of long-term research, whose application cannot be seen today but could be crucial in 5, 10, or 20 years to come. The long-term technologies are critically important in the future for the sustainability of the industry.

572 Ibid
573 Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg,
574 Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg
575 Ibid
576 Ibid
577 Ibid
578 Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
579 Ibid

Further, Dr R noted of the challenges involved in working with the government and the need for more efficient communication and coordination. This is made difficult especially when working with the government because of the high turnover with 'every time a new person coming in. That has been a frustrating thing … today you're working with person A, next week person A is gone, then you've got to work with person B, you don't always hear that person A has left. That is a big challenge, working with the government, and just keeping up with some of the changes in people. Somebody has just gained an understanding with each other and oops, a new person, new personality'.

The biggest constraint in the implementation of the National Forest Protection Strategy has been funding (FSA Annual Report 2013:11). This problem limits the optimisation of research with regard to the failure to implement the recommendations by researchers in terms of pro-active forestry protection based on scientific evidence. Thus, effective control of pest and pathogens would require monitoring nationally and that includes all the areas and not only those managed by commercial companies to determine what the infestation rate in an area is and that it would not go beyond the economic entry level[580]. This process is costly, as it needs human resources and vehicles. Much of the funding for monitoring has been coming from the industry but DAFF has not been able to meet its commitments[581]. The industry has been doing well in terms of monitoring and intervening, but the impact could have been greater had the government managed to contribute as agreed by integrated forest protection strategy plan. The unreliability of government funding is, therefore, a blocking mechanism in terms of realising the benefits of R&D in South Africa.

[580] Dr B3. Research and Strategy Manager, Merensky Timbers, interviewed by Mushangai, Parktown, Johannesburg
[581] Mr B.P. Research and Development Manager, Forests Mondi South Africa, UKZN, 27/10/2017

Appendix 1, Box 5: The Genomics Case: FABI-University of Pretoria

Origin of the project

The genomics project is led by Prof B46, based at FABI at the University of Pretoria. According to Dr B1, a quantitative genetics researcher at SAPPI, the project started as part of SAPPI's tree improvement program[582]. Dr B1 noted that at the time (2009) when the project was started, they were very much aware of the developments that were taking place around the world in terms of understanding genetics and DNA markers in tree breeding programmes[583]. This understanding compelled SAPPI to send Dr B1 in the early 2000s on a worldwide tour of various institutes that are employing the most cutting-edge technologies to get a sense of the developments in genomics and DNA technologies[584]. From the evidence that was gathered during the tour, SAPPI concluded that for effective tree breeding program all these new genomics and DNA technologies had to be developed in South Africa. Hence, there was a need for collaboration to get the expertise developed locally at local universities[585]**.** However, to kick start the project, the shortage of skills caused the protagonists to romp in a Ph.D. student who was completing his studies in quantitative genetics at a European University. The student was inivited to come and set up the genomics research group at the University of Pretoria[586].

The University of Pretoria provided a small amount of funding. However, much of the funding came from the big firms in the forestry sector which collaborated in funding project[587]**.** Also the Department of Science and Technology (DST) came on board with much more funding but only after the group had started to use such tools as the DNA fingerprinting and when the government officials could now see that the collaboration between the industry and the university was really working[588].

The genomics programme is multi-faceted with a number of aims including the breeding of faster growing disease and drought resistant trees, the breeding of trees with suitable traits, the management of tree varieties, and the conservation of tree species etc[589]. The multi-faceted goals of the genomics project defines its three main functions namely, the conservation function; the management function; and the breeding function[590]. The conservation function is partly deals with the conservation of the natural populations that is where the exotic trees making the South African plantation economy came from[591]. The eucalyptus species came from Australia and the pines came from Central America. The natural populations have to be conserved outside their natural environments especially as they are threatened in their natural environments. For instance, inside of Mexico and Australia those natural populations can be under threat. The breeding function involves the selection and improvement of genotypes. The management function refers to ability to identify material when moving it around in South Africa so as to make sure that the genetic diversity (variation) is maintained. According to Prof B46, all of these technologies are new for, 'it is the first time we're looking at the Genomics of the tree, so it is all new information'[592]. This implies creative destruction as a result of the employment of R&D.

The genomics project is important in illustrating the importance of science in productivity improvement. It is also important in demonstrating how limited support from the government can make a difference in the optimisation of R&D. Further, it is important in demonstrating how collaborations may lessen funding bottlenecks and the burden of skills shortage.

Definitions

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[582] Dr B1. Former Genomics Researcher, SAPPI (2009), interviewed by Mushangai, Pretoria, 24/10/2017

[583] Ibid

[584] Ibid

[585] Ibid

[586] Ibid

[587] Ibid

[588] Ibid

[589] Ibid

[590] Prof B46. Genomics Programme- FABI, UP, interviewed by Mushangai, UP, 19/09/2017

[591] Ibid

[592] Ibid

Genomics referred to using all the information of the DNA. However, people have a different, operational understanding of what Genomics is depending on what they want to do. When looking at molecular breeding scientists analyse DNA markers that are linked to different traits be able them to 'say if you have this DNA variant then you might have 10% faster growth or you have higher cellulose'[593]. It is mostly about information in the DNA and can be looked at different levels depending on what the application is about. Typically for forestry it is about molecular breeding. This involves things like identifying the tree or identifying the parents of the tree or mapping the pedigree of a lot of trees[594].

DNA fingerprinting is the ability to identify the tree based on its DNA. It is like any fingerprint. Each tree has a unique DNA fingerprint. The technique is mostly important in making sure that the right trees are planted in the right sites. It is used primarily for things like keeping track of the identities of the individuals in breeding programs[595].

Biotechnology is the exploitation of biological processes for industrial and other purposes. This involves genetic manipulation for improved production[596]. In agriculture, it focuses on developing genetically modified plants for the purpose of increasing yield (wood formation) or introducing characteristics to those trees that provide them with some advantage growing in regions. This may also involve identifying characteristics, including the gene that causes it and then putting that gene in another plant so that it gains desirable characteristics e.g. pest resistant, drought resistant[597].

The project

The Genomics project was set up as an industrial program, one that would be based on cutting edge technology development. There was, therefore, need to demonstrate industrial applicability soon enough to gain the trust and support of the industry[598]. This involved getting the teams focused on delivering to the industry[599]. A system was set up to enable working closely with the research teams in various locations. It took us about three to four years to establish this'[600]. This was done contractually and committees comprising of three people from the companies and three breeders, and then three of staff and students from the universities were involved[601]. Researchers from the university where to have academic freedom, to go where they need to go in terms of doing the research, discover, and generate knowledge to be able to develop tools[602]. According to Dr B1, 'we managed to inculcate in the university researchers that we needed practical output that meant something on the ground. We managed to inculcate that actually it's really new techniques that are coming that are going to absolutely revolutionise tree breeding and we've got to work out how to adopt them into industrial tree breeding programs[603].

The Genomics technologies are targeted at companies that are big enough and have their own breeding programs. This explains why the SMES are not involved. This according the Prof B46, is because, 'the large-scale growers have the means to provide with the necessary genotypes to do the necessary crosses and establish the necessary populations, and the kind of techniques we're using. If you look at genomic selection these are all based on incredibly large populations' genotyping thousands of trees'[604]. According to Dr B1, the project is part of the tree improvement program looking mainly at biotechnology applications and 'various propagation technologies'[605]. This involves

593 Ibid
594 Prof B46. Genomics Programme- FABI, UP, interviewed by Mushangai, UP, 19/09/2017
595 Ibid
596 Dr B1. Former Genomics Researcher, SAPPI (2009), interviewed by Mushangai, Pretoria, 24/10/2017
597 Ibid
598 Ibid
599 Ibid
600 Ibid
601 Ibid
602 Ibid
603 Dr B1. Former Genomics Researcher, SAPPI (2009), interviewed by Mushangai, Pretoria, 24/10/2017
604 Prof B46. Genomics Programme- FABI, UP, interviewed by Mushangai, UP, 19/09/2017
605 Dr B1. Former Genomics Researcher, SAPPI (2009), interviewed by Mushangai, Pretoria, 24/10/2017

the use of biotechnology tools and mark-assisted breeding to accelerate breeding programmes of forestry to increase productivity and to increase natural resistance to pests and pathogens[606]. Biotechnology applications would include technologies like DNA fingerprinting and then the more complex technologies like the whole area of genomics and using DNA markers for tree breeding to improve tree variety[607]. These techniques are important in trying to understand the fundamental biology of trees. Again, the techniques are crucial in understanding the transcription regulation behind the wood formation and how transcription factors and other genes can be employed to engineer enhanced woody biomass production[608]. This last function involves functional gene testing in trees and evaluating different gene candidates to see if they have a pronounced effect on tree growth, on wood biomass properties[609].

The Genomics project benefitted from other countries around the world. The interaction of the Genomics programme at the University of Pretoria and the TPCP at the University of Pretoria facilitated the programme to benefit from the Polymerase Chain Reaction (PCR) a technique that was first employed by the TPCP programme in gene sequencing[610]. The PCR is a molecular technique to multiply DNA so that you can sequence the genome on micro-organisms and plants and get that barcode for identification[611]. The TPCP programme was the first to employ the PCR technology in gene sequencing[612]. The PCR technology was developed in America and 'with international collaboration and learning, researchers were able to bring these technologies to SA and fine-tune and apply them to our field'[613]. For example, around 2009 the genomics group internationalised their research going to Europe, America, and Latin America, to sequence the genes of eucalyptus as part of a conservation measure to protect the natural species and their diversity[614]. Dr B1 noted that, 'Countries from all those areas provided various forms of funding and various in-kind contributions to make that happen. And the leader of that team was Prof Zander Myburg from the University of Pretoria. He led the group. It took them a couple of years to sequence and put it all together'[615].

Importance of interaction and collaboration

As a result of local and international collaboration the Genomics project in South Africa has been at the forefront of a lot of the new developments for South Africa and the African continent. To kick start the project there was need for expertise in genetics and quantitative genetics and this expertise was not located was in the industry but at universities especially at FABI-University of Pretoria. Collaboration enabled the forestry firms to tape into this expertise obtaining at universities. Also, the University of Pretoria provided a small amount of funding to kick-start project. However, universities do not grow trees. The companies helped by establishing experimental populations on the plantations to enable the setting up of crosses and massive trials with hundreds of individuals[616]. Thus, the big companies had the means to provide the researchers with the necessary genotypes to do the necessary crosses, establish the necessary populations, and the kind of techniques. The genomic selection techniques which the researchers employed were based on large populations' gene typing thousands of trees. More still the industry provided some funding for the project. The government department –DST joined later and provided more funding for the project through their Innovation Fund.

International collaboration enabled the adopting and adapting international technologies by the researchers in the project. This is with reference to the PCR, which was developed in the USA. The internationalisation of the project involved going to Europe, America, and Latin America, to sequence the genes of eucalyptus as part of a conservation measure to protect the natural species and their diversity. This exercise brought in more funding from international sources. International collaboration were/are important in that the international partners also had technologies and expertise, which are not readily available locally. International collaboration also opened opportunities for students, as some were sent to America and Europe for training in quantitative genetics.

[606] Dr B5. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018
[607] Dr B5. Lecturer, FABI-UP, Forest Molecular Genetics Program, interviewed by Mushangai, UP, 08/02/2018
[608] Ibid
[609] Ibid
[610] Prof B47. Plant and Soil Sciences, FABI, UP, interviewed by Mushangai, UP, Pretoria, 13/07/2016
[611] Ibid
[612] Ibid
[613] Ibid
[614] Dr B1. Former Genomics Researcher, SAPPI (2009), interviewed by Mushangai, Pretoria, 24/10/2017
[615] Ibid
[616] Prof B46. Genomics Programme- FABI, UP, interviewed by Mushangai, UP, 19/09/2017

Result

The project has a lot of potential in terms of going forward in genetic resource management and breeding. The project has led to breakthrough technologies. The DNA fingerprinting tool is phenomenal. It has been developed and adapted for many uses such as management, keeping track of the identities of the individuals in your breeding programs. Tree breeding programs happen over long spans of time, to keep everything accurately labelled can be a challenge, and there is a risk that you may lose the identity of individuals. The DNA fingerprinting revolutionised breeding, management, and conservation of individual populations. The tool is important for quality control, making sure, you got the correct individuals in your program, and that you got the correct individual in your orchard.

The project has had other spin-off discoveries that were not imagined when it was initiated. It has helped in keeping ahead of climate and environmental changes by introducing fast growing drought, pest, and disease resistant trees. As noted by Mr B12 from Mondi, 'if today you plant the same genetic material that you used to plant 30-years ago you would hardly get any crop off the land, because of the suite of pest and diseases and because of the climate pattern that has changed the growing conditions over time'. The knowledge of genomics was/is important in the improvement in our knowledge of tree species diversity in the country, and according to Dr B1, 'we've helped in developing disease resistant planting material for industry, technologies to screen this material started off with planting trees'.

The project has enabled the big firms to provide small growers in their outgrowers schemes such as SAPPI's Project Grow with fast-growing trees. The DNA fingerprinting tool has allowed the tracking and arresting of people who were stealing these improved trees from the plantations of small growers in Zululand[617]. According to Dr B1, 'By analysing the DNA in some leaves of the recently planted trees they have been able to prove that they had taken our material'.

South Africa has its own prototype GM tree that is greenhouse based which is part of intellectual capital.

The impact has been realised in the use of information for breeding, for genetic resource management, and for conservation. You can go straight from that information to having a management tool.

[617] Dr B1. Former Genomics Researcher, SAPPI (2009), interviewed by Mushangai, Pretoria, 24/10/2017

Appendix 1, Box 6: The eco-furniture School Desks project

The eco-Furniture School Desks Project

The programme is part of the Value-Added Industries (in this case value addition is defined in terms of the beneficiation of alien invasive wood biomass into use values) by the Department of Environmental Affairs (DEA) in partnership with the Department of Basic Education (DBE) and makes use of cleared Invasive Alien Species (IAPs) biomass to produce school desks[618]. The programme has employed 2010 people in 7 operational factories. The 7 operational factories are in George - Western Cape; Durban- KwaZulu-Natal; Ga-Rankuwa-Gauteng; Heidelberg- Gauteng; Graskop-Mpumalanga; Ficksburg-Free State; Albasini- Limpopo (DEA, Environmental Programmes Prospectus, April 2016:2). The school desk project offers value in terms of social (employment, skills, and school support) and economic benefits from investments made on the clearing of IAP activities. The desks are supplied to schools throughout the country (Goosen 2014:4). The desks and other products produced help to address the needs of the government in schools and government departments. The programme is implemented by the South African National Parks[619]. SANParks was selected by the Extended Public Works Programme (EPWP) to implement the Eco-Furniture Project as part of SANParks' Biodiversity Social Projects (BSP)[620]. SANParks was selected as the implementer because it has the capacity to run the Eco-Furniture Project as it has been managing invasive plant species in South Africa[621]. In addition, SANParks has to ensure that skilled and experienced factory managers are heading up factories and harvesting operations (Goosen 2014:55). A figure of R383 million had been invested in the project over the three-year period (2011-2013) (Goosen 2014:4). The first shipment of 23 500 school desks was delivered to 245 schools in Mthatha in the Eastern Cape, in 2013 (Goosen 2014:54). The second shipment of 24 500 school desks was delivered to schools in the North-West Province in April 2014 (Goosen 2014:54). These desks were produced from all the eco-furniture school desk factories across the country.

Heidelberg Factory Case study

The Heidelberg factory is rented from the Lesedi local municipality. The factory includes a wet mill and 4 000 m2 dry mill and was opened in September 2013 and is producing 2 600 desks a month (Goosen 2014:54). The dry mill has one production line but there are plans to implement a second line (Goosen, 2014:54). The operations at Heidelberg start with the harvesting of IAPs in the neighbouring areas.

Harvesting and training

The invasive species are harvested on municipal and private land. Private land owners have the responsibility to contact SANParks to remove these species from their land in terms of the Conservation of Agricultural Resources Act (CARA) no 47 of 1983[622] (Henderson 2001:4).

The harvesting teams receive their training through demonstrations on the field. The in-the-field training is done at harvesting locations near the factories. The most important training in harvesting operations is the chainsaw training[623]. This training is provided by Enviro Chainsaws, a Stihl dealer from Centurion's training division (Goosen 2014:5).

The trainees have to attain competency in chainsaw operations before training in specialised tree felling techniques[624]. The course involves

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618 Ibid
619 Ibid
620 Ibid
621 Ibid
622 Ms B41. Deputy Director: Strategic Support in the Office of the Chief Director of NRM, interviewed by Mushangai, DEA, Cape Town, 09/06/2017
623 Mr B49. Technical Manager- DEA Eco-Furniture Industries, interviewed by Mushangai, 27/06/2017
624 Ibid

discussions and demonstrations of advanced felling techniques that suits working in challenging environments where trees grow uncontrolled and unmanaged in rural and urban areas (Goosen 2014:5). The training prepares the chainsaw operators to deal with the high risk and dangerous nature of their work[625]. Some of the trees to be harvested are found leaning sideways, multi-stemmed, have large crowns or located next to buildings or structures. The training thus differs from those required for harvesting in managed plantations where trees are in rows and well maintained (Goosen 2014:5).

The trainees are trained to plan for felling. This involves the assessment moveable and unmovable structures, how to do clearing around the tree, determining the wind direction, slope, underfoot conditions and to establish a 45^0-escape route or safety (Goosen 2014:5). This also include looking for leaning trees, dead or decaying wood, flaking bark and fungi around the stem (Goosen 2014:5). Other aspects of the training would involve how to use equidistant equations to determine the reach of a tree when it is felled (Goosen 2014:6).

The training also involves the choice of felling equipment such as felling bars, felling wedges, throw lines, rigging ropes, pulleys, rigging karabiners, anchor slings, prussic cords, and winches are designed to make the chainsaw operation's job easier and safer (Goosen 2014:6). The felling techniques that are taught, 'are not used in normal commercial forestry harvesting practices, as in plantations trees grow straight up and without defects' but are critical in the eco-furniture project to make sure that, 'the operators know exactly what they are doing when using these techniques' (Taljard from Enviro Chainsaws cited in Goosen 2014).

After the felling of trees, the trainees are also trained delimbing which involves the removal of branches using correct debranching techniques (Goosen 2014:8). This can only be done after assessment to guarantee safety. In this exercise the trainees are trained to crosscut the logs for processing on the portable sawmills. The training is done through demonstrations[626].

Machines supply and the training of operators

The sawmilling equipment is supplied by companies such as Nukor and Wood-Mizer. Nukor supplies machines such as the Lucus Mills and the Timber Kings. The Heidelberg factory has two Lucus Mills from the Nukor Group. According to Wayne Bowyer from the Nukor Group, the mills are ideal for the Eco Furniture Project as they are easy-to-use and set up and very productive (Goosen 2014). The Heidelberg furniture factory has some the Timber King that offers improved recovery and production (Goosen (2014).

The Heidelberg factory has both wet mills and dry mills managed by contractors[627]. Initial processing is done in the field by portable sawmills (Goosen 2014:8). Initial processing involves cutting harvested timber into portable logs that are then transported to the factories for further processing[628]. In-the-field processing has the advantage of reducing transport costs and is more effective and less time-consuming[629]. In field processing also limits the effect of a metabolic rift as waste remains left behind decompose and provide nutrients to the growing species. At the factory logs are processed into cants or planks[630]. The companies such as Nukor provides training to the machine operators at the Heidelberg factory.

Drying

[625] Ibid

[626] Mr B49. Technical Manager- DEA Eco-Furniture Industries, interviewed by Mushangai, 27/06/2017

[627] Mr B49. Technical Manager- DEA Eco-Furniture Industries, interviewed by Mushangai, 27/06/2017

[628] Ibid

[629] Mr B49. Technical Manager- DEA Eco-Furniture Industries, interviewed by Mushangai, 27/06/2017

[630] Ibid

Timber drying at the Heidelberg factory involves air dying and solar kiln drying[631]. Heidelberg factory has two three 66 m3 solar kilns[632]. However, these are inefficient and it takes several months for drying hardwoods[633]. The factory produces 2 600 desks a month. However, 180 cubic metres of dried timber is required to meet their target of 4000 school desks. This means that timber drying is a big challenge[634]. As of now, drying capacity is outsourced from Ficksburg in the Free State[635].

Finishing activities are done by hand and handheld power tools, while lacquer and varnish spraying is done outdoors. Products are also assembled on-site[636].

Challenges

The project works with 'jungle timber', which is extremely hard and difficult to work with as compared to plantation timber[637]. The problem is that the wood causes constant machine breakdowns because the machines are not designed to for this timber[638]. Also, the timber cannot be properly dried through the solar kilns available at the Heidelberg factory. As a result of the lack of proper kilns for drying, the timber is not enough at times to meet production targets, such that the factory has to rely on plantation timber to meet the orders[639]. This causes conflicts with other industry organisations such as the South Africa Furniture Initiative (SAFI) because they had an agreement with DEA that the eco-Furniture industries were only to rely on IAPs.

Other challenges confronted by the Heidelberg Eco-Furniture school desk factory are that:

- The Heidelberg factory does not have technicians to maintain the machines and it takes a long time to get a technician to fix the machines ones broken[640]. Production time is therefore wasted.
- The workshop at Heidelberg does not have enough ventilators hence the workers are exposed to health hazards such as TB[641]. This is against the principle of sustainability, which also emphasise the safety of the workers at the workplace.
- The contractors complained about the burden of state regulation such as labour regulations and the workman′s compensation. They are struggling to operate profitably[642].
- The other challenge pertains to delays in payment of workers.
- Also, the project has employed too many people that make it inefficient.

[631] Ms B37, Small Wet Mill Contractor, interviewed by Mushangai, 30/06/2017
[632] Ibid
[633] Mr B49. Technical Manager- DEA Eco-Furniture Industries, interviewed by Mushangai, 27/06/2017
[634] Ibid
[635] Ms B38, Small Drymill Business Contractor, interviewed by Mushangai, Mpumalanga, 30/06/2017
[636] Ibid
[637] Mr B25. Machine Operator: Heidelberg School desk Project, interviewed by Mushangai, Mpumalanga, 30/06/2017
[638] Ibid
[639] Ms B38, Small Drymill Business Contractor, interviewed by Mushangai, Mpumalanga, 30/06/2017
[640] Mr B25. Machine Operator: Heidelberg School desk Project, interviewed by Mushangai, Mpumalanga, 30/06/2017
[641] Ibid
[642] Ms B38, Small Drymill Business Contractor, interviewed by Mushangai, Mpumalanga, 30/06/2017

Appendix 1, Box 7: The Timber Winch Project

Origin

The pulp and paper production line gets a significant amount of wood fibre from the small-scale timber growers and other small-scale enterprises that harvest exotic tree-infested riverine areas. However, the SMEs face challenges in the harvesting and extraction of timber from the harvesting sites to the point of sale. This is usually achieved at a high cost; which limits returns on investments. In 2016, the ICFR Forest Operations Research embarked on engineering focused research with the aim of designing a small-scale customised timber winch to improve the efficiency of timber harvesting and extraction for small scale enterprises (ICFR Annual Report 2016:29). The project is demand-led for it was the small-scale growers who approached ICFR. According to Mr B15, 'The guys wanted something to draw up timber from steep slopes, and then they come to the research institute and say, could you assist us, build an instrument that will assist us to extract our timber, because we've planted on steeps, that is the only land we've got'[643].

The project

The project to design and make a timber winch for small growers is led by Simon Ackerman from the UKZN (ICFR Annual Report 2016:29). The project has two Masters Students under the supervision of Simon Ackerman[644]. The project involves collaboration between different stakeholders in the forestry SSI. The DST provides funding for the project under the Forest Innovation Fund[645]. Forestry South Africa representing forest companies brought in chainsaw experts from the companies, one from Mondi and the other one from SAPPI[646]. The team is working with the biggest chainsaw company in South Africa, which is Stihl and Husqvarna[647]. Also, the FPM SETA is participating as a funding partner[648]. DAFF is also part of the project[649].

The small scale timber winch was designed to use a chainsaw engine because the small businesses involved have chainsaws. These very chainsaws could be used to cut trees down and, 'when you finished cutting your trees down and want to extract them up the slope, you disconnect the chain and the guide bar and you use the same chain, you plug it into the system and wrench your trees up'[650].

The results were presented at ICFR field days and the DST Forest Innovation Fund stakeholder symposium in 2016 (FSA Annual Report 2016:16).

The benefits

The machine is suited for small-scale growers for 'it is affordable, it is small, and it is practical'[651]. The machine is portable and is carried on the back of the 'bakkie'. This makes it easy especially considering that some small-scale enterprises are always relocating to sites where the resource is found. The convertibility of the machine makes it amenable for many uses such as felling and pulling the timber up the slopes. The winch was tested in the field and it exceeded productivity expectations. According to Miss U, the machine 'it's improving the efficiency

643 Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017
644 Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017
645 Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017
646 Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017
647 Ibid
648 Ibid
649 Ibid
650 Ibid
651 Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017

10 times over what it was when a guy had to do it by hand[652]'. However, the FSA noted that initial results have indicated that this winch could increase the production of the small growers by up to 12% (FSA Annual Report 2016:16).

The two masters' students working on the project received a DAFF/FSA award for their work (ICFR Annual Report 2016:28). The small timber winch project generated interest among government departments with regard to small business customised technologies. The DST has now recognised the need to have technology and mechanisation appropriate for small-scale growers who do not have funding to pay for it[653]. The DST was impressed because 'it is a real community innovation type project'[654].

Mechanisation and appropriate technologies are important in growing the small business because 'we don't want to keep small-scale growers small; we don't want them to remain small and, just get a livelihood out of growing trees. We would like research to support small-scale growers to become entrepreneurs and become successful. If that means improving their working conditions and giving them appropriate technologies, that is what it is about'[655].

The ICFR will be marketing the timber winch throughout the provinces in South Africa during the field days. The simplicity of the machine is likely to facilitate its absorbability. As noted by the SI scholars such as Malerba (2006) the adoption of technologies is affected by the relative advantage of an innovation, and compatibility with the need of the adopter, and difficult for understanding, and easiness of testing.

The importance of collaboration

The project was made possible because of the funding from the DST. Further, the collaboration with the established firms with capabilities made it possible for Mondi and SAPPI to avail the experts in chainsaw for the project. This was further enhanced by the participation of the chainsaw manufacturing firms such as Stihl and Husqvarna. The two Masters students involved in the project were exposed to the expert knowledge of those who participated from the big companies. Technological knowledge is collective (Bergek et al (2010:117) hence the participation of different experts from different companies and departments provided the required knowledge for the project.

[652] Ms B39. Knowledge Manager- ICFR, interviewed by Mushangai, ICFR-UKZN 27/10/2017
[653] Mr B15. Small Business Manager- FSA, interviewed by Mushangai, ICFR-UKZN 27/10/2017
[654] Ibid
[655] Ibid

Appendix 2

List of Interviewees for the entire thesis

Name of the Interviewee	Organisation	Title	Place	Date of interview
Dr B1	Former Mondi Researcher	Researcher: Genetics	Pretoria	18/10/2017
Dr B2	4Sight Futures	Research Manager, Genomics	Pretoria	24/10/2017
Dr B3	Merensky Timbers,	Research and Strategy Manager	Parktown, Johannesburg	10/11/2017
Dr B4	Forestry South Africa (FSA),	Research Director	Illovo, Johannesburg	16/10/2017
Dr B5	FABI	Lecturer- Forest Molecular Genetics Program,	FABI- University of Pretoria	08/02/2018
Dr B6	CSIR	Researcher- Improvement and Reproductive Biology	CSIR- Pretoria	13/08/2016
Dr B7	Nelson Mandela University	Programme Coordinator Forestry & Veldfire Management	NMU George Campus	07/04/2018
Dr B8	SAPPI Technology Centre	General Manager-	Pretoria	02/03/2018
Mr. B9	DAFF- Forestry Scientific Services	Research Manager-	Pretoria	25/10/2017
Mr. B10	Small business owner (Cabinet manufacturer)	SME owner	Soweto, Jabavu, Johannesburg	20/09/2017
Mr. B11	H Farm	Worker-trustee	Mpumalanga	06/11/2015
Mr. B12	Forests Mondi South Africa,	Research and Development Manager,	UKZN	27/10/2017
Mr. B13	NCT Forests	Forestry Technology Manager	Johannesburg-	26/06/2018

			telephone interview	
Mr B14	Rural Action Committee (now defunct)	Director	Mpumalanga	06/11/2015
Mr B15	FSA,	Manager- Small Business Development	ICFR-UKZN	27/10/2017
Mr. B16	H Farm	Trustee-Worker	Mpumalanga	06/11/2015
Mr. B17	Worker (Cabinet maker)	Y Cabinet Manufacturer	Orlando Industrial Park. Soweto	28/06/2019
Ms. B18	L Cabinet Manufacturer	Employee (Marketer)	Orlando Industrial Park, Soweto	28/06/2019
Ms. B19	Employee (Marketer)	L Cabinet Manufacturer	Orlando Industrial Park, Soweto	28/06/2019
Mr. B20	SME Owner,	Cabinet manufacturer	Orlando Industrial Park- Soweto	28/06/2019
Mr. B21	Agri-SETA	Implementation Manager	Pretoria	27/06/2017
Mr. B22	DRDLR	Provincial Director,	Mpumalanga (Discussion with the Sociology of land Reform team from Wits University)	06/11/2015
Mr. B23	FPM SETA	Research Manager-	Wits University	24/09/2017
Mr. B24	TWK Agri (Pty) ltd	Research and Development Manager	Johannesburg-Telephone interview	13/11/2017
Mr.B25	Heidelberg School desk Project	Machine Operator	Mpumalanga	30/06/2017
Mr. B26	Sawmilling South Africa	Director	Johannesburg	07/04/2018
Mr. B27	Fort Cox College	Head of Forestry Department	Fort Cox- Eastern	06/11/2017

Mr. B28	H Farm	Director	Mpumalanga	06/11/2015
Mr. B29	Small Dry Mill contractor	Machine Operator	Mpumalanga	30/06/2017
Mr. B30	SME owner	Cabinet Manufacturer	Orlando Industrial Park	26/06/2019
Mr. B31	Small Dry Mill Contractor	General Worker	Mpumalanga	30/06/2017
Ms. B32	SAFCOL	Senior Manager- Transformation	Nelspruit, Mpumalanga	26/10/2017
Ms. B33	FPM SETA	Former Administrator-	SEDA, Pretoria	07/06/2017
Ms. B34	Roadside Cabinet seller	Business Owner	Mphuti Street, Jabavu, Soweto	26/06/2019
Ms B35	Roadside cabinet Seller	Business owner	Mphuti Street, Jabavu, Soweto	26/06/2019
Ms. B36	Centre for Small Business Development-University of Johannesburg	Director	University of Johannesburg, Soweto Campus	10/10/15
Ms. B37	Small Wet-mill Business	Contractor	Mpumalanga	30/06/2017
Ms. B38	Small Dry-mill Business	Contractor	Mpumalanga	30/06/2017
Ms. B39	ICFR	Knowledge Manager	ICFR-UKZN	27/10/2017
Ms. B4O	Wits- REAL	PhD Student,	Wits, Parktown - Johannesburg (conversation)	13/03/19
Ms. B41	DEA, Cape Town	Deputy Director: Strategic Support (NRM)	DEA, Cape Town	09/06/2017
Prof B42	Stellenbosch University	Lecturer, Forestry Harvesting	Johannesburg (Telephone interview)	27/06/2018

Prof B43	University of Pretoria- Department of Forestry Studies	SAFCOL Research Chair, Lecturer- Socio-ecology, Agroforestry, Soils	UP, Pretoria	13/07/2016
Prof B44	University of Pretoria- Department of Forestry Studies	Retired Visiting Prof- Forest Ecologist	UP, Pretoria	29/05/2017
Prof B45	Wits-REAL FPM SETA	Research Chair	Wits-REAL, Johannesburg	23/04/2018
Prof B46	FABI	Prof Genomics Programme	FABI- Pretoria	19/09/2017
Prof B47	FABI	Prof Plant and Soil Sciences	UP, Pretoria	13/07/2016
Prof B48	Wits University (Environmental Studies)	SAPPI Research Chair	Braamfontein, Johannesburg	31/01/2018
Mr B49	DEA Eco-Furniture Industries,	Technical Manager-	SANParks-Pretoria	27/06/2017

Appendix 3

The schedule for gathering data from personnel at skills development institutions

Contextual questions

What are the major changes in production in the forestry industry over the past 3 decades?

What are the supply chain dynamics like and how do they affect how the large corporate players help smaller firms; what influence over the forestry industry do other players have in the supply chain like the saw mills, the pulp mills, and the furniture manufacturers?

What does the forestry regional or sectoral innovation system look like?

- Who are the main players?
- What are the inter-connections and interactions?

Tell me about your institution

What is the primary role of your Centre /department/college and how did it arise?

1. **Extent of forestry research and development in South Africa**

A. What is your view of the state of forestry research and development in South Africa?

B. What has been the link between domestic forestry R&D and international developments?

C. How have these trends impacted on South Africa's forestry research and development?

2. **Partnership- Higher education, industry and the government**

A. Have there been any partnerships between universities/research institutes and the government in forestry research? Probe

Are these partnerships formal or informal in structure?

Are they triple helix type arrangements?

B. What have been the implications of these on the development of forestry skills in particular and the forestry industry in general?

3. **Focus of personal research**

A. What has been the focus of your research and in what ways have they been beneficial to the forestry industry of South Africa?

Has there been new knowledge generation and skills development as a result of these researches?

B. Has there been new knowledge generation and skills development as a result of these researches?

Try question and emphasise the idea of new and <u>joint</u> knowledge production, knowledge <u>flow,</u> sharing and transfer

Is it <u>tacit</u> how does the codified formal knowledge interact with the tacit in applied context?

C. In your opinion what have been the impact of your enterprise on the development of the forestry industry in South Africa?

D. What in your view has been done to ensure the diffusion and application of scientific knowledge to small scale growers? (also, the role technology transfer office at UP)

4. Capacity development

A. What has been done so far to ensure the development of young forestry scientists in South Africa?

B. What has been the role of the university/institute in the development of forestry scientists?

C. What has been the role of industry and government in this undertaking?

D. Of what relevance has been such an undertaking in the development of the forestry industry in South Africa?

E. What are some of the post graduate programmes you offer? What has been the impact of these programmes on forestry production in South Africa?

4, Research and success

A. Do you think R&D has anything to do with the success of forest plantation firms in South Africa?

B. In what way is knowledge generated in research translated into profits at firm level?

Appendix 4

Schedule for interviews with personnel from the BIG firms in the sector

1. What are the challenges and opportunities currently in plantation forestry in South Africa?
2. What are the main focal areas of for research and development identified by your organisation to address the current and future challenges?
3. What do you consider to have been the major successes of research and development in the history of your organisation?
4. What have been the interplay of the government, the university and the industry in the development of the forestry sector?
5. What have been the challenges and how have these been resolved?
6. Currently do you have any forms of cooperation with other organisation in the generation and application of forestry R&D?
    - Are they university level partnerships?
    - Industry collaborations?
    - bursaries
7. How crucial is the partnership of the industry, the government, and the university in the generation and application of new knowledge and forestry sectoral technologies?
8. Where do firms experience smooth pipeline, major bottlenecks, or skills gap?
9. What strategies or mechanisms are important for ensuring that skills keep pace with rapid changes in technology? How important are universities in addressing the needs of the industry?
10. What are the challenges that you face in facilitating technology transfers among your members? What have been done to mitigate these challenges?
11. Do you have a mechanism for gauging the impact of technology transfers on production? What is it?
12. Do you work with universities in reviewing the progress that you and your colleagues make in the commercialisation of technologies?
13. How important are the stakeholders in technology transfer processes and reviewing the success and failures of these processes?
14. Why are some firms complaining how hard it is to work with universities? Do you have any challenges in working with universities in R&D? What nature? How have you tried to resolve them?
15. What has been the role of the SETAs in forestry research and development? Has this role, had any impact on your organisation?
16. Has there been an impact of productivity emanating from forestry certification pressures? If any, how have you dealt with these pressures?
17. Do you comply with sectoral regulations in terms of labour, health and safety, environment and sustainable development practices as outlined by the FSC, ISO or national legislation?
18. Do you consider government regulations a hindrance or enabler in plantation in the development of enterprises in the forestry sector of South Africa?
19. What has been the impact of contracting on the development of the forestry sector as a whole?
20. How important has been international cooperation in the development of the forestry sector in South Africa? Explain

21. What would you consider to be the major advances in relation to forestry productivity in areas such as silviculture, tree improvement, pests and diseases etc. emanating from R&D?
22. What are the future prospects of the forestry sector considering the current dynamic?

Appendix 5

Schedule for interviews with personnel from SMEs including Co-operatives

QUESTION	**PROBE**	**ANSWER**
1.1 **Business name**		
1.2 Participant's name	Name of interviewee	
1.3 Positions of participant	Owner or Position in the firm	

2. **Business Information**

2.1 What services does your business provide /what products are you trading in	What do you do (products/services)? Where and when? What needs/functions do you satisfy? Which customers/clients do you serve?	
2.2 What is your business's legal form?	Closed corporation, company, trust NGO/ hybrid, an Association	
2.3 How do you describe the sector of your operation?	Retail, building, services manufacturing	
2.4 For how long have your business been operational?	Number of years/ Was there a time the business operated as an unregistered entity	
2.5 Do you comply with government regulations	Have the businesses registered for tax? Do you have a tax clearance? Have you done the returns for the DTI? Are all your government forms in order?	
2.6 Capital-Where did you obtain the capital for your business?	Family, own money pension, bank, etc.	
2.7 Has the formalisation of your business assisted you in any way?	Production know how? Finance? Marketing? Partnerships and collaborations etc.	
2.8 Would you like your business to	If yes –under what circumstances and in	

grow?	which areas	

3. **Extremal Enterprise Support**

3.1 Have you got any material/ non-material support through government, Universities/research institutes or any external stakeholders? What type of support if any?	External stakeholders-government agencies, banks, companies' enterprise development, incubator, free training, mentorship or business network. Explain	
3.2 How does each of the support/lack of it influence the success or lack of it with regards to your business?	Probe How support of the lack of it has influenced the success or lack of it If little how did the business benefit from it- Focus on collaborations with universities and the government	
3.3 Did you think the support /lack of it have anything to do with the formalisation of your business and why	In what ways do you think universities can assist your business?	

4. **Vision, Mission, Values and Strategy**

4.1What is your vision for your business?	The participant to state his/her vision, mission. What motivated him/her to start the business? What role do employees play in the realisation of the dream?	
4.2 Strategy: How will you realise the dream?	Capture the participant's strategy for the realisation of the dream	
4.3 What need to happen for the vision /dream to materialise?	What are you doing, to do? Do you need any support from whom and why? (Knowledge acquisition)	
4.4 How do you ensure that this happens?	What will you do for the success of your strategy? What have you planned to overcome the obstacles?	
4.5 Has the government assisted you in any way in this regard	Did you receive government/ government institutions/ universities support in this regard/Can government support enhance your success chances	
4.6 Do you know of any government	If yes, which once have assisted you or	

institutions that can assist you in realising your vision?	you have requested for assistance from? /if no have you tried to find out?	
4.5 What are the values guiding your business?	Explain values in relation to services products such as high quality, honesty, transparency in dealing with clients. Why is the quality of services/ products important to the owner? (Emphasis on innovation and upgrading)	
4.6 What effects do your business have on society	How do you take your business, what does it mean to you? Do you think it gives meaning or add value to society? Who are these and why would they say so?	

5. Operational Issues

5.1 Where is your business located? What is your for feeling about the idealness of your business location?	Appropriateness in relation to the product offered. Why is your business located where it is located? Probe – would the business do better if it where run from home, office park, or closer to plantations/sawmills? What are the pros and cons of the business location? Has the government assisted in this regard/ do you know and have you approached any government agency responsible for assistance	
5.2 What are the risks of running a business and how do you manage them?	Risks may include anything crime, flooding, pests, diseases, health, fire etc.	
5.3 Do you think the government/research institutes have a role in mitigating these risks?	What has the government done so far/ in your case or the area?	
5.4 Do you have access to material, suppliers, basic amenities (supply chain) or is there a good flow between the different components to produce your product or service to the customer?	This relates to supply chain management/flow- this includes not only the manufacturer and, suppliers but, transporters, warehouses, retailers and customers themselves	

5.5 Do you offer (besides your main product) other supplementary products and services (evidence of diversification)	E.g. selling machines and training how to use machines	
5.6 Do you comply with sectorial regulations in terms of labour, health and safety etc. (is formalisation any advantage or a disadvantage)	Other sectors have minimum wage. Food industry has health standards and regulations. What are some of the agreements, charters and regulations governing your business?	
5.7 In what ways do these compliance requirements impact on formalised businesses	How have these charters and agreements and regulations help or hinder the progress of your business	
5.8 Do you have access to business transport to and from markets?	Do you have own car for products transportation? If not, what do you rely on / is the station near the business? Do you need a car to visit clients and market your product?	

6. **Sales**

6.1 Who does sales in your business?	Do you do it yourself or do you have someone appointed for the job/	
6.2 Does the person responsible for marketing undergone marketing training	What type of training? Is the training sufficient? What other training is needed? What role has the government/public institutions played or can play in this regard to enhance the success of your business?	
6.3 On what basis is your sales driven to ensure the best possible sales figures?	Do you have sales targets, incentives or commissions?	
6.4 Do you have a marketing strategy	E.g. Selling through agent, direct sales/marketing. Is your strategy successful? Is there anything needed to be done to make it more successful?	
6.5 How do you retain your customers?	Do you make follow ups to ensure that your customers are happy with the	

	services provided to them?	
6.6 Do you have competition in your business? How do you deal with competition?	Important to determine whether the market is oversaturated with the service or whether the service is unique and what the person does to stay in play-quality of service also	
6.7 Did you receive any form of help from the government or government agencies or education institutions on how to improve your marketing?	If yes, what form of help and how did it impact on the business? If not, do you know of any government's agencies providing such kind of support and have you approached any of these	

7. Human resources management

7.1 How many people work for your business?	Number- full-time, part-time, family etc.	
7.2 How were they recruited and why were they recruited in this way?	Important because small business often hire people 'of the streets' and end up with incompetent people How professional are they in recruiting people?	
7.3 Do you train your staff?	Do you send them for external courses or do you do in-house training? What kind of training do you invest in and why/	
7.4 Who manages Human resources and how?	How is it managed? Do you have someone taking care of that and are the employed full-time or part-time?	
7.5 Have you received any form of assistance in this regard from government?	What kind of assistance, drawing of contracts? Motivation of workers? Do you use labour law person to do contracts etc.	
7.8 What do you do if you have problems with staff, e.g. Non-performance, excessive absenteeism,	How are problems with staff dealt with? By an external person, does the interviewee do it him/herself?	

stealing, alcohol abuse etc.		
7.9 Do you have regular performance appraisal or evaluation of your staff?	How do you do these performance appraisals? How often?	
7.9.1 What is the spirit or culture among your staff members in your business?	Do you work as a team? Can individuals take decisions for themselves or do you prefer a strong manager? Autocratic or democratic leadership styles-probe	
7.9.2 Do you take care of your staff's wellbeing? If yes How?	Wellness- health, safety, psychological, HIV/AIDS in work place and the general	
7.9.3 What impact do your employees have on the growth or success of your business?	What role do they play in your business? Do they help to make it a success? How? What needs to be done to improve their productivity?	
7.9.4 Does your business respond to the government's call to care for the environment? – Sustainable management	E.g. – With regard to soil compaction, erosion, emission, toxic waste, resource wastage, keep area clean, no dumping of material. If yes have this had anything to do with the success of your business	

Financial Management

8.1, Have you received any financial aid from external stakeholders?	E.g. Government or financial institutions. If yes, why do you think you were successful? If no what did they were the reason for the failure of your application	
8.2 How is your business finances managed?	If yes, do you keep your budget? If not why not?	
8.3 How do you manage your cash flow?	Do you take care of 'tomorrow'- to purchase stock by banking it or do you live from the till? What6 do you do when you are short of money? Can you lend?	

8.4 How do you do the costing of your products or services; what factors do you consider?	What costs would you include to determine the price of the product or you go by the market price or your competitor's prices?	
8.5 Did you receive any external stakeholders' assistance (training) in this regard?	What have been the advantage / disadvantage of keeping of updating and keeping/not keeping your books of accounts in order?	
8.6 Do you have a business plan?	Probe- Did you draw it yourself? Did someone help you or did it for you?	
8.7 Is your business plan important to you?	In what ways? when dealing with external stakeholders	

Appendix 6

Schedule for interviews with government officials from DAFF AND DEA and NGOs

1. What have been the focal areas of government intervention in relation to the development of forestry sector-based firms?
2. What are the main institutional arrangements that have been put into place to ensure sustainable forestry sector resource development?
3. What has been the impact of these on forestry resource development and industrialisation?
4. Has there been involvement of forestry stakeholders in the formulation of policy and regulatory frameworks? Why/How?
5. What have been the main activities defining your approach to forestry resource and enterprise development? Who have been you partners in this undertaking?
6. What has been the motivation of working with these partners? What have been the challenges involved? What mechanisms are in place to resolve these challenges?
7. How do you ensure that stakeholders comply with the demands of institutional arrangements in the sector?
8. What have been the major challenges in this and what mechanisms or strategies has your department put in place to ensure compliance?
9. What do you consider to be the major threats to forestry resource development? Alien species/water management/ pest and disease/environmental degradation/ access rights of other people/problems of the commons
10. How effective is policy in dealing with these threats?
11. In what way has your department been able to deal with issues pertaining to the lack of capacity in policy implementation?
12. How to do capacity limitations impact on your vision?
13. What has been your role in in ensuring skills development in your areas to address these capacity limitations?
14. Do you have any links with the knowledge and skills development institutions in addressing skills challenges and in capacity building within your sector?
15. What have been your activities in relation with other government departments in the development of forestry resources?
16. Are there any challenges in working with other departments in addressing the challenges in the development of resource development in your sector? What are these challenges? How could they be addressed?

Appendix 7

Schedule for interviews with personnel from the SETAs

1. What are some of the main focal areas that you have identified for research and innovation?
2. What type of interventions do you have in place to address these focal areas/?
    - Are they university level interventions?
    - Industry level interventions and/partnerships?
    - Support bridging interventions/partnerships?
    - Bursaries?
3. What have been the main partnerships – nature of these partnerships and how have they assisted in the formation of DEEM/high level R&D skills?
4. Where do you see that support role the FPM SETA and the AgriSETA in the development of high-level R&D skills?
5. Where do you see that support role of the SETAs in the NSI/ forestry SSI?
6. Have you managed to meet the targets in relation to your focal areas?
7. What do you consider to be the factors that enable or hinder the development of skills and application of R&D in the forestry sector? Explain
8. How can the efficiency of the SETAS be enhanced in relation to the development of R&D skills in the forestry sector?