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Livelihoods, ecosystem provisioning services and social differentiation: An empirical study of KwaZulu-Natal, South Africa (1993 – 2011)

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Student name: **Philipp Censkowsky**

Student number: **1935820 (Wits) and 11711824 (Paris)**

E-Mail: **philipp.censkowsky@posteo.de**

Phone/Cell: **+49 151 56611390**

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Supervised by: Dr. Gavin Capps (Wits University), Dr. Liliana Cano (Paris XIII)

External supervision: Dr. habil. Ilona Otto (Potsdam Institute for Climate Impact Research, PIK)

EPOG Economic Policies in the Age of Globalisation

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USPC Université Sorbonne Paris Cité

University of the Witwatersrand, Johannesburg

Sworn declaration

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Potsdam, 31.05.2019

P. Censkowsky

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Abbreviations

CFCs - Chlorofluorocarbons

Direct ES - Direct ecosystem provisioning services

ES - Ecosystem services

GHGs - Greenhouse gases

KIDS - Kwa-Zulu-Natal Income Dynamics Study

KZN - KwaZulu-Natal

PSLSD - Project for Statistics on Living Standards and Development

SES - Social-Ecological Systems

Stats SA - Statistics South Africa

UC - Use category

Abstract

This research report critically adopts and extends an approach of identifying and mapping social-ecological systems (SES) to analyze household livelihood domains emerging from ecosystem service (ES) use in KwaZulu-Natal (KZN), South Africa. ES use is proxied by the degree to which households directly utilize ES provisioning services (direct ES) as observed from national census and panel survey data between 1993 and 2011. The analysis fully relies on the expressiveness of a characteristic bundle of five direct ES, namely crop production, animal production, use of natural building materials, use of freshwater from a natural source and the collection or main usage of firewood for energy purposes. This bundle was argued to represent an integrated expression of the connection of households to their direct local environment and thus, of the overall SES characterized by low, medium or high degrees of direct ES use (Hamann et al., 2015a).

It is shown here that identifying SES that co-exist within a spatially delimited geography should require (i) a dimension of time and (ii) an exploration of the differences between households that live in a given type of SES. The results support the hypotheses that first, direct ES use varies substantially over time which makes a dynamic view on direct ES utilization appropriate and second, that aggregated SES face the risk of omitting important dynamics of social differentiation at household level that are rooted in the political economy of land access and capital accumulation, for example in the agricultural sector in KZN. Moreover, the possibilities to use the characteristic bundle as a novel indicator to various ends, including human well-being and social deprivation, ecological footprints and human-nature relationships are discussed at length. The relevance of this approach is underlined firstly by recent community resistance against large biofuel projects in the "economically underutilized" former homeland areas in South Africa that are shown to be overlapping with areas identified with high degrees of direct ES use and thus with strong ties to the direct natural environment. Second, a dynamic picture of direct ES use intensities may provide a glimpse of the waning agricultural transition in KZN, i.e. a transition from a rural-agricultural to urban-industrialized societies in which entirely new sustainability management problems arise. Third and on a more theoretical note, this study illustrates the need for combining SES theory with considerations of class, power and history inherent in any system majorly driven by human agency.

Future research avenues are identified along the lines of connecting scalable empirical research on SES with critical social science approaches that enable to provide insights, for example about the ongoing question of land reform in South Africa.

Key words: Social-ecological systems, livelihoods, social differentiation, ecosystem services, agriculture, land reform, South Africa

1 Introduction and research design

Ecosystem services (ES), i.e. provisioning services like food and water, regulating services such as flood or disease control, supporting ES that include the nutrient cycle and soil formation and cultural ES, e.g. spiritual engagement or recreation, are essential for human well-being and co-constitute livelihood domains (Millennium Ecosystem Assessment, 2005a-e; Haines-Young and Potschin, 2010; Hamann et al., 2016; Neves, 2017). Their importance has been underlined by leading researchers arguing for an integration of explicit goals related to the integrity of ecosystem services into the SDG-2030 agenda as a part of the "twin priorities", respecting planetary boundaries and reducing poverty in the Anthropocene, the new epoch in which the human has become the major driver of geological change (Rockström, 2009; Griggs et al., 2013; Steffen et al., 2015; Future Earth, 2018). This is crucial since the supply of ES is being increasingly put under pressure due to increased claims to ES by growing populations and their economies which resulted in the transgression of several global and local environmental thresholds (Schellnhuber, 2009; Nelson et al., 2013; Cole et al., 2014; Future Earth, 2018). Cross-scale dynamics stemming from local environmental degradation and global patterns of environmental change, most notably climate change, increasingly affect livelihoods and most severely those in countries of the global South that are most vulnerable to environmental change. This sparked a new wave of multi- and transdisciplinary research aiming at better understanding the complex interactions between humans and their natural environment and addressing these challenges (Ellis, 1998; Carpenter et al., 2009; Cole et al., 2014; Hamann et al., 2015a).

To date, most concepts applied on livelihoods in South Africa, remain locked-in a perspective of human-nature dichotomy and analyse livelihood domains as if ecosystem services would not matter. Also the lack of purpose-collected data and the difficulty to combine biophysical and socio-economic datasets are responsible for substantial lacunae in this field of research (Duraiappah, 1998; Cavendish, 2000; Hamann et al., 2015a). Consequently, most livelihood analyses in Sub-Saharan Africa focus on diverse forms of income, including formal work income, state cash transfers, remittances and informal economic activities (e.g. Scoones et al. 2012; Neves 2017). Natural resource harvesting, coterminous with direct ES, i.e. the collection of timber, water, natural building materials, wild foods or medical plants in rural areas received far less attention. Few existing case studies show the significant extent to which mainly (but not exclusively) rural households in South Africa depend on a vast basket of such direct ES (Cavendish, 2000; Shackleton and Shackleton, 2011; Paumgarten et al., 2018). Only the approach by Hamann et al. (2015a, 2016) attempts to systematize the use patterns of selected direct ES at the South African national scale and pre-empted the supposition that high direct ES use areas may stand in conflict with changes in land use, such as promulgated by the South African Biofuels Strategy in concerned parts of South Africa (Department of Minerals and Energy, 2007). They devised an approach to identify and map three different types of SES based on household-level direct ES use and combine them with indicators of human well-being from survey data (*ibid*.). These studies draw on the emergent and transdisciplinary field of research on SES where feedback mechanisms and interdependencies between humans and the environment are explored (Millennium Ecosystem Assessment, 2005a; Carpenter et al., 2009; Levin et al., 2013). Hamann et al. (2015a) in particular draw on the archetypal typology of SES of Cumming et al. (2014) and the corresponding challenges for sustainability management. They define two opposite types of SES in the context of the agricultural transition, namely rural-agricultural “green-loop” systems that, as the agricultural transition unfolds, transit towards urban-industrialized “red-loop” systems. Despite the emphasis on this typology, the studies of Hamann et al. (2015a) dismiss direct ES use dynamics, in other words, the evolution of direct ES utilisation over time. Also, and this is argued to be a general feature of the literature on SES, results are not connected to processes of social differentiation, or in other words, the determinants of socio-economic differences between households co-inhabitating these systems. The absence of the former in these studies applying an SES-approach to South Africa is puzzling, in particular since scholars in the field emphasize the significant changes SES undergo over time and the need to understand them (Folke et al., 2004). The latter is particularly problematic since any aggregated analysis, for example at local or district municipality like Hamann et al. (2015a), omits important differences between households within a given geographical unit. This study seeks to fill in this gap and proposes a new perspective in a region where contextual changes continuously alter the means and possibilities of constituting livelihood domains.

Thus, the central research questions ask (i) how household use intensities of the characteristic bundle of direct ES adopted from Hamann et al. (2015a) evolved between 1993 and 2011 and (ii) how these use intensities can be connected to processes of social differentiation between households. The hypotheses connected to these questions are stated as following. Firstly, the static identification and mapping of SES is insufficient given the presumably dynamic and differentiated nature of direct ES use over time; Secondly, the analysis of SES at aggregated levels like the local or district municipality risks to omit important differences between households within one type of SES rooted in the political economy of accumulation and land access, notable for example in the agricultural sector.

This bundle of direct ES is defined according to basic human needs and data availability in South Africa and consists of five direct ES: freshwater for drinking from a natural source (river or spring), the collection of fuelwood as a main source of energy, natural building materials (residence in a traditional hut), crop production and animal production (subsistence or small-scale agriculture). As opposed to other ecosystem services, such provisioning services have been shown to be best quantifiable and relatable to livelihood analyses (Cavendish, 2000; Shackleton et al., 2008; Shackleton and Shackleton, 2011; Hamann et al. 2015a; Paumgarten et al. 2018).

The report proceeds as follows: section two provides the necessary conceptual foundations regarding livelihoods, ecosystem services and social differentiation (2.1.1-2.1.3) as well as conceptual foundations regarding SES and their operationalization in South Africa (2.2). Section three comprises the methodological part. Starting by a summary of procedures (3.1), a presentation of the data sets and the study area covered (3.2.1-3.2.3), it explicates in detail the three main procedures, namely the cluster analysis with 2011 census data (3.3.1) and the evolution of direct ES use over time as well as the household-level analysis of social differentiation with panel data (3.3.2). Moreover, all variables used are explained (3.3.3). Section four presents the empirical results (4.1-4.3). Section five discusses livelihoods as emergent properties of SES in general (5.1), provides outlooks for potential uses of the characteristic bundle of direct ES as indicators to various ends (5.2) and proposes some policy suggestions (5.3). Section six concludes.

2 Literature Review and Theory

2.1 Livelihoods, ecosystem services and social differentiation – conceptual notions in general and studies from South Africa

2.1.1 Livelihoods

The notion of livelihoods has been early on defined as the capabilities of people and their means of living, including food, income and assets (Chambers and Conway, 1992). Further, a sustainable livelihood denotes the ability to "cope with and recover from stresses and shocks and maintain or enhance […] capabilities and assets both now and in the future, while not undermining the natural resource base" (DFID, 1999, adapted from Chambers and Conway, 1992). Before the turn of the millennium, it entered into disciplines such as environmental and development studies, human geography and economics. Nowadays it is used in the multidisciplinary field of development research and practice with a focus on poverty alleviation in rural or peri-urban areas in countries of the global South and as an umbrella term in the sustainable development discourse and international development co-operation (United Nations, 1992; Millennium Ecosystem Assessment, 2005a; Future

Earth, 2018). Analysing livelihoods at the household level be further understood as practicing economics at its roots. The Greek term *oikonomía* from which the common linguistic use of economics derives, consists of the words *oikos* (usually translated as "household") and *nemein* ("management" or "dispensation"). Correspondingly, the management of the household thus best translates into *oikonomía* and therefore to household-level livelihood analyses.

O'Laughlin (2004, p. 385f.) discerns two distinctive approaches to the livelihood framework. The understanding of the livelihood notion within the first approach may be positioned as a general critique of the linear model of development, i.e. the transition from rural-agricultural peasantry societies to urban-industrialized worker ones. Rather than speaking of "the worker" or "the peasant", it better mirrors the complex socio-economic realities of households in societies which are transiting from agricultural to industrial ones (e.g. Bernstein et al., 1992; Francis, 2000, 2002). Thus, speaking of livelihoods does not accentuate the expansion of the specialization of labour, but resonates more with challenges of livelihood diversification (Ellis, 1998). This is particularly relevant in countries with high formal unemployment rates, like South Africa, where labour migration is widespread and official rates of unemployment reach 30-40% in 2011, based on either the narrow or expanded definition of unemployment (Stats SA, 2012a, p. 49). Overall, this first approach foremostly serves as a descriptive categorization that goes beyond the dualistic terminology of the linear model of development.

The second approach can be understood as an operationalization and formalization of the idea of livelihoods into a framework of poverty reduction strategies. The term "livelihood strategy", O´Laughlin argues, allows individuals (or households) to diversify their livelihood portfolio, minimize risk and maximise utility in a context of scarcely available resources. As rational agents with all sorts of different capital, including natural, social, human, financial and physical, the poor can optimise their means of living and lift themselves out of poverty under the "right" conditions, e.g. access to (micro-)credit markets (Burjorjee et al., 2002). Building on the premise of methodological individualism, it is therefore compatible and widely adopted by mainstream economics. Since the late 1970ies in Africa, when "development economics simply ceased to serve the needs of the establishment […] [and] preeminence was now given to the macroeconomics of stabilization" (Mkandawire, 2014, p. 178), concepts supporting the idea of market- and individual based solutions came in handy instead of speaking of redistributive reforms in which the state has a major role to play to fight poverty (World Bank 1981, 1998). Livelihoods are a "useful concept since it brings together the many ways in which people construct a living" (Hebinck and Shackleton, 2011, p. 3). However it is important to conceive this "useful" notion in the bigger picture, in which poverty exists not only because some people in society "lack something", but because of "an outcome of social relations, structures and processes" (Oya, 2009, p. 35).

Indeed, the use of the term "capital" as an analytical category to understand livelihoods has been widely criticized and alternative frameworks exist (Murray, 2002; Arce, 2003; Scoones, 2009; Hebinck and Shackleton, 2011; Neves, 2017). One of the criticisms is that the focus on capital omits non-commoditized dimensions of livelihoods that include networks based on kinship or neighbourhood (Hebinck and Shackleton, 2011, p. 4), but also goods and services provided by local ecosystems that are relevant to this work. The term "resources" is therefore suggested to be the analytically more adequate category since it "takes into account not only bio-physical qualities but also social relations" (*ibid*.). An integrated and synthesized understanding of livelihoods as properties of SES however, is currently absent from both the livelihood and SES-literature and a confluence yet to realize.

In South Africa, livelihood analyses have profusely been carried out focusing on rural areas and particularly, on former homeland ("bantustan") areas. These areas served as labour reserves during the early industrialization of South Africa under apartheid, when, as a result of lawful eviction, millions of black South Africans were "dumped" in these typically unfertile areas (Annex V). In spite of rural development policies of the post-apartheid state, more than two decades after the political transition to democracy, these areas remain the most impoverished and deprived ones in South Africa, with KZN containing the ex-bantustan areas KwaZulu and Transkei (Bank and Minkley, 2005; Sender, 2012; Rogerson and Nel, 2016).

Stemming from qualitative case studies and South African survey data, Neves (2017, p. 27-34) defines four constitutive livelihood domains prevalent in rural areas, namely formal employment and remittances, state transfers, informal economic activities and agriculture as well as other land-based activities. The first one involves the scarcely available formal labour opportunities in rural areas and remittances, i.e. intra-household transfers of households with an urban pole. Long before agriculture, the social service sector most notably contributes to formal employment in rural areas. The second livelihood domain comprises state cash transfers, constituting the main source of income for 36.6% of all rural households in 2012 (Altman et al., 2009). These "social grants", frequently critizised for excluding working-age men from the welfare net and not resolving structural problems of poverty (e.g. van der Berg, 1997), are directed towards children, old and disabled people and thus towards beneficiary groups overrepresented in rural areas. The third livelihood constitutent, informal economic activity, by definition faces the difficulty of meaningful measurement. Despite this, estimates found it to be relatively small when compared to other countries in the global South, at least when speaking about high-value informal economic activity (Devey et al., 2006; Neves, 2017).

Both subsistence and surplus agriculture is partly comprised by the informal sector, however, Neves (2017, p.32) assigns a fourth livelihood constituent category to agriculture and other land-based activities since “they are sufficiently distinctive to warrant focused discussion”. Both agricultural activity, defined by Stats SA (2011, p.22) as “[t]he growing of crops, the raising of livestock, and the utilisation of forestry and fishery resources”, and the engagement in other land-based activities, i.e. natural resource harvesting or non-agricultural direct ES like wild foods, medical plants, natural building materials, firewood or freshwater are livelihood constituents germane to the focus of the present study and are therefore presented in more detail. First of all, this last livelihood domain stands in the context of the widely proclaimed process of de-agrarianisation in South Africa, i.e. “the occupational, social and economic movement out of agriculture” (Neves, 2017, p. x). This is largely argued to be the case due to fewer and fewer formal jobs in the agricultural sector (Aliber et al., 2007). Secondly, Neves states several challenges related to its analysis, namely (i) the occurrence of variegated forms and scales of agricultural production all too often subsumed under the term “small-scale” agriculture, thus necessitating class-differentiation (Cousins, 2010); (ii) the unequal distribution of agricultural production possibilities due to variable local agro-ecologies (Aliber and Hart, 2009); and (iii) the difficulties of quantifying non-agricultural direct ES (Cavendish, 2000; van Averbeke and Khosa, 2007; Hebinck and Shackleton, 2011). Moreover, data paucity and the lack of “dedicated inquirement” (Neves, 2017) contribute to the relative absence of comprehensive studies on this livelihood domain which further motivates the present investigation.

Past studies suggest a number of stylized facts on the fourth livelihood domain defined by Neves (2017). As far as agriculture is concerned, it nowadays continues to stand as a priviledge, typically requiring access to land and capital input which are both not available to the most deprived population groups (Cousins, 2010; Neves, 2017). This priviledge has been reinforced through decades of apartheid-state subventions to white-commercial, large-scale agriculture which persists also after the transition to democracy especially supported under the Mbeki government (1999-2009), albeit now with a clear focus on market efficiency and de-racialisation of agriculture (Cousins, 2017). Subsistence farming however, remains crucial for food security, particularly in the former homelands where recent data suggest the highest shares of agricultural engagement outside of paid jobs (Daniels et al., 2013; Rogan, 2018). Across South Africa, the proportions of households engaging in any kind of agriculture seem to have halved between 2008 and 2010 from 35% to 18% (*ibid*.), but which according to Neves (2017, p.32) is likely to be a measurement error. Indeed, a recent comprehensive assessment of biophysical land cover change suggests that in the period between 2005 and 2011, both the absolute (+370.000ha) and relative (+175%) proportions increase more quickly for subsistence agriculture than for any other type of land use in KZN (Driver et al., 2015). This finding is largely supported, at least in some parts of KZN, by the subsequent identification of households engaging in increased crop and animal production at the household level that forms part of the characteristic bundle of direct ES analysed in this study.

2.1.2 Ecosystem services

Ecosystem services (ES) essentially constitute life-support systems and contribute, both directly and indirectly, to livelihoods and therefore human well-being (Millennium Ecosystem Assessment, 2005a; Haines-Young and Potschin, 2010; Hamann et al., 2016; Neves, 2017). The seminal work published by the World Resource Institute at the beginning of the millennium categorizes ES into four broad categories that are each linked with multiple constituents of human well-being (Millennium Ecosystem Assessment, 2005a-e). It distinguishes between: supporting ES, that include for example nutrient cycles and soil formation; regulating ES referring to, among others, climate, flood and disease regulation; provisioning ES involving the supply of food, freshwater or wood for energy and lastly, cultural ES, meaning the contribution of ecosystems to human aesthetic, spiritual, educational or recreational claims to nature (Annex I, *ibid*.). Altogether, ES are linked with human needs of security, material necessity, health, social relations and their integrity is argued to be a precondition for the opportunity of possessing freedom of choice and action (Millennium Ecosystem Assessment, 2005a, p. vi). This first comprehensive assessment regards ES from an anthropocentric point of view in which ES are analysed in terms of their benefit to human society as well as human feedbacks on the functioning of these ES (Carpenter et al., 2009). Both, the benefit from and the feedbacks to the four categories of ES are undergoing a process of non-linear or abrupt change (*ibid*.). As population grows and economic development unfolds, claims on provisioning ES have more than tripled and thus growing at an unprecedented and often unsustainable rate (Foley et al., 2010; FAO, 2017). Regulatory ES are globally on the decline due to a variety of interconnected factors including climate and land use change (Carpenter et al., 2009; Ding et al., 2010), sea level rise and coastal erosion (IPCC, 2013) and biodiversity loss (Oliver et al., 2015). Biogeochemical flows in terrestrial and aquatic bodies fundamentally contribute to supporting ES which have over the past decades been critically perturbated by the heavy but globally very unevenly distributed load of phosphorus and nitrogen originating from fertilizer use (Rockström et al., 2015). Lastly, recent evidence showed declining trends of cultural ES to offer a space for human recreation, at least for some selected Western countries (Pergams and Zaradic, 2008). However, with rising numbers of nature-based tourism, cultural ES rose to be a highly valuable source of national incomes that, at the same time, poses a threat to the integrity of the underlying ecosystems (World Bank, 2018). Given the most recent estimates of population growth to 9.8 billion by 2050 (UN Department of Economic and Social Affairs, 2017) and economic growth continuing to be the single most pursued economic policy objective (Victor, 2008), these trends are likely to continue unless international cooperation proves to succeed in addressing these ever more pressing challenges.

South Africa is ecologically megadiverse, meaning it has a high variety of ecosystems that are possible to be grouped into the following six categories, namely terrestrial, river, wetland, estuarine, coastal and offshore ecosystems both providing services to and absorbing feedbacks from the society. Comprehensive ecosystem services assessments have been undertaken since 2004 and the most recent National Biodiversity Assessment assign a threat hierarchy to these groups of ecosystems. Most threatened are wetland (65%) and coastal (58%) ecosystems that serve as a protection against floods and storms and as water purification bodies, many of which are located in KZN along the Indian Coastal Belt in the southeast of the country (Driver et al., 2012). These two are followed by river ecosystems (57%) vital for freshwater provision, estuarine ecosystems (43%) that serve as sources for fishing and nursing grounds, offshore ecosystems (41%) exploited for fishing, transport and oil and gas extraction and lastly, terrestrial ecosystems (40%) of which key services include (but are not limited to) pollination, grazing and arable land and ecotourism. The threat status reveals "the degree to which ecosystems are still intact or alternatively, losing vital aspects of their structure, function or composition, on which their ability to provide ecosystem services ultimately depends" (*ibid*., p.3).

Few livelihood studies from Southern Africa focus on non-agricultural (and non-touristic) ecosystem services, for example the collection of wild foods, medical plants, timber and firewood or building materials. Cavendish (2000) shows with purpose-collected data that the poorest households in Zimbabwe constitute up to 40% of their incomes from a wide range of direct ES and Shackleton and Shackleton (2011) reviewed the relatively few empirical studies on South Africa available to them. They assert that whilst wild natural resources (excluding agriculture) may often not be the primary livelihood domain, its contribution constitues up to one-quarter of total livelihood streams, be it as a tool for income generation or self-use, and are thus "keenly appreciated by rural communities" as a natural safety net (*ibid.*, p. 211ff.). Unlike Hamann et al. (2015a), these studies have however focused on comparatively small populations.

2.1.3 Social differentiation

Qualitative differences between households or individuals can be demonstrated on the basis of a variety of factors. In occidental sociology, most class-or milieu based analyses of social differentiation have their precursors in Marx, Weber and more recently, Bourdieu. Marxian perspectives on class formation focus on the social relations of production, i.e. on differences in society based on the possession of the means of production, enabling one to either extract and another to dispose of surplus labour (Wright, 2005). At the latest since publishing the 18th Brumaire of Louis Napoleon, Marx embeds his analysis of class formation also in the wider context of a historically constructed political economy (Marx, 1852). Weberian-inspired studies tend to account more for a multidimensionality of class formation, including the Marxian juxtaposition of class, but also status, power and life chances (Breen, 2005; Ritzer, 2011). Lastly, Bourdieu´s theory of the social space also assumes the division of society into classes differing in terms of their endowment with various types of capital, namely social, economic, symbolic and cultural capital (Bourdieu, 1986). The construction of identities on the latter, cultural capital, has often been perceived as the centrepiece of Bourdieu´s contribution, something that according to Melber (2017, p.147) has critical importance for the multiethnic pan-African context. In a nutshell, Bourdieu´s multidimentional perspective also captures next to the structural embeddedness of a given social space, subjectivist and relational moments in which it matters whether one simply lives in a shack or whether one lives in a shack and is looked down upon (Noret, 2017, p. 657). This in mind, as an observer, it emerges that the positionality in society can be identified either by the resources one has access to, or by those one lacks (*ibid.*). This last point has recently been developed into a Bourdieu-inspired perspective of class differentiation based on the social-metabolism, i.e. the material and energy throughput responsible for an individual ecological footprint constituted of carbon emissions, land and non-renewable resource use, generation of waste etc. (Fischer-Kowalski, 1997; Otto, 2019). Owing to the possibility that the Bourdieu-inspired perspective of social differentiation has thus already been conflated with systems thinking and society-environment metabolisms, preference is given to it over that of critical agrarian studies which, although limited in some several aspects as well, would represent another good theoretical approach.

In South Africa, detailed typologies of households are frequently the result of applying an approach of social differentiation in combination with a livelihood framework (Scoones et al., 2012; Neves, 2017). For example, Neves (2017) characterizes four classes of rural households. Firstly, there are “Moving-Out” households that correspond to the local elite, have strong labour market linkages and evidence of reinvestment and accumulation of capital. Second, he finds “Inching-Up” households with middling labour market ties, some livelihood diversification and expanded social reproduction. Third, there are “Hanging-On” households that tend to be more vulnerable with few or no labour market linkages, only receive some social grants and do not manage to broadly diversify their incomes, including agriculture. Fourth and lastly, there are “Dropping-Down” households that represent the poorest and most vulnerable segment in this typology. They seldomly receive significant state cash transfers nor are they capable of engaging in any form of agriculture. The latter is congruent with many other studies that provide evidence that the capacity to engage in agricultural activities is a privilege in South Africa (Cousins, 2017; Neves, 2017). Moreover, there exist substantial differences between agricultural households, depending on the contribution of the produce to the social reproduction capacity of the households (Cousins, 2010). According to Neves (2017), female and older households, often well-situated and with current or past labour market linkages are more likely to be engaging in agricultural activity.

For this study, the only conceivable moments of the complex picture of social differentiation in a multi-ethnic and historically turbulent geography like KZN is the observed utilization or non-utilization of the bundle of direct ES and its association with household characteristics. Thus, the purpose of this part of the study is rather modest and illustrative (see 3.3.2.2). This is due to the fact that the data used rather permit to draw general conclusions than to set up specific typologies of households such as the small case studies of Neves (2017) or Scoones et al. (2012) do. Owing to the relative lack of subjective indicators on a household´s position in its respective social space, it must entirely rely on objective measures like income, property or land ownership and labour market linkages.

2.2 Social-Ecological Systems

Speaking of SES, rather than analyzing social and ecological units separately, reflects the need of addressing the complex challenges that sustainability imposes on humanity in the 21st century. It breaches with the occidental conception of a dichotomous "human" (social) and "non-human" (natural/ecological) world by emphasizing the intricate interdependencies between humanity and non-human nature as well as by overcoming disciplinary boundaries assigned to analyze either of the two dimensions.

An SES can be defined with the following properties (Redman et al., 2004, p. 163):

- a coherent system of biophysical and social factors that regularly interact in a resilient, sustained manner;
- a system that is defined at several spatial, temporal, and organizational scales, which may be hierarchically linked;
- a set of critical resources (natural, socioeconomic, and cultural) whose flow and use is regulated by a combination of ecological and social systems;
- a perpetually dynamic, complex system with continuous adaptation.

The last point has led leading researchers to speak of complex, adaptive SES to emphasize the non-linear and cross-scale dynamics that feedback mechanisms between social and ecological systems exhibit in a context of surprise and uncertainty (Faber et al., 1992; Levin et al., 2013; Berkes et al., 2008). Non-linear dynamics refer to processes of incremental change that may occur in response to the behavior of single components of the system at global (e.g. exponential rise of global temperatures due to anthropogenic greenhouse gas (GHG) emissions → melting of ice sheets → reduction of the world´s capacity to reflect solar radiation (albedo) → incremental heating of global temperatures) or at local scales (e.g. the overuse of a local forest due to logging → the loss of habitats, soil erosion protection and biodiversity → degradation of the entire underlying SES at greater speed). Cross-scale dynamics in SES occur in time and space, i.e. the feedback mechanisms between the change in the property of one system component may alter the state of the system with a time-lag and at different scales. Examples include the concentration of chlorofluorocarbons (CFCs) or GHGs in the atmosphere or the overuse of fertilizers in intensive agricultural production that will affect future generations much more than present ones and hit the most vulnerable people in countries of the global South more severely than moderate climate zones and wealthy population segments (Ostrom, 2007; Berkes et al., 2008; Schellnhuber, 2009; Otto et al., 2018).

Of relevance to the present study is the point of identifying different types of SES through distinct characteristics of the linkage of biophysical (e.g. the supply of direct ES at a local level) and social factors (e.g. the political economy of land access) that differ sufficiently enough in space to assign clear spatial boundaries.

One archetypal typology was put forward by Cumming et al. (2014). They propose two antithetic types of SES, within which human civilizations evolved at first over millennia and centuries, but since the rise of capitalism, also over decades (**Tab. 1**). Note that these two types of SES are highly stylized and do only in abstract terms conform to reality.

	1. Green loop system	**2. Red loop system**
Characterization	• rural-agricultural • local economies strongly relying local ES, hardly on any external economy • direct feedback mechanisms between environmental	• urban-industrialized • little or no direct dependence on the surrounding ecosystems • economy is built on remote extraction of ES from distant ecosystems through trade

	degradation and human well-being	• indirect feedback mechanisms environmental degradation and human well-being
Major sustainability challenges	• "Green trap", i.e. a vicious circle between growing poverty and local environmental degradation • Overuse or undersupply of local ES	• "Red trap", i.e. unsustainably growing ecological footprints (i.e. waste products) resulting from overconsumption and production • Problems of scale in overall throughput of material/energy: overuse of ecosystems as sources and sinks • Surplus appropriation and attendant social inequality

Tab. 1 – Characteristics of green and red loops and related sustainability challenges. Based on Cumming et al. (2014) and Hamann et al. (2015).

The first type, rural-agricultural or "green loop" systems is characterized by local economies that strongly rely on directly available ES, most notably provisioning ES, and hardly on any external economy. Thus, there are direct feedback mechanisms between environmental degradation and human well-being (*ibid*., Hamann et al., 2015). Contrary to this, the second type, urban-industrialized or "red loop" systems are marked by little or no direct dependence on the surrounding ecosystems. The economy is built on remote extraction of ES from distant ecosystems, i.e. ecosystem goods and services that involve transportation, commercialization and a large degree of the division of labour (*ibid*.). Here, society is largely disconnected from the natural environment and people "become less aware of ecological degradation and less concerned about it" (Cumming et al., 2014, p. 51). Contrary to green loop systems, the material and energy supplied to the red loops from faraway ecosystems tends to be extremely high. Thus, very distinct sustainability challenges for each system type apply (Hamann et al., 2015). On the one hand, the challenge in green-loop systems is to avoid the "green trap", a vicious circle between growing poverty and local environmental degradation. On the other hand, red loop systems are haunted by the "red trap", i.e. unsustainably growing ecological footprints resulting from overconsumption, overgeneration of waste products and concomitant excessive claims to ecosystems as sinks (*ibid*., p.218f.).

The transition from the first to the second type of SES involves a variety of historically specific and transformative factors and represents a gradual regime shift (Folke et al., 2004; Cumming et al., 2014). To name only a few, this includes new technologies, population growth, the upscaling of economic and political systems and their integration into the world economy, all of which results in an enlargement of metabolic flows, concerning both inputs and outputs to the economic process.

To specifically tailor policies for sustainability management in either of these types of SES, including a third system type "in transition", Hamann et al. (2015a) devised a novel approach to identify and map these SES by analyzing the distribution of use intensities of a characteristic bundle of direct ES[1] from cross-sectional 2011 census data at the national scale in South Africa. Their major findings are that predicting a type of SES (high-use of direct ES: green-loop, medium-use: transition loop, low-use: red-loop) at local municipality level depends more on social factors than the supply of ES in a given locality. Social predictors notably include income, gender of the household-head, property ownership and population density, in this order (*ibid*., p.223). ES supply variables measured at the municipal level, like the supply of wood, the mean annual runoff of water and the grazing and cultivation potential based on climate and soil properties, were found somewhat less important. Based on a municipality-level cluster analysis of average household use intensities of their defined characteristic bundle of direct ES, they found 152 municipalities belonging to low direct use systems, 50 in the medium direct use system and 32 in the high direct use system, representing 78.2%, 14.4% and 7.3% of the total number of households in South Africa, respectively (*ibid*., p.221).

In connection with the here presented conceptual framework, this work replicates and extends this approach for the province of KZN, one of the regions in South Africa (next to the Eastern Cape) where the highest proportion of high-use category municipalities were found. For what is overtly missing in this approach is a perspective of direct ES use dynamics and of political economy, the former being hypothesized as an inherently changing feature of SES dynamics and the latter as a factor concretely determining the access to land, and thus the possibility to engage in the livelihood domain of agricultural and non-agricultural direct ES.

[1] The exact bundle used by Hamann et al. (2015) consists of the exact same provisioning services, apart from that wood has been analysed separately, wood for cooking and wood for heating. For further details see subsection 3.2.4.

3 Data and methods

3.1 Summary of procedures

This report is an empirical household survey research fully relying on secondary data. It applies several methods performed on cross-sectional as well as panel data from South Africa, including cluster analysis, spatial mapping and panel regression covering a period of 18 years with data collection in 1993, 1998, 2004 and 2011.

In short, the initial cluster analysis (procedure I) is performed to identify the three different types of SES corresponding to low, medium and high use intensities of the characteristic bundle of direct ES as observed from 2011 census data in KZN. Throughout the thesis, these three types of SES will be interchangeably denoted by low, medium or high use categories or red-, transition and green-loops, respectively. The results from the cluster analysis are visualized in star plots (4.1) and mapped spatially, using the official municipal border demarcation files downloaded from the South African Demarcation Board (2016a, 2016b).

Subsequently, the evolution of direct ES use intensities in the province of KZN since 1993, the year before the political transition to democracy, is constructed retrospectively (procedure II, 3.3.2.1). Clustering is performed again on the initial set of households from the panel data set to subdivide the new data in the same three use categories of direct ES. Based on this, the evolution of average levels of direct ES use in this 1993-cluster solution is observed until the last data wave in 2004 and compared to the 2011 cluster solution. Hence, the observer is able to grasp and interpret the direct ES use dynamics of this characteristic bundle of direct ES over a period that witnessed profound social, economic and political change.

Lastly, a household-level panel regression is deployed to associate direct ES use intensities as the dependent variable with factors underpinning the socio-economic status of sampled households (procedure II, 3.3.2.2). This analysis is designed in a way to open room for discussing the choice of the bundle of direct ES consisting of agricultural and non-agricultural ES as well as for discussing variegated dynamics of social differentiation associated with either of the three types of SES. All methods are explicated in further detail in subsection 3.3.

3.2 Data sets and study area

Two data sets have been chosen for this study. On the one hand, the first ever comprehensive and representative household panel study in South Africa, namely the "KwaZulu-Natal Income Dynamics Study (KIDS)" which was collected in three data waves between 1993 and 2004, covering the province of KZN in the South-East of the country. On the other hand, most recently available census data from 2011 which has a nation-wide coverage and was therefore subset to KZN only. Some issues regarding comparability between the two surveys arose and include the different sampling procedures, the definitions of key variables and slightly varying questions regarding the use of direct ES, all of which will be addressed in subsequent sections. In both data sets, responses to household-level variables were made by self-declared household heads or core persons in KIDS, if the initial household head from 1993 could not be tracked down anymore. The province of KZN was chosen as a study area because it was found to be one of the two provinces (together with the Eastern Cape) in which Hamann et al. (2015a) found the highest concentration of direct ES use in 2011. At the same time, according to their analysis, it is a geography in which all three types of SES co-exist. Moreover, it is the only province for which data reaching back as far as 1993 exists.

3.2.1 Census data 2011

National censuses are the source for basic information on population and housing statistics. In post-apartheid South Africa, the 2011 census is the third of its type, collecting information through face-to-face interviews with nearly every person present in South Africa between October 9th and 31st. It is usually carried out by Statistics South Africa (Stats SA) every ten years. Publicly available is a 10% sample with corresponding weights. The units of analysis in the census are both, the household and the individual. For this study, all analyses were carried out at household level, which was defined as “a group of persons who live together and provide themselves jointly with food or other essentials for living, or a single person who lives alone. Note that a household is not necessarily the same as a family” (Stats SA, 2011a, p. 55). The census is geographically explicit at local and district municipality as well as provincial levels, where the local municipality represents the smallest geographical unit publicly available. Unlike the KIDS panel data, census data is cross-sectional, that is, a snapshot of the country in one point of time. One relevant particularity of the 2011 census is the separately available sample of agricultural households, i.e. households that engaged in some form of agricultural activity (Stats SA, 2011b). Once joined into one dataframe, the weighted share of agricultural households in KZN in 2011 was 28.24%.

For the cross-sectional analysis in 4.1 and the provision of descriptive statistics, a dataframe consisting of 260.229 single household observations as rows and 17 variables as columns (including the corresponding weights) was constructed (Annex VI).

3.2.2 KIDS data 1993-2004

In 1998 and 2004, the team behind KIDS re-interviewed households in KZN originally visited in 1993 through the nationwide “Project for Statistics on Living Standards and Development (PSLSD)”. KIDS is the first comprehensive panel survey able to track changing socio-economic parameters up until before the political transition to democracy in 1994. However, it is limited to the province of KZN. The original 1993 households were randomly chosen based on a two-stage self-weighting design which should make it unnecessary to use weights for their representativeness (Aldermann et al., 2000, p. 11f). The definition of households for the KIDS enumeration was somewhat looser than in the census. Any person who (i) lives under the same "roof" 15 days or more out of the past year or who (ii) shares food from a common source when they are there, and (iii) share in or contribute to a common resource pool were conceived as household members (SALDRU, 1993, p. v).

The main difference between panel and cross-sectional data is that panel data have an internal structure represented by an index, in this case, household ID and year (Kleiber and Zeileis, 2008, p. 84). On the one hand, panel data are more complicated to handle. On the other hand, they permit to meaningfully track change over time. The latter motivates the utilization of the panel data, although for the analysis in 3.3.2.1, KIDS data are used as cross-sections at the local and district municipality level for the respective years. Consequently, only the integration of time and space-fixed effects in the household-level panel regression makes usage of the panel nature of this dataset. Several issues that need clarification arose when dealing with the KIDS-panel, including (i) population group specificity; (ii) split-households; (iii) attrition of households and (iv) differing administrative boundaries when compared to 2011.

In regard to (i), it needs to be pointed out that unlike the PSLSD, KIDS only followed African and Indian households which add up to 97% of all households in KZN at that time, rendering the other two population groups (Whites and Coloureds) too little represented in the sample and too highly concentrated in some areas "to permit meaningful inference" (University of KwaZulu-Natal, 2004). For a higher variance in the original sample, white and coloured households are kept in the 1993 wave.

Concerning (ii), split households were identified only in the 2004 wave, making it necessary to introduce new unique household identifier (hhid) numbers. This was implemented by adding two digits $Z \epsilon \{00,02,03,04,05,06,11,20,24,25,26,40,45\}$ to the six or seven-digit hhid of 1993. If Z equals zero, the hhid represents a household with at least one core member from 1993. The other codes represent several types of split households, including first splits, second splits […], next generation households and children of core members that had to be taken care of by foster parents and so on, that fulfilled the criteria to be a new core person. Core persons are defined as major decision makers within the household and have been tracked down for the second and third wave of data collection. They either represent the self-declared household head from the original sample in 1993 or are closely related to him or her (see exact definition in Annex III). Split-households, particularly the new generation households effectively freshen up any sample reduced by the dropping out of households throughout the data collection.

This process is called household attrition (iii) and is caused for example by death or the inability to locate the household. Per wave, it was found to be lower than 20% and therefore within a typical range of household attrition in longitudinal survey of this magnitude (Aldermann et al., 2000, p. 12).

Lastly, (iv) turned out to be quite problematic since the procedure 3.3.1 requires exact information of *where* a household had been living, particularly to compare the within-cluster evolution of direct ES use intensities (see section 3.3.1). The problem was that the geographical disaggregation of KIDS was provided by magisterial district codes, which are boundaries that do not exist anymore and cannot be compared with the current local and district municipality classification. However, KIDS provided the real names of the enumeration clusters, i.e. those areas that have randomly been selected for interviews in each magisterial district, it was possible to locate nearly all observations of these clusters in present local and district municipalities through in-depth research. Despite that, meaningful mapping of the average direct ES use intensities at municipality level with KIDS data turned out to be impossible, since data collection has only been performed in 20 out of 48 local municipalities and 10 out of 11 district municipalities.

To sum up, a panel dataset of 4067 observations as rows across three data collection waves (1993, 1998 and 2004) and 44 variables as columns was constructed from raw data, merged, cleaned and transformed to perform the subsequent analyses (Annex VI).

3.2.3 Description of the study area

KZN is one out of nine provinces in South Africa, located in the South-East of the country bordering Mozambique and Eswatini in the North and Lesotho in the West (**Fig. 1a**). Stats SA (2012a) provide data on population dynamics. According to this source, the population grew from 8.572.302 individuals in 1996 to 10.267.300 in 2011 (2.539.429 households that represent 17.6% of all households in South Africa). This makes KZN the second most populous province after Gauteng in 2011.[2] In current administrative terms, KZN is subdivided into one metropolitan municipality (eThekwini) and 10 district municipalities that are further subdivided into 44 local municipalities, eThekwini being counted as both local and district municipality (**Fig. 1b**). According to the 2011 census, the population was majorly composed of Africans (86.8%), Indians/Asians (7.4%), Whites

[2] This figure excludes the estimated 717.116 agricultural households as observed from the separate agricultural census. For all subsequent analyses, the total figure of 3.183.486 households is used as the universe. Note that when after merging agricultural and non-agricultural household datasets, it was found that 6.335 households were listed both as agricultural and non-agricultural household. To avoid double entries, it was decided to delete the 6.335 non-agricultural households and preserve the information of the 6.335 agricultural ones.

(4.2%) and Coloureds (1.4%). In most of the province, the main language is Zulu, alongside with Xhosa, English and Afrikaans.

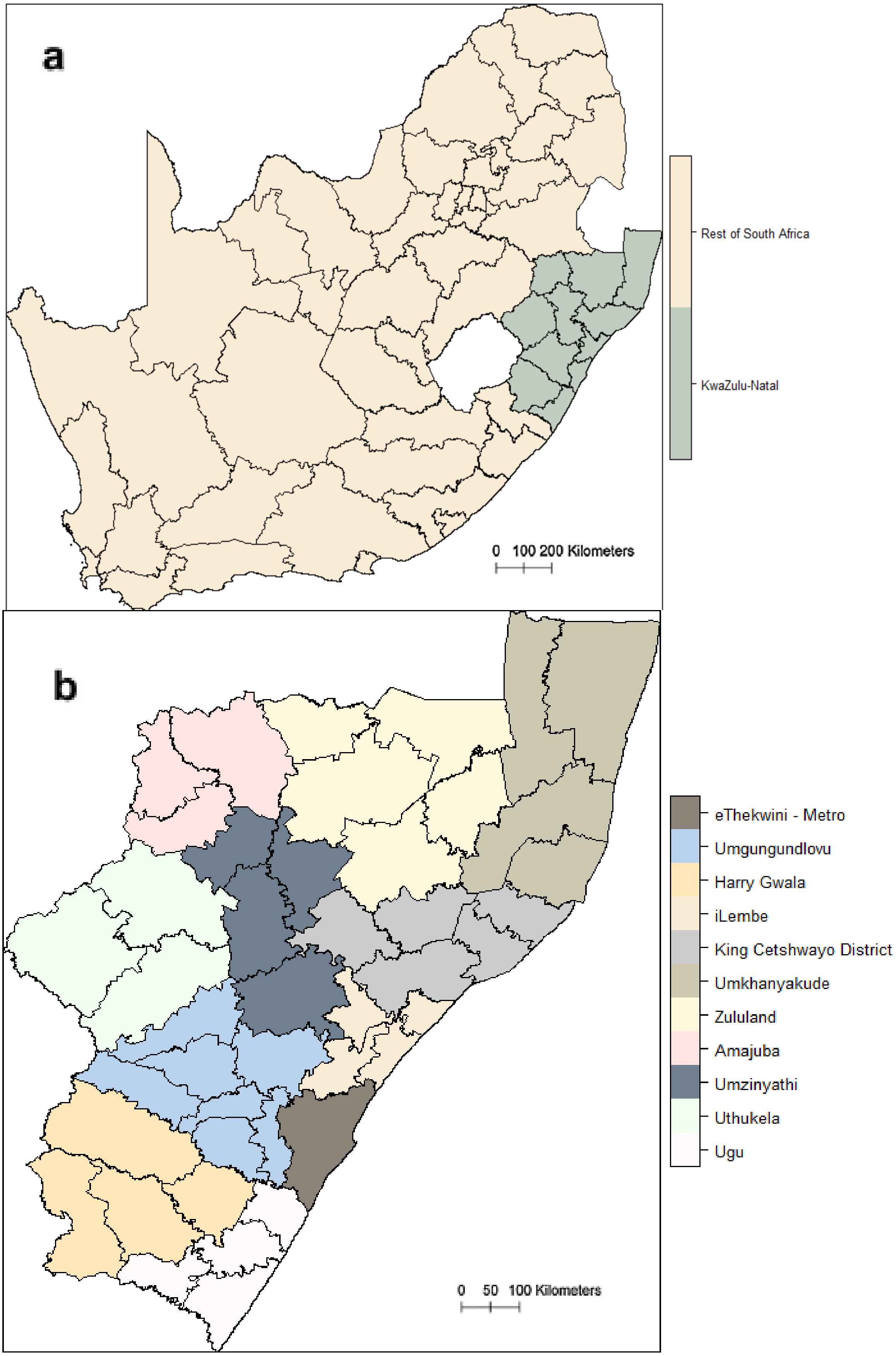

Figure 1 - (a) Location of KZN in South Africa. District municipality borders are shown. (b) District municipalities in KZN. Local municipality borders are shown. See Annex IV for a full list of local municipality names by district. R-package: *sp*. Data: Official shapefiles from the South African Demarcation Board (2016a, 2016b).

Pietermaritzburg is the political capital of KZN located in the district uMgungundlovu. Durban is the biggest city, an important economic hub and South Africa´s major port, handling over 30 million tons of cargo every year (Driver et al., 2015). Important economic activities in the interior of the country are coal mining and steel production and along the coastal belt, sugar cane production and fruit production as well as tourism.

3.2.4 Defining a characteristic bundle of direct ES

The definition of the characteristic bundle of direct ES by Hamann et al. (2015a) adopts its design to the quality of existing, non-purpose collected survey data regarding local natural resource use. Indeed, only the most basic needs satisfied through the local ecosystem (energy, food, water and shelter) can be taken into consideration. The exact composition of the adopted characteristic bundle for this study is presented in **Tab. 1**. On the one hand, this bundle of ecosystem services does not allow to do justice to the complexity of human-environment interactions on the basis of local natural resource extraction like smaller case studies achieve, e.g. Cavendish (2000) who demonstrates the vast variety of direct ES on which many rural livelihoods depend. On the other hand, it manages to adopt to the reality of socio-economic household survey data in most countries and is easily scalable since this data is available in many countries around the world. On the household level, high use intensities of this bundle are likely to indicate, depending on the local supply of direct ES, a wider use spectrum of natural resources utilized in reality. For this reason, this bundle can serve as a proxy for the overall connectedness of households to their direct natural environment (Hamann et al., 2015a). Use intensity is denoted at its maximum (=5) if all direct ES are utilized and vice versa (=0).

Dummy variable (1 = Yes, 0 = No)	**Observation**
Animal production	The household farmed one or more types of animals or poultry in the past year.
Crop production	The household harvested one or more types of crops in the past year.
Natural building materials	The household resides in a traditional dwelling (hut). Stats SA (2012b, p. 19) define a traditional dwelling as “A dwelling made primarily of clay, mud, reeds or other locally available natural materials. This is a general term that includes huts, rondavels, etc. Such dwellings can be found as single units or in clusters”

Freshwater	The household mainly sources its freshwater for household use from either a spring, stream or river.
Wood	Wood as the main source of energy AND average number of trips of at least one household member collecting wood per week ≥ 1 for KIDS. For census, this variable is proxied only with wood mentioned as the main source of energy for either cooking or heating.

Table 2 - Composition of the characteristic bundle of direct ES. A full description of the variables and the related questions from the KIDS and census questionnaires is available in Annex II.

The inclusion of the first two components of the bundle, crop production and animal production, is distinctive from most other studies concerned with resource use that most often focus on "wild" natural resources. From a perspective of SES though, it is crucial to assume all activities involving the direct use of local ecosystems, formal and informal, for self-use or income generation as subsumable within the scope of the here defined characteristic bundle of direct ES. Given the importance of agriculture for the reproduction capacity of households in South Africa, this step is important. However, and this anticipates one result of the regression analysis in 4.2.2, land ownership predicts higher direct ES use intensities, which in this case are likely to consist of crop and animal production that do not necessarily indicate household vulnerability when standing dissociated from the use of the other components of the characteristic bundle. Agricultural households can well be wealthy pensioners or active labor force members with boreholes or municipal tab water supply that live relatively disconnected from local ES in modern brick houses (Hamann et al., 2015a, p. 224). Indeed, as Neves (2017, p. 36) argues, the most vulnerable and precarious rural households carry out only vanishingly little or no agriculture. Being able to produce crops or animals presupposes the capacity to access arable or grazing land, which is by no means a given in South Africa.

Regarding the third component of the characteristic bundle of direct ES, the residence in a traditional dwelling serves as a proxy for the use of natural building materials. 2011 census data tells us that it is a particularly relevant variable for KZN. While national trends saw the share of households living in such dwellings halve since 1996 to 7.9% in 2011 (Stats SA, 2012a, p. 57), the share of households in KZN was still 28.9% in 2011, and even as high as 60% in the high use category areas (marked as "green-loops" in **Fig. 2**).

In terms of freshwater usage from natural sources, KZN also stands out in national comparison and in 2011, 14.1% of all households did not have access to piped water (Stats SA, 2012a, p. 59). These households thus rely on the supply of freshwater directly extracted from rivers, springs or wells and are therefore seriously at risk of water pollution. In South Africa, the water pollution is amplified through the pervasive spread of dams that significantly alter the capacity of running freshwater ecosystems to provide potable water (WWF, 2016, p. 20).

Due to differing questions asked in the questionnaire, the fuelwood variable had to be coded somewhat distinctively for census and KIDS data. While a dummy of one for census means that fuelwood was indicated to be used as a main source of energy for heating or cooking. In addition to being the main source of energy, in KIDS data it signifies that at least one household member collected fuelwood at least once in the past week. Unlike census data, KIDS data therefore allow coding wood as directly extracted from the local ecosystem whereas the results calculated from the census may also comprise households that purchased wood. Since the 1990ies, fuelwood use has received the greatest attention by academia and has been shown to have caused a "fuelwood crisis" in which this resource was severely overused in many parts of South Africa (Bembridge and Tarlton, 1990; Dovie et al., 2004; Hebinck and Shackleton, 2011). Fuelwood throughput was estimated to be as high as 4343kg/year per user household in 2004 and was clearly shown to be among the most important livelihood activities of marginalized households (Dovie et al., 2004). Overusing forestry resources does not only directly affect the satisfaction of household energy needs, but is also associated with declines in regulating and supporting ecosystem services and therefore at risk of triggering potentially irreversible and non-linear domino effects (Brinkmann et al., 2012).

3.3 Methodological approach

3.3.1 Procedure I – Cluster analysis and spatial mapping of direct ES use in KwaZulu-Natal

A cluster analysis is a multivariate statistical method and is used to subdivide data sets into groups that share common characteristics (Brock et al., 2008; Janssen et al., 2012). For this study, it is deployed to characterize geographical units (local and district municipalities in KZN) into low, medium and high use categories from 2011 census data. For example, in local municipalities grouped as low use, only about four percent of all households indicated in 2011 to have a natural spring or river as their main source of freshwater for household use (**Fig. 2**).

The repartition of municipalities to either of the three categories is performed with the kmeans function from the *stats* package that relies on the Hartigan-Wong algorithm (Wong and Hartigan, 1979). It is carried out on two levels, namely local and district municipality scale. The kmeans algorithm minimizes the within sum of squares given by

(1) $$WSS(C_k) = \min \sum_{x_i \epsilon C_k} (x_i - \mu_k)^2$$

where WSS is the within sum of squares or total intra-cluster variance, C_k is one out of $k \epsilon \{1,2,3\}$ clusters, x_i represents the individual data observation of a single municipality and μ_k the mean value of all municipalities clustered in k. The method picks random starting values for each of the groups (n=25) and allocates individual observations (average household use intensities on a given scale) to one of the three groups corresponding to the lowest *WSS* as defined by numerical iteration (n=10.000). By minimizing the *WSS* for each random starting point, the algorithm converges against three centroids that contain the least dissimilar observations. This method relies on the Euclidean distance as a measure of (dis-)similarity between individual observations with variables coded between zero and one (percentage of households that indicated direct ES use at the local or district municipality level). In accordance to and for comparison with Hamann et al. (2015a), the number of groups was set to three prior to implementation. The choice of kmeans with three group centers as an adequate clustering method was verified using the *clValid*-package in which only "hierarchical clustering" scored similarly well to kmeans in regard to internal and stability measures.[3] Within-group means are reported at the two scales in star plots, in which the petal length indicates the percentage of households utilizing the specific direct ES at a given scale (**Fig. 2**). The range of standard errors of the mean is reported in the notes below the figure. Moreover, individual direct ES is subjected to a correlation analysis to identify pairs or groups of direct ES that are likely to be used together.

The results have been mapped using the most recently available shapefiles for municipal border demarcation in KZN (**Fig. 3**). All spatial data has been downloaded from the South African Demarcation Board (2016a, 2016b), combined with a vector containing the cluster solution for the direct ES use categorization and plotted in R using the packages *maptools*, *rgdal* and *sp*.

3.3.2 Procedure II – Adding the components of intertemporal change and social differentiation at household level to the analysis of direct ES use

3.3.2.1 Comparison of 2011 census data with the panel sample from KIDS 1993 – 2004

This section describes the procedure to complement the approach adopted from Hamann et al. (2015a) explained in section 3.3.1. To analyze direct ES use dynamics, a component of time is added to the static distribution of SES in 2011 that is shown in **Fig. 2** and **Fig. 3**. How did direct use dynamics evolve since before the transition to democracy? How did the percentage of households living in low use (red loop) categories and high use (green loop) categories, or in between (transition loop) evolve since 1993 and which conclusions can be drawn from this evolution?

[3] Measures used are "Connectivity", "Dunn" and "Silhouette". All cluster methods checked against can be compared from the R-Code provided in the Annex. For two, four, five or six numbers of groups, other methods did score better than kmeans.

To answer these questions, the representative sample of initially 1519 households selected in the 1993-PSLSD-study has been analyzed. Not only does this data contain all the information to construct the characteristic bundle of direct ES, but also sufficient additional information to construct the subsequent in-depth analysis of social differentiation. Of interest to this section, is not the panel nature of the study or the household itself. At this point of the investigation, the evolution of the aggregated use intensities of the five direct ES within an identified type of SES, i.e. a direct ES use category. KIDS data disaggregates its observations to enumeration areas (EA), which are "the smallest geographical unit […] into which the country [South Africa] is divided" (Stats SA, 2011a). EAs typically consist between 100 and 250 households (*ibid*.). In total, KIDS visited 73 EAs where it randomly selected its households.[4] Thus, it was possible to identify the three types of use categories at a much smaller and more meaningful scale, namely the EA scale, based on which the same kmeans-cluster algorithm deployed in 3.3.1 was carried out. The preference for this smaller scale is supported by statistical evidence, which shows that the variation of use categories determined at EA level within-municipalities (local or district) is substantial. To observe within-EA change of direct ES use, representative for the entire area of KZN, it was decided to take the 1993 cluster solution as a point of reference and calculate the average percentages for each direct ES in the two following years, 1998 and 2004.

3.3.2.2 Predictor variables for variation of direct ES use between households

This approach identifies key predictor variables for high use intensities at the household level. Using the geography-specific KIDS-panel data, it is possible to control for both year- and use category fixed effects for the household level analysis. Direct ES use intensities are used as the dependent variable.

The model is designed to associate high use intensities of the characteristic bundle of direct ES with household characteristics including the accumulation of wealth, gender of the household head or core member, ethnic differences, land access as well as variables relating to the urban-rural nexus in South Africa. Although direct ES use depends on both social factors and the supply of ES at the local level, this model only uses social factors to explain ES use. This is in line with the aforementioned predictions of Hamann et al. (2015a) that find ES supply clearly less significant to predict the average use intensities of direct ES at municipal scale.[5] More significant are income, the gender of the household headship, the population density and traditional authority areas. For these reasons emphasis is put on social factors. The longitudinal nature of the data set enables the results to hold

[4] From these 73 EAs, 67 were re-visited in 1998 and 2004. In total, by today, eight of these clusters lie outside of KZN.
[5] This biophysical data has been communicated to the author of this thesis, however, for reasons of confidentiality (and time), they were not included in the model.

throughout time and therefore fit into a picture of direct ES use dynamics in an era minted by political, social and environmental change.

The conceptual model is given by

(2) $$ES = f(HH, MUN, ESS)$$

where the utilization of direct ecosystem provisioning services (*ES*) is given as a function of household characteristics (*HH*), municipality characteristics (*MUN*) and local ES supply (*ESS*). Due to the reasons stated above, the main interest of the model is to empirically validate the association of a given use intensity of direct ES with *HH*. From *MUN* only the population density was integrated as a proxy. Other potentially influential variables may be the general quality of public service provision, institutional factors like regulations of land access mediated by traditional authority and not property ownership etc. Although available to the author, *ESS*-variables, i.e. the biophysical qualities of the respective local ecosystems (e.g. soil quality, water availability or wood supply) were not used in this model due to time constraints. An analysis of the statistical significance for co-determining the type of an SES with such variables is available in Hamann et al. (2015a) that specifically include data on the grazing potential, the farming potential, the local wood supply and mean annual runoff of water at municipality level. Hence, *ESS* and *MUN* will mostly remain unobserved and are therefore likely to reduce the goodness of fit of the regression.

The formulation (3) introduces the linear formulation of the model used here. It is given by:

(3) $$ES_{UCi,t} = \alpha_{HH} HH_{UCi,t} + \beta_{HH} MUN_{j,t} + \varepsilon_{UCi,t}$$

where *UC* is the use category (high use, medium use, low use) in which household *i* lives in municipality *j* year *t*. Further, $\varepsilon_{UCi,t}$ is the error term. Containing all immeasurable factors relevant to $ES_{UCi,t}$, expanding the error term helps to understand the operating space of this model. It is given by

(4) $$\varepsilon_{UCi} = \vartheta_{UC} + \vartheta_{UC,t} + \vartheta_{UCi,t}$$

where ϑ_{UC} is a time-invariant set of within-*UC* characteristics (such as the widespread unavailability of *ESS* or the needlessness of using them due to sufficient infrastructural coverage and income levels in cities (e.g. in eThekwini), $\vartheta_{UC,t}$ is a time-varying set of factors that may influence the demand for or supply of direct ES (such as ecological or economic shocks) and $\vartheta_{UCi,t}$ is a household-specific, time-varying error component. Since the data is geographically explicit and has been collected in three waves, it is possible to effectively eliminate any *UC* and time specific effects across waves (i.e.

a temporary drought or economic shock). This is the reason why the longitudinal KIDS data was preferred over the cross-sectional census data.

Including this, the final specification of the model, is given by

$$(5) \qquad ES_{UCi,t} = \alpha_{HH} HH_{UCi,t} + \beta_{HH} MUN_{j,t} + \vartheta_{UC} + \vartheta_{UC,t} + \vartheta_{UCi,t}$$

Time-specific effects of the α_{HH} are dealt with through the inclusion of year-fixed effects, location-specific effects through the inclusion UC-fixed effects as well as by considering subsets of the data by UC separately. Doubts remain about whether there are within-UC time-varying factors that are correlated with the changes of demand for or supply of direct ES. Such unobserved heterogeneity may occur for a variety of reasons, for example changes in land access, ecological shocks at the local level or increased availability of direct ES substitutes.

Concretely, the model is estimated with the package *plm* as a panel fixed-effects ordinary least square (OLS) regression model (Croissant and Millo, 2008). This model was chosen since it allows for the specification on an index (“hhid” and “year”) as well as for the calculation of “within” estimators. The difference to ordinary OLS pooling models is that individual observations are not treated homogeneously (*ibid.*, p.4). This is necessary since direct ES use dynamics showed to be dynamic over time and vary across space. Cross-checking with a mixed-effects linear model from the standard package *lme4* that combines fixed- and random effects showed no significant differences in the estimates (Bates et al., 2015).

The model was implemented across all use categories with *UC*- and time-fixed effects as well as for each *UC* separately with time-fixed effects. It is given by

$$(6) \; Use_{Intensity} \sim HH\ income + Ownership\ House + Ownership\ Land + Female\ HH\ headship + African + Labour\ market\ linkage + Send\ Remittances + Receive\ Remittances + Population\ density + factor(Year) + factor(Use\ Category\ 1993)$$

The results of the resulting four regressions, one across all UCs, and three for the respective low, medium and high UC-subsets are reported in **Tab. 6**.

3.3.3 Variable description, transformation and imputation

The dependent variable in the mixed-effect regressions is constructed from the characteristic bundle of direct ES which was explained in detail in 3.2.4 which thus does not warrant further explication.

Household income, above included as one of the explanatory variables is measured as the yearly household income in real 2004 South African Rands (ZAR) and re-scaled to an income category in which the lowest out of ten corresponds to a yearly household income between $ZAR \in [0;3000]$, the second lowest to one between $ZAR \in]3000;6000]$, the third lowest $ZAR \in]6000;12.000]$ […] and the highest income category to $ZAR \in]768.000; Inf.]$. The mean income category in 1993-low use areas is 5.85 (0.038), in medium use areas 4.63 (0.042) and in high use areas 4.47 (0.055).[6] Household income was a constructed variable provided by KIDS in all three waves, consisting of the wide (or narrow) spectrum of monetary income sources available to household members per month. The construction of yearly household income relies on the assumption of equally distributed earnings of household members across the year. Income data has been adjusted for inflation using the online tool by Crause (2019).

The house ownership variable was constructed as a dummy that takes the value one if the household indicated property ownership and zero if not. The land ownership dummy was created from the type of access to land either for grazing or for farming purposes. It takes the value one if either of the two were indicated and zero otherwise. Ownership of land or houses plays an important role since it signals accumulation outside the traditional arrangements of land access (Neves, 2017). In KZN however, particularly the former homeland areas remain under traditional authority managed through the Ingonyama Trust that owns 30% of the land (~3.000.000ha) and accommodates nearly four million people (Driver et al., 2015). Affirmations of ownership of the place of residence of household were widespread across the three data waves. In 1993, 78% of the households in the sample indicated to be the owner of the dwelling, 71% in 1998 and 89% in 2004. Land ownership is scarcer, but also widely observed. However, here the *de jure* nature of land tenure in former homeland areas under the Ingonyama Trust (or other communal arrangements) needs to be taken into account: Households may indicate they own land in spite of factually not owning it in a formal sense (Neves, 2017). In the sample the share of households indicating to own either grazing or farming land was about 30% in 1993, 12% in 1998 and 41% in 2004. Household and land ownership are positively associated with a correlation coefficient of $r = 0.25$ signalling some irreducible multicollinearity between the two variables (re-scaling of a dummy does not work) but also still sufficient variation between households to not having to comprise them in one variable.

Female headship of the household was included in the model since it was one of the most significant variables in the national-scale analysis of Hamann et al. (2015a). Also Neves (2017) finds female-headed households more likely to engage in agriculture than men. It takes the value one if the main

[6] Standard errors reported in brackets.

respondent (household head or core member) to the survey is female. Of all households in the sample, there were 450 female-headed households in 1993 and 373 and 638 in 1998 and 2004, respectively.

Labour market linkages were found to be a distinctive characteristic of the social positionality of a household, most notably for rural areas (Neves, 2017). It builds on the very loose definition of at least one household member that indicated to having had regular employment in exchange for a wage, including self-employment, in the last week. However, it does not comprise temporal employment or the receipt of old age or unemployment grants. The rates of regular employment in the sample decreased between 1993 from 56.48% to 51.32% in 1998 and 33.87% in 2004. This might have to do, despite the inclusion of split and second-generation households, with the underrepresentation of young people in the last data wave.

Rural households with household members that work in urban areas, or vice-versa, are called households with an urban or rural pole, respectively (Neves, 2017). In South Africa, due to the small size of labour markets in the homeland areas, urban poles are an important part of livelihood diversification and link rural areas to urban economic opportunities and shocks (*ibid*.). Similarly, rural areas serve as important counterparts of retirement, retreat and recuperation (*ibid*.). An indicator for urban-rural or rural-linkage that might indicate that a household is relatively better off through support from distant household members are thus the receipt or the sending of remittances. In 1993, 30.09% of the households received remittances from distant household members, 36.81% and 27.45% in 1998 and 2004 respectively. Household receiving and sending remittances were found to be fewer than 4.6% in every data wave which signals little multicollinearity between the two variables.

Population density is a variable included from 2006 census data to better represent the population estimates at the time of KIDS (Stats SA, 2006). The variable is coded as the population density per square kilometre (absolute number of people per district municipality divided by the area of this same municipality) and has been re-scaled by the division of thousand yielding a range of $x \epsilon [0.042;1.394]$.

Observing differences between the population groups in terms of their predicted direct ES use is consistently possible from KIDS only for African and Indian households since these are the two only groups KIDS followed until the end of data collection. Thus, there is a dummy variable included in the regression that turns one if the household is African (=1) and zero if it is Indian (=0). Descriptive analysis shows that in 1993, households visited from the other two (underrepresented) population groups in KZN indicated vanishingly little engagement in direct ES use, namely one out of 112 white households for crop production and two coloured households for water from a natural source.

Data imputation of missing values was a crucial step before running the panel regression. The share of missing values of some key variables was found to be between 2.8% (ownership of a house) and 10.8% (population density). The latter is due to, again different municipal boundaries in 2006 that could not be translated into the current administrative structure. The remaining missingness of values is normal for socio-economic survey data and can have several reasons. Data can miss just at random, i.e. that the absence of a data point has nothing to do with other variables or its hypothetical value. But it can also miss not at random, i.e. because of the nature of the question. This typically occurs in household surveys with sensitive questions on, for example, income or tax data. Having that in mind, it is the responsibility of the researcher to choose to either drop or impute NA´s and to justify the adequacy of the procedure. Due to the strong spatial segregation of population segments in South Africa and the geographical explicitness of the survey data, it was decided to use the *knnImputation*-function from the R-package *DMwR* to replace missing values with those non-missing values of the nearest neighbour of the missing observation. This is clearly a strong assumption and omits within-cluster differentiation but was deemed to be the most appropriate imputation method for the reasons stated above. Dropping all incomplete observations would have reduced the sample size (and thus the variance) by about 900 households. Note that the households that were not engaging for example, in crop or animal production, were reported as missing values due to the design of the questionnaires. Hence, for some dummy variables missing values needed to be coded as zeros instead of imputing them with the *knn*-algorithm.

4 Results

4.1 Cluster analysis and spatial mapping of direct ES use dynamics in KwaZulu-Natal with most recent 2011 Census data

The cluster analysis (procedure I, section 3.3.1) divided municipalities into three categories of high, medium and low direct ES use that were argued to be in line with green-, transition- and red-loop types of SES described by Cumming et al. (2014). In low-use local municipalities for instance, an average of only about 4.8% of the households indicated to source water from either a river or natural spring, compared to 41.6% in high use local municipalities (**Fig. 2**). The biggest difference between low and high use categories however seems to be resulting from wood use for cooking or heating, namely 16.0% vs 73.5%, respectively. The range of the average percentages of households indicating residence in a traditional dwelling made from locally available materials was between 13.1% in low and 62.4% in high use categories. The consistently low levels of crop (between 12.9% and 16.4%)

and, to a lesser extent, animal production (between 12.5% and 29.9%) in all use categories when compared to KIDS data, are likely to underestimate real agricultural engagement of households.

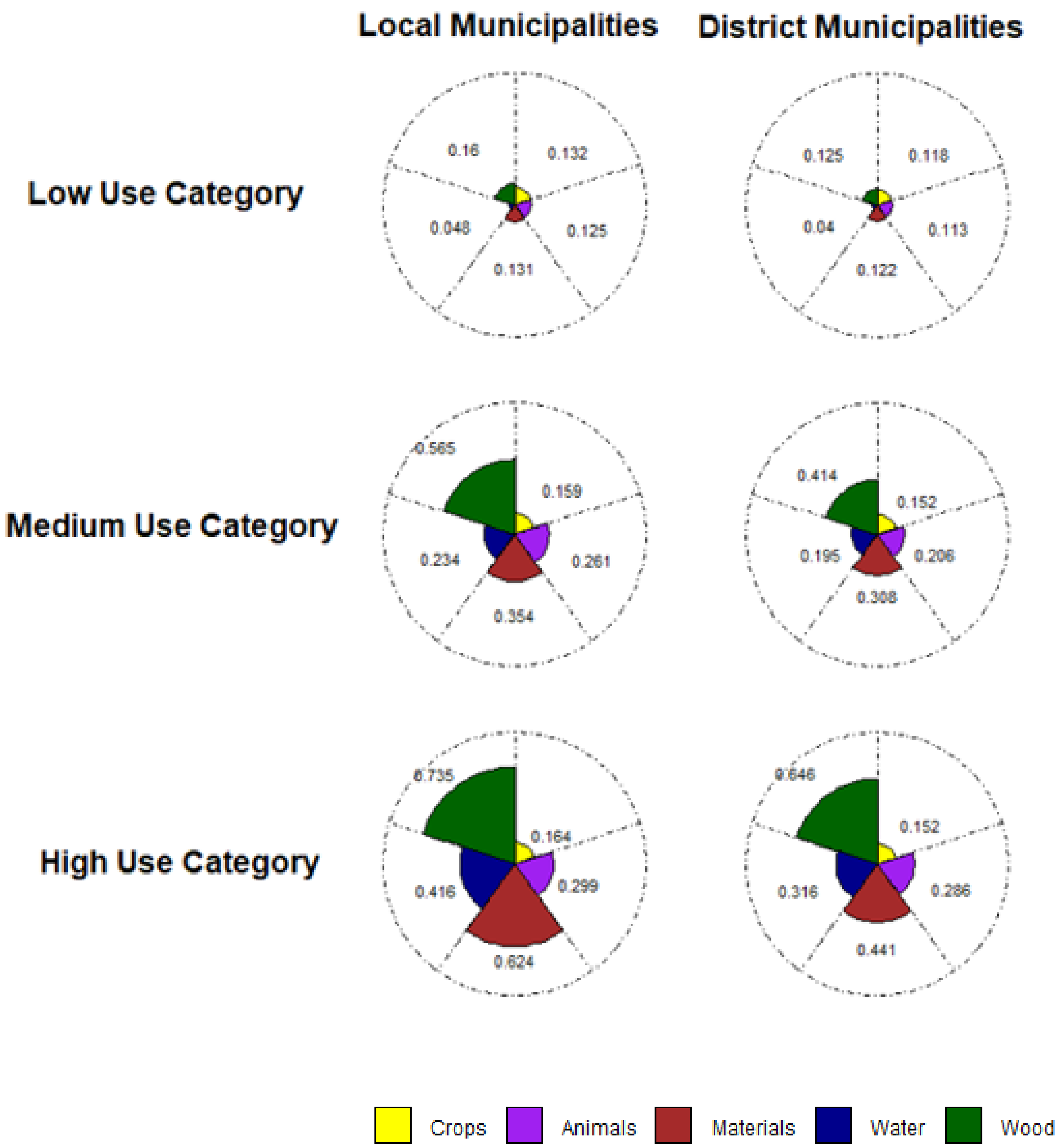

Figure 2 - Typical composition of direct ES use intensities at local (left column) and district municipality level (right column) by type of SES. Petal length indicates the percentage of households in a given municipality using a direct ES. R-package: *ggplot2*. Data: Census 2011. Standard errors of the mean within the range of se ϵ [0.008; 0.042] for the local municipality solution and se ϵ [0.005; 0.090] for the district municipality solution.

Results were mapped at both local (**Fig. 3a**) and district municipality scale (**Fig. 3b**) to observe effects of scale in their distribution. These effects are rather small – the aggregation at district municipality yields average within-district percentages of the five direct ES that are 1.5%, 7.5% and 7.8% lower when compared to the local municipality solution for low, medium and high use systems, respectively.

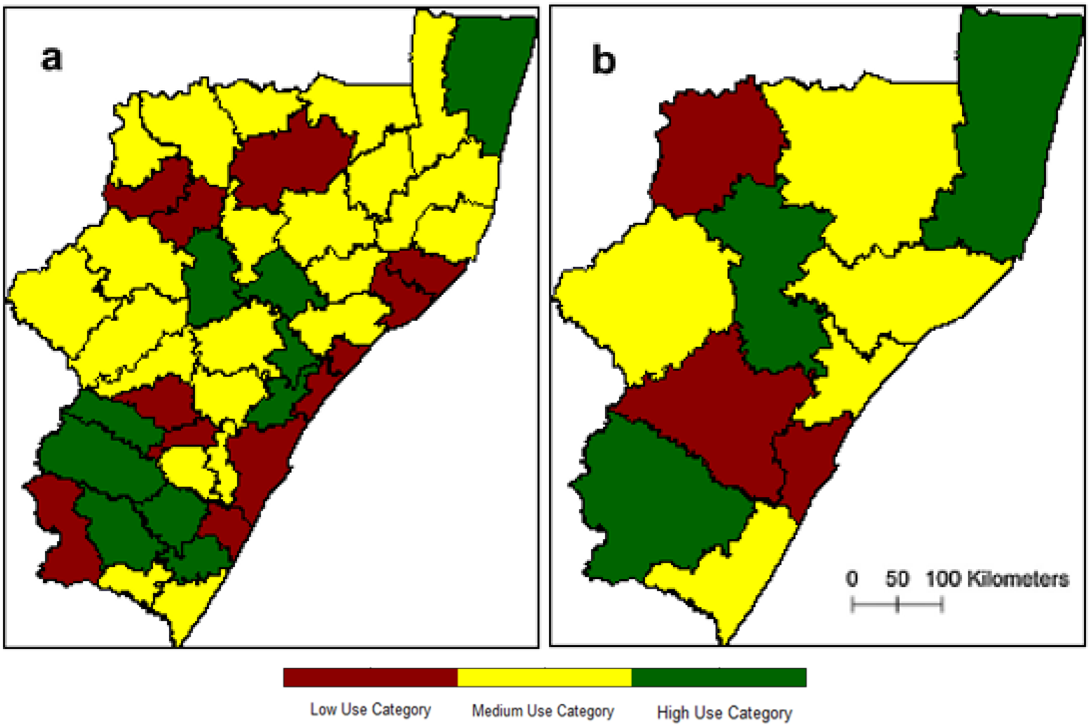

Figure 3 - (a) Distribution of red-loop, transition loop and green-loop types of SES at local municipality level in KZN; (b) Distribution of red-loop, transition loop and green-loop types of SES at district municipality level. R-package: *sp, maptools and rgdal.* Data: census 2011 mapped with official shapefiles (South African Demarcation Board, 2016a and b). Notes: eThekwini is counted both as local and district municipality. For those local municipalities that merged into new ones in 2016, some conflicting categorizations were found for Alfred Duma (one part low-, one part medium-use), Dr. Nkosazana Dlamini Zuma (one part medium-, one part high-use) and Ray Nkonyeni (one part low-, one part medium use). These municipalities have been assigned the respectively higher use category by default.

Very notable is the location of high use areas in many parts of the former homeland (ex-bantustans) of the apartheid-South Africa. Located in today´s KZN were the semi-independent homelands of KwaZulu and in part, Transkei, designed by the apartheid government to serve as “dumping grounds” for Zulu or Xhosa people, respectively, as an act of racial segregation. The homelands also served as important labor reserves for the capitalist development of South Africa. For a distribution of the former homeland areas in KZN, refer to Annex V.

Assigning clear spatial boundaries to an SES is however a matter of contention for complex system scholars (Zeleny, 1996; Cilliers, 2001; Janssen et al., 2012). As observed from comparing the scales of analysis between local and district municipality, it emerges that the higher the scale, the higher the range of standard errors for each component variable of the three identified types of SES. Therefore, the border zones between system types are illustrative rather than exact.

Tab. 2 further provides a detailed overview of the composition of each category in terms of the absolute numbers of clusters and the absolute and relative numbers of households.

	Local municipality scale			**District municipality scale**				
	Abs. # of clusters	Abs. # of HH	% of all HH	Abs. # of clusters	Abs. # of HH	% of all HH	Area in km^2	% of total area
Low use category "red-loop"	15	1.982.012	62.26	3	1.534.625	48.21	19.260	20.41
Medium use category "transition loop"	25	770.599	24.21	5	1.138.862	35.77	42.206	44.73
High use category "green loop"	11	430.875	13.53	3	509.999	16.02	32.893	34.86
$\sum x$	51	3.183.486	1	11	3.183.486	1	94.359	1

Table 3 - Exact composition of the 2011 cluster solution. Three use categories and corresponding number of clusters, households and percentages of households. Data: Census 2011 and South African Demarcation Board (2016b). Notes: After the elections in 2016, several local municipalities merged into bigger ones, including Emnambithi/Ladysmith and Indaka (now Alfred Duma), Imbabazane and Umtshetzi (now Inkosi Langalibalele), Ingwe and KwaZani (now Nkosazana Dlamini Zuma), Ezinqoleni and Hibiscus Coast (now Ray Nkonyeni) and Hlabisa and The Big Five False Bay (now Big Five Hlabisa). Moreover, Vulamehlo and Ntambanana were annexed by existing municipalities. This in mind, the 51 identified clusters correctly correspond to the current 44 local (including the one metropolitan) municipalities. Due to the lack of data on the area cover for the seven former municipalities that dropped out, area data (in km^2) has only been provided at district level. Lastly, households include both agricultural and non-agricultural households. 6335 non-agricultural households that had double-entries in both datasets were removed.

Unsurprisingly, it emerges that the vast majority of households live in low use categories or red-loop type of systems (62.26%), vis-à-vis medium use category or transition-loop type of systems (24.21%) and high use category or green-loop type of systems (13.53%) when observed at local municipality level. When the share of households is compared with the share of total area, it follows that low-use categories have the highest population density, high-use categories the lowest. Indeed, at district level, the 16.02% of all households living in high use categories inhabit an area that covers 34.86% of the total land area in KZN. Contrarily, the 48.21% of households in low-use categories occupy an area as small as 20.41% of the total land area.

In the correlation analysis, individual direct ES use was found to occur in groups or bundles (**Tab. 3**). Most correlated in 2011 was the use of wood as a primary source of energy and the use of water from a natural source (r = 0.41) as well as wood and natural building materials (r = 0.49).

	ES_water	ES_wood	ES_materials	ES_crop	ES_anim
ES_water	1	0.413	0.337	0.037	0.170
ES_wood	0.413	1	0.489	0.086	0.284
ES_materials	0.337	0.489	1	0.054	0.206
ES_crop	0.037	0.086	0.054	1	0.294
ES_anim	0.170	0.284	0.206	0.294	1

Table 4 - Correlation matrix of the utilization of individual services from the characteristic bundle of direct ES from 2011 census data. It consists of freshwater use (ES_water), fuelwood use for cooking or heating (ES_wood), natural building materials use (ES_materials), crop production (ES_crop) and animal production (ES_anim). Data: Census 2011.

The cluster analysis yields a very similar picture to what Hamann et al. (2015a) have produced from the same 2011 national census data. Indeed, the overlap of the high (or medium) use areas correspond to a significant extent to former homeland areas. These areas are argued to be "economically underutilized", containing much of the arable land required for the expansion of bioethanol, sugar cane, sugar beet, biodiesel sunflower, canola and soy beans (Department of Minerals and Energy, 2007, p. 3). This official industrial strategy aims at achieving clear targets, including substituting foreign oil imports, support of renewable energy and the creation of jobs where there are none. However, a recent consultative case study from KZN´s bordering province, the Eastern Cape, has shown pervasive community resistance against these projects (Amigun et al., 2011). The reasons of the local interviewees varied but revolved around the scarcity of land that is perceived as part of their identity, air and water pollution and thus health issues, unnecessary infrastructural development, food security and upheaval of community cohesion. This resistance might be explained in part by high degrees of dependence on direct ES in these areas (Hamann et al., 2015a) which may be relevant by the same token for concerned areas in KZN.

4.2 Adding a component of intertemporal change and an empirical basis for a household-level analysis of social differentiation

4.2.1 Evolution of direct ES use since 1993

This section presents the evolution of average direct ES use shares of households by use category at EA level between 1993 and 2004 and compares this evolution with the 2011 census snapshot reported in 4.1 (refer to procedure II, 3.3.2.1). For each direct ES, the data points (a value between zero and one) correspond to the average percentage of households in a given use category for each year (**Fig. 4**). Across the three types of SES, very different dynamics with clear patterns are observed. In the high use category (green lines), with initial average percentages of households engaging in direct ES use between 43% (Materials) and 77% (Animal production), all five direct ES significantly declined until 2004. In the medium use category (yellow lines), with initial average percentages of households engaging in direct ES use between 17% (Crop production) and 48% (Wood), a more mixed trend occurred. While wood collection increased somewhat and agricultural production (crops and animals) increased notably, housing in dwellings made from locally available materials dropped together with water from a natural source significantly. Lastly, in the low use category (red lines), with initial average percentages of households engaging in direct ES use between 0.08% (Water) and 3.5% (Animal production), direct ES use slightly increased or stayed flat. Most notable in low use areas is the positive change in agricultural production at the household level, an increase from 2.3% to 30.8% (crop production) and from 3.6% to 14.9% (animal production). The relative shares of households inhabiting the three use categories are reported in **Tab. 4**.

When compared to the 2011 findings from census data that cover the whole population of KZN (marked as * in the line plots), several observations arise. Firstly, some relevant questions asked in the surveys of KIDS and census differ in nuances which may explain some of the "leaps", e.g. for crop or animal production. The average share of households engaging in some form of agriculture seems to have been substantially higher across all types of use categories between 1993 and 2004 than the reported share of agricultural households by the census, particularly for crops. This might be explained by the nature of the questions: KIDS explicitly included a variety of crops farmed for self-use (subsistence farming) whilst the census asked without specification about animal, poultry or vegetable production. Thus, census data might underestimate the real number of households engaging in agriculture. This hypothesis is supported by the aforementioned physical land and ecosystem account (Driver et al., 2015). It shows that land used for subsistence agriculture was the one land class found to be increasing the most rapidly in both absolute terms (+429.670ha) and relative terms

(+175%) between 2005 and 2011, far quicker than other changes in land cover, i.e. for settlements or intensive agriculture.

A second observation is the sudden drop of households living in traditional dwellings made from locally available building materials. This trend stands in contrast to the high-confidence census data that reports the average share of households living in such dwellings in high use areas to be as high as 60%, in medium use areas nearly 40% (compare observations marked as stars in **Fig. 4** or star plots in **Fig. 2**). Thus, the sample estimates are likely to underestimate the real average percentage in the decades before the census enumeration. The comparatively high share of traditional dwellings also gives hints also about the cultural rootedness and acceptance of living in dwellings made up from locally available natural building materials.

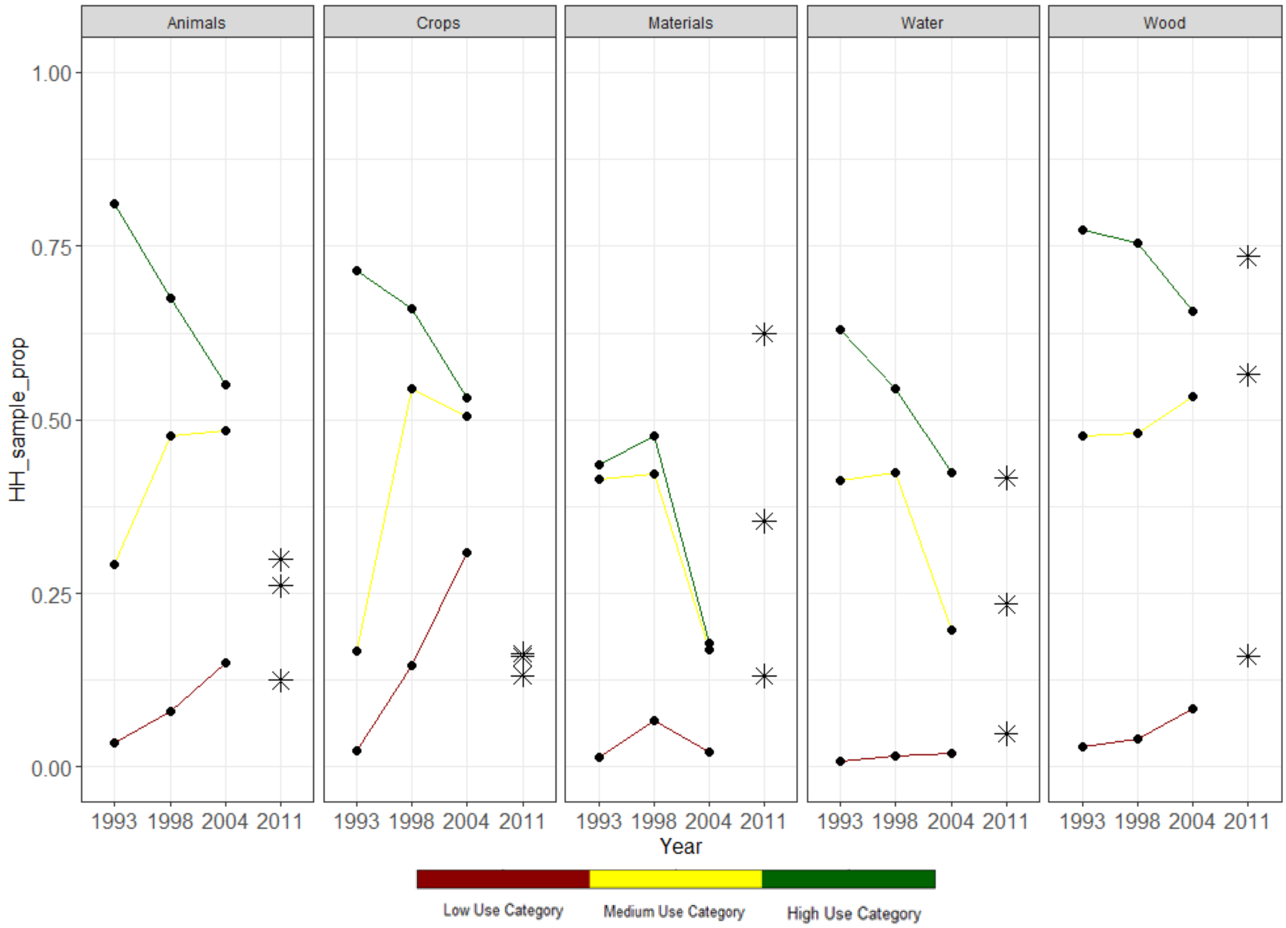

Figure 4 - Evolution of direct ES utilization of a random sample of households in KZN between 1993 and 2004. Level of analysis is the enumeration area (EA). The green lines correspond to the green-loop type of SES or high use categories, yellow lines to the transition-loop type of system of medium use categories and the red line to the red-loop type of system of low use categories. The average share of households engaging in any of the five direct ES as observed from 2011 census data is reported with stars, representing the hierarchical cluster solution according to their position measured against the y-axis. Data: KIDS 1993-2004 and 2011 census data.

In general, the relative shares of households by use category identified in the KIDS-1993 cluster solution is very similar in the 2011 solution where 48%. 36% and 16% of the households lived in low, medium and high use areas. From the 2004-wave of KIDS however it is possible to discern a movement of households from low use categories to areas identified in 1993 as medium or high use (**Tab. 4**). This might be explained by the fact that areas in the countryside typically stand as poles of attraction for retirement or to raise children and the movement of sampled households towards these areas must have outweighed migration in the opposite direction.

	Enumeration-area (EA) scale			
Year	Use Category	# of enumeration areas visited per use category	Abs. # of HHs in the sample by use category and year	Rel. share of HHs in the sample by use category and year
1993	Low Use	37	814	0.5358789
	Medium Use	22	453	0.2982225
	High Use	14	252	0.1658986
	$\sum x$	73	1519	1
1998	Low Use	31	556	0.4748079
	Medium Use	22	378	0.322801
	High Use	14	237	0.2023911
	$\sum x$	67	1171	1
2004	Low Use	31	536	0.389252
	Medium Use	22	527	0.382716
	High Use	14	314	0.228032
	$\sum x$	67	1377	1

Table 5 - Composition of the representative EAs visited for the data collection of KIDS by identified use category at the EA-scale. Data: KIDS 1993-2004.

Noteworthy is also the somewhat different correlation of individual direct ES use when compared to the correlation matrix from census data reported in **Tab. 4**. From KIDS, most correlated are the use of freshwater and the collection of wood (r =0.47) as well as crop and animal production (r = 0.55).

	ES_water	ES_wood	ES_materials	ES_crop	ES_anim
ES_water	1	0.471	0.298	0.242	0.288
ES_wood	0.471	1	0.309	0.326	0.400
ES_materials	0.298	0.309	1	0.156	0.239
ES_crop	0.242	0.326	0.156	1	0.549
ES_anim	0.288	0.400	0.239	0.549	1

Table 6 - Correlation matrix of the utilization of individual services from the characteristic bundle of direct ES. Coefficients reported from observations across all years. Data: KIDS 1993-2004.

The fact that smaller scales should be favored is supported by the comparison of the EA-based solution to the identification of low, medium and high use categories at local and district municipality level. The latter have been retrospectively constructed to adequately locate EAs visited by KIDS at a comparable scale. In 1993, however, the correlation coefficient r between the vectorized kmeans cluster solution at the EA level and the solution at the local municipality level was found at $r = 0.701$, at the district municipality level, at only $r = 0.630$. Consequently, SES identified at the local or district municipality level are likely to contain EAs that would be clustered differently. As a corollary, identifying SES at EA-level is favoured. This insight calls for higher resolutions in the geographical aggregation of survey data, for example at ward-level, to consistently obtain coherent spatial units as the basis for the identification of SES whilst keeping confidentiality of interviewees.

These results show clear support for the hypotheses that direct ES use varies substantially throughout time and thus make a dynamic approach to model SES based on a context-specific characteristic bundle of direct ES adequate. Most notable are the opposite trends of utilization rates between high use and low use categories. In high use categories direct ES use is overall decreasing and in low direct ES use categories trends are mostly flat except for increasing average shares of households using agricultural direct ES. While the former clearly signals some effectiveness of infrastructural provisions in terms of energy and water supply in 1993 high use categories, the latter would require more research for interpretation. It could for instance hint at increasing relevance of urban agriculture, a common practice in townships (Coetzee and Van Averbeke, 2011).

Identifying patterns of an agricultural transition from these dynamics is possible only with some reservation due to the relatively small time period analyzed in this study. Cumming et al. (2014) present their model of agricultural transitions on time scales of several hundred, if not thousands of years between which the transition between a green-loop and a red-loop type of SES unfolds. However, due to the dramatic social, political and economical changes over the past two decades in South Africa and the consistent decline of the average share of households engaging in the use of direct ES in high use categories of KZN, the overall pattern is here interpreted as a waning agricultural transition in a geography within which modernity and its infrastructural and economic by-products are substituting direct ES at an observable pace.

4.2.2 Identification of predictor variables for variation of direct ES use between households

This section presents the results about testing the statistical significance of selected social predictor variables of household use intensities of direct ES across all use categories and for subsets of households that reside within one use category (**Tab. 6**). Use categories were identified from the 1993-cluster solution at EA-level. The coefficients α_{HH} denote the effect of the household characteristics $HH_{UCi,t}$ as predictor variables on the use intensity of direct $ES_{UCi,t}$. With population density being the only variable not coded from KIDS data, it is the only β_{HH} coefficient reported for a municipality characteristic. A negative sign implies a negative correlation between the explanatory variable and the dependent variable and vice versa. Only statistically significant variables with p-values < 0.1 are interpreted.

In column (1) all variables are found to be statistically significant, except the dummy for African households and annual household income. It shows the coefficients and standard errors of regressors across all types of SES. In the order of the magnitude of the statistical significance and with the sign of the effect reported in brackets, it is found that the fixed effect for living in medium or high use categories affects the likelihood of high direct ES use intensities most (+), followed by owning land (+), being connected to the electricity grid (-), having the capacity to send remittances (-), receiving remittances (+), owning a house (+), being a female-headed household (-), having at least one household member with a labour market linkage (-) and high population density measured by people/km^2 (-) with p-values < 0.1. Being African or not across all types of SES is not significant, however, since Indian, White and Coloured households are concentrated nearly entirely in low use categories the statistical insignificance is likely to be attributable to the lack of variance of the population group variable in the other two areas.

The estimation in column (2) is based on the subset of households residing in clusters assigned to the low use category. Here, the same effects are found, albeit with smaller standard errors and hence more robustness. One important difference is household income which predicts a lower direct ES use intensity, possibly due to more formal labour opportunities as well as the widespread availability of direct ES substitutes, like gridded electricity, supermarkets for food and private or municipal tab water supplier.

	Dependent variable:			
	Use Intensity			
	All UCs	Low UC	Medium UC	High UC
	(1)	(2)	(3)	(4)
Income_Category	−0.019	−0.025**	−0.019	−0.028
	(0.012)	(0.010)	(0.026)	(0.032)
Ownership_House	0.153***	0.004	0.135	1.168***
	(0.047)	(0.029)	(0.139)	(0.237)
Ownership_Land	0.827***	0.809***	0.790***	0.972***
	(0.038)	(0.038)	(0.070)	(0.109)
Electricity	−0.577***	−0.168***	−0.678***	−0.682***
	(0.038)	(0.036)	(0.071)	(0.103)
Female_HH_Headship	−0.135***	−0.125***	−0.122	−0.191*
	(0.039)	(0.032)	(0.080)	(0.103)
Labour_Market_Linkage	−0.095**	−0.003	−0.099	−0.163
	(0.039)	(0.029)	(0.082)	(0.120)
Remittances_Receipt	0.135***	0.052*	0.112	0.015
	(0.035)	(0.031)	(0.071)	(0.089)
Remittances_Send	−0.175***	−0.088**	−0.222**	−0.167
	(0.045)	(0.035)	(0.093)	(0.126)
African_HH	0.021	0.157***	0.407	0.505
	(0.051)	(0.030)	(0.688)	(1.167)
Population_Density	−0.106***	−0.073***	−0.270**	−0.269*
	(0.032)	(0.018)	(0.123)	(0.151)
factor(Medium UC)	1.056***			
	(0.045)			
factor(High UC)	1.637***			
	(0.054)			
Observations	4,067	1,906	1,358	803
R^2	0.590	0.299	0.184	0.239
Adjusted R^2	0.589	0.295	0.176	0.227
Note: UC - Use Category.	*p<0.1; **p<0.05; ***p<0.01			

Table 7 - Panel fixed-effects regression results. Direct ES Use Categories as identified from 1993 EA-cluster solution. Unit of analysis: household with time- and use-category fixed effects for each year of data collection. Dependent variable coded from 0 to 5. R-Package: *plm*. Data: KIDS 1993-2004.

Another difference is the statistical insignificance of house ownership, an indicator of accumulation that in high use areas predicts higher direct ES use. Due to the sufficient variance of African and Indian households in the low use categories, here Africans are shown to be more likely to use the characteristic bundle of direct ES.

The regression reported in column (3) comprises only households living in medium use categories. Here only the connection to the electricity grid (-), the capacity to send remittances (-) and population density (-) and the ownership of land (+) are found statistically significant. Annual household income does not play a determining role of direct ES use. In column (4), the regression is run only on the subset of households living in high use categories, that constitute the smallest subset of the sample. Similar patterns occur than observed in column (3). However, the ownership of a house is now strongly predicting higher direct ES use intensities at a statistically significant level. This might be attributable to the fact that land is generally better accessible from the place of residence, due to, among others, lower population density. But most importantly this observation validates the finding that in former homeland areas, that were shown to correspond to a significant degree to high use areas (Annex V), ownership is not necessarily to be a symbol of high economic status since traditional local authorities (chieftaincies) and some government housing schemes allow for property or land tenure and property ownership also for the poor (Hamann et al., 2016, p. 4). Indeed, in most of the high use categories property ownership is as high as 50% among households. Higher standard errors of the population density predictor suggest that the variation of population densities in medium and high UCs is bigger than in low use categories.

One general observation is that direct ES use intensity is strongly influenced by social factors, an insight that validates the finding from Hamann et al. (2015a). The strong positive influence of factors related to property ownership warrants further discussion and allude to the question whether high use intensities are an outcome or a determinant of the household´s position in the social space. On the one hand, access to land can be mediated by tribal or government authority schemes that secure land and property tenure, but outside the reach of traditional authority, they signify economic status, power and implication in the formal economy, the ownership of land most notably implication in the agricultural sector. The fact that they are associated with higher direct ES use intensities might well be explained here by the composition of the characteristic bundle of direct ES that includes both agricultural and non-agricultural ES. From more qualitative case studies of social differentiation regarding households in rural areas that engage in some form of agriculture, it seems evident that they are typically better off than others (Neves, 2017). The most impoverished households do not have the capabilities (in terms of agricultural inputs) or rights (ownership or networks for communal land) to carry out agriculture. Thus, if used as an indicator of social deprivation, the present composition of the bundle of direct ES might be misleading as long as it includes agriculture, or at least, not differentiates between the various forms and scales of agriculture.

In medium and high use categories, household income does not play a statistically significant role. Since the real mean income in both areas is comparable (44.613ZAR in medium use categories vs. 39.050ZAR in high use categories), but significantly lower than in low use areas (107.502ZAR), it was argued that in the latter, next to labor opportunities, substitution mechanisms for direct ES exist such as municipal or private energy and water supplies for nearly all households in the sampled area. In the other areas, non-price-based mechanisms might occur, such as the time-intensive collection of wood, the fetching of water or the collection of natural building materials for own use, exchange or barter. This is supported by studies on the use of fuelwood as a major livelihood activity in rural areas in South Africa which found that cash income does largely not determine the use of wood as a primary source of energy in rural South Africa (Dovie et al. 2004).

In summary, analysing the social relations from within an SES at the household level provides some first important insights into the dynamics of social differentiation. Clearly, this analysis could benefit from purpose-collected data, that involves a wider spectrum of direct ES (fishery resources, medical plants etc.) and the possibility to distinguish between the variegated forms and scales of agriculture. Despite these drawbacks, the second hypothesis, that social differences do not exist only between different types of SES but also within them, can be supported. In combination with insights from small-scale case studies, qualitative factors might explain the use or disuse of direct ES and can contribute to a better understanding of the dynamics of social differentiation in SES. Such factors may include anthropologic investigations on the cultural acceptance of using provisioning services like water and wood from the direct natural environment in green loops or class-analytic studies related to the material-energy metabolism and connected CO_2-emissions from households with relatively high incomes in red loop systems.

5 Discussion

This section discusses the results synthesizing livelihoods as emergent properties of SES and identifies possibilities to use the characteristic bundle as a novel indicator to various ends, including human well-being and social deprivation, ecological footprints and human-nature relationships. In addition to that, some policy issues are raised for future land use and sustainability management policies in South Africa.

5.1 Livelihoods as emergent properties of Social-Ecological Systems

Ecosystems and the services they provide has been suggested to be conceived as livelihood support systems that contribute to the satisfaction of basic needs, i.e. food, shelter, energy and water. That this is still relevant for significant segments of the society in KZN has consistently been shown by identifying those households living in medium and high use areas, but even in low use areas, direct ES continue to play an important role, for example for urban agriculture. An analysis of social differentiation focused on the socio-economic status of households has shown some important predictor variables for direct ES use intensities. In theoretical terms, it is argued that it is necessary to merge the literature from SES and livelihoods with critical social science approaches that are context-specific, history-sensitive and cognizant of the political economy that shapes and is mediated by human agency. This suggestion indeed increases the complexity of analyses of SES but also the realism involved. Two issues arise here that shall be discussed.

Firstly, the capacity of households to sustainably construct their livelihood and respond to external stresses or changes. Since opportunities to construct a living significantly differ by the type of an SES, this idea will be developed for both types of SES. In red-loop systems, the ES suitable for direct human use tend to be undersupplied for example in built-up areas, degraded (e.g. severly eroded or desertified) land areas or intensive agricultural land (e.g. monocrop plantations). Livelihood portfolios hence cannot diversify into the use of direct ES, and at the same time, are not directly subject to feedback mechanisms if one or the other service fails to renew or recover from overuse. Other livelihood domains in the formal or informal sector gain more importance. Feedback mechansims between households and distant ecosystems they depend on (for the satisfaction of basic needs, but also for the material resource base of luxury goods) tend to occur indirectly, lagged both in time (e.g. climate change through rising atmospheric GHG-concentration) and space (e.g. degradation of ecosystems that provided services to the production of goods transported to the site of consumption). Thus, shocks or stresses in red-loops on livelihoods are of indirect nature, like water shortages, increased competition for formal and informal labour opportunities due to a sudden influx of climate or political refugees to economic hubs or heat waves. Contrary to that, green-loop systems are co-determined by the supply of direct ES (e.g. fertile soils, water availability, biodiversity and woodlands) but even more so, by social factors. They may include the absence of adequate substitutes to direct ES, the inability to purchase these substitutes and or simply stronger cultural ties and practices regarding the local environment. This enhances a more direct connection and more consciousness towards the environment, also argued for as the environmentalism of the poor (Martinez-Alier, 2002). Here, direct ES user households have available a "natural safety net", but are, at the same time, subject to immediate feedback mechanisms of local environmental change, such as the overuse and concomitant depletion of lcoal resources like in the case of fuelwood (Dovie et al., 2004) as well as global stresses like temperature variability and weather extremes (Fischer et al., 2002; Vogel and Reid, 2006; Kusangaya et al., 2014). At this microlevel with individuals or households as the focal unit, a more in-depth understanding of the capacity of livelihoods to persist, adapt and transform in response to external shocks or stresses and thus livelihood resilience, is required to formulate adequate livelihood support mechanisms as policy responses.

The second issue regards the political economy of access to and control over the key resources emerging from direct ES use. Access to and control over resources is the foundation of power and wealth (Zimmermann, 1933). In South Africa in general, this means the access to and the control over land and land-based resources. SES scholars do recognize the importance of political systems that ultimately shapes the interaction between social and ecological system components, but on the question of power they largely remain silent. While one might argue that power does not play a role for "diffuse" resources, like direct ES (Baldwin, 1956; Vahabi, 2017), the analysis in 4.2.2 clearly showed the significance of property and land ownership for a higher direct ES uses. While "wild" resources such as forestry and fishery goods, water from a natural source and collected building materials may be truly diffuse and therefore less appropriable, agricultural direct ES are clearly not. They require access to or ownership over land and also at viable subsistence scale, capital inputs. As has been argued previously, the apartheid state has supported the white-owned, large-scale commercial model of agricultural development which led, after decades of state subventions, to the current state of affairs in which 67% of the land in South Africa is operated by some 40.000 farming units (a number that halved over the past 40 years with the tendency to further concentrate) still largely consisting of white-owned, large-scale commercial agriculture (Walker and Dubb, 2013). The remaining land is classified to 15% as "black" communal land (the homeland areas, that are either state-owned or under entities such as the Ingonyama trust in KZN), 10% other state-owned (mostly conservation areas) and only some 8% urban areas (*ibid*.).

Despite the ambitious land reform of the African National Congress (ANC) target of redistributing or restituting 30% of white-owned land after the transition to democracy in 1994, today "the land reform has barely altered the agrarian structure of South Africa, and has had only minor impacts on rural livelihoods" (Cousins, 2017, p. 142). This is why today, many are calling for a fresh start of land reform in South Africa (Aliber and Hart, 2009; Cousins, 2017; Hall and Kepe, 2017). From the findings of the pervasive importance of the fourth livelihood domain of agriculture and other land-based activities (Neves, 2017) particularly in the former homelands (but clearly not limited to them), the access to land and tenure security seems of crucial importance. For this reason, under 5.3, policy suggestions that go beyond the mere support of land ownership as the "ultimate goal of tenure upgrading" (Cousins, 2017, p. 143), like traditional or novel governance schemes of the commons are discussed.

5.2 The potential of characteristic bundles of direct ES as an indicator for human well-being and social vulnerability, ecological footprints and human-nature relationships

5.2.1 Human well-being and social vulnerability

Human well-being is essentially dependent on a variety of ecosystem services, including provisioning services like food and water, regulating services like flood and disease control and supporting services for the nutrients cycle (Millennium Ecosystem Assessment, 2005a; TEEB, 2010). In another paper, Hamann et al. (2016) devise an approach to align the identification of SES-types from the characteristic bundle of direct ES with indicators of human well-being consisting of income, life expectancy, property ownership, employment and education in South Africa. Congruent with the regression findings in 4.2.2, they find low direct ES use systems to largely correspond to areas with high and medium incomes, high education and low unemployment (Hamann et al., 2016, p. 9). Areas with low incomes and high property ownership were significantly co-constituted by previously identified areas of high direct ES use. One important trait emphasized in this multidimensional approach to quantifying and mapping hotspots of human well-being and social deprivation in the context of transiting SES from green- to red-loop dynamics, is the different speed of change of variables involved (*ibid*, p.16). They argue that while ecosystem service use might change rapidly when a region changes from high or medium to low direct ES use, changes in indicators of human well-being such as education or life expectancy might involve substantial time-lags. Studying the evolution of these human well-being indicators and comparing their trends with the actually observed trends of direct ES use from this study may well pose an interesting future research avenue to better track social change in the context of a waning agricultural transition.

5.2.2 Ecological footprints

As previously alluded to, the sustainability management challenges between the two archetypal types of SES defined by Cumming et al. (2014) differ fundamentally. The major difference is the degree to which the local economy of an SES relies on tangible (material inputs, intermediary products etc.) or intangible (e.g. knowledge, financial) capital from the rest of the world. In green-loop systems, this degree of external linkage is comparably low, in red-loop systems comparably high. Based on consumption patterns on the demand side of the produce of this local economy, lifestyle-related GHG-emissions of households could be calculated through of a variety of factors concerning consumption, most notably from the use of energy. Whereas only 28% of all sampled in the identified green-loop system were connected to the electricity grid in a country where two-thirds of the total primary energy supply come from coal or crude oil (Department of Energy, 2018), in red-loops it was nearly 90%. Correspondingly, just as in the previous section on well-being, the characteristic bundle of direct ES use could be linked with indicators within each type of SES that are related to the ecological footprint of households stemming from emissions based on food, energy and transport consumption. Thus, ecological footprints could be identified, mapped and correlated in an equal manner to the use intensities of direct ES. In combination with a socio-metabolic and class-analytic approach as suggested by (Otto, 2019, submitted), ecological footprint profiles of households could further be identified from intra-system variation of these indicators. In summary, this approach could contribute to reveal lifestyle related emission hotspots at municipality level as well as to identify socio-metabolic profiles and thus high-emission population segments from household-level data.

5.2.3 Human-nature relationships

Human-nature relationships appear in diverse forms in human history, dependent on cultural belief. Although both green- and red loop systems depend on ecosystem services, in red-loop systems this connection becomes less obvious and people behave as if they were largely disconnected and independent from their natural resource base (Cumming et al., 2014; Hamann et al., 2015a). What Marx (1962) had termed commodity fetishism, or in other words, the loss of social relations in situations of capitalist market exchange, could be extended to a notion of fetishism in which the commodity not only masks the human suffering behind exchange, but also the unsustainable uses of distant ecosystems and waste products that are generated along the supply chain. Thus, from a Marxian perspective, the relative disconnectedness of households from their natural environment in red-loop systems is a result from the ongoing extension of a capitalist market economy. In green-loops, high shares of households (compare **Fig. 2**) continue to vitally depend on local ecosystems for the satisfaction of basic needs. Although the cash economy extends into nearly all areas of South Africa, households have a much stronger connection to their direct natural environment. This might at first sight be attributable to utter need of diversifying their livelihood for a lack of formal labour opportunities, but it also has another dimension than the instrumentalist valuation of nature. In fact, the first reason stated against large-scale biofuel projects in the former homelands from local communities (that were found to largely correspond to green-loops by Hamann et al. (2015a)), was their identification with the land in question (Amigun et al., 2011). This suggests that their connection with local ecosystems goes beyond material claims.

5.3 Policy outlook and future research avenues

Most urgent in contemporary South Africa is the question of eradicating poverty and ending widespread unemployment. Land reform projects are by many not seen as the panacea to these two fundamental problems, but at least as one tier of combating poverty and unemployment next to restoring justice after the ravages of apartheid. To secure livelihoods across KZN and South Africa, official land reform projects currently propose either the actual redistribution of land, the restitution of formerly evicted households or improvements of tenure security. It has been mentioned before that the large farm path pursued in South Africa was built largely on the premises of racial superiority, disempowerment and forced migrant labour (Bernstein 1998, p.2f). Even after the transition to democracy, large-scale farming was especially supported under the Mbeki government (1999-2009) but now with a clear focus on market efficiency and de-racialisation of large-scale agriculture (Cousins 2017, p.137f). With the creation of the Department of Rural Development and Land Reform (DRDLR) in 2009 under Zuma, next to disadvantaged large-scale commercial and medium-scale farmers, also landless households and small-scale (subsistence) producers are now (re-)targeted as beneficiary groups (DRDLR 2009, p.18), although today commercial viability reigns supreme (Hall and Kepe 2017, p.1). Based on the insights from this study about KZN, direct ES continue to contribute to livelihood domains in green loop areas more than 70% like in the case of wood (**Fig. 2**). In these areas, described as high use categories or green-loops, land reform projects may embrace more diverse forms of governance schemes for common resource pools that do not solely rely on ownership or commercial viability. Since such large shares of the population are concerned, responses to both environmental and human pressures should move beyond simple answers to complex governance problems and panaceas ("one solution fits all") and build on both local specifics and sound sustainability science (Ostrom, 2007). In combination with indicators about local environmental thresholds, the official recognition of "social tenure" systems, i.e. informal land tenure that accommodate large numbers of people under local oversight and *de facto* already confer tenure security in many parts of South Africa, could lead to more flexible, inclusive and sustainable outcomes of land and direct ES use in land reform projects (Cousins, 2017).

Future research avenues for the analysis of complex SES are manifold. The dynamic approach of identifying SES from KIDS data has been argued to provide a basis for the analysis of a waning agricultural transition. Open questions are however, how (i) the socio-economic variables of the households changed over the same period of time and which factors mostly caused the decreasing trends in the identified high use categories; (ii) how exactly biophysical variables (e.g. integrity of soils, forestry and aquatic resources for example related to the ES in question evolved in parallel to the social rates of direct ES utilization; or (iii) how household behaviour in each type of system differs in response to external shocks or stresses. Methodologically, the former two questions could build on the methods deployed here (descriptive statistics, clustering and regression), the latter could make use of agent-based modelling in which different behavioural equations would be allocated to heterogenous agents based on the classification of the surrounding type of SES and their positionality in the social space within a given type of SES.

6 Conclusion

Over the politically turbulent period of the years between 1993 and 2011, three types of SES have been identified and mapped based on the use or dis-use of a characteristic bundle of direct ES. The overall downward trend of direct ES use, except for agriculture in low use areas, was set as a proxy for underlying transition processes of SES that mediate and are shaped by human agency. Two types of SES have been adopted from the archetypal distinction of Cumming et al. (2014), namely green- and red-loop type of systems, one in which households exhibit strong ties with the direct natural environment and the other, where households are increasingly disconnected from their natural resource base with distinct implications for land and resource use planning as well as sustainability management.

The main achievement of the present work was to elaborate on evidence based on household survey data to support the hypotheses that (i) SES are inherently dynamic and interactions between different system components change over time therefore necessitating a dimension of time for their identification and spatial exploration; and (ii) that differences do not only exist between the defined types of SES but also within these systems between households, differences largely rooted in the political economy of land access and accumulation.

The first hypothesis was corroborated by identifying the distribution of a set of three initial clusters representing the three types of SES in 1993 (low, medium and high direct ES use, based on varying direct ES use intensities) and comparing the subsequent average shares of household use intensities in these exact clusters (**Fig. 3**). The second hypothesis was validated by taking the use intensity of direct ES as a dependent variable in a panel regression and associate it with variables concerning household characteristics on the one hand, and information about the population density of a given municipality on the other (**Tab. 6**). It was shown that across all types of SES, mostly the location of households within KZN plays the decisive role for predicting the degree of direct ES use, next to the access to land, formal labor market linkages, capacity to send remittances, ethnicity, population density and infrastructural provision of electricity. One finding from medium and high use categories is the statistical insignificance of yearly household income which validated previous findings on fuelwood use that showed the profuse utilization rates of wood in certain areas in South Africa independent of the socio-economic status of the household. Despite the widely proclaimed de-agrarianisation, this analysis has shown that both agricultural and non-agricultural direct ES remain vital as livelihood constituents and this not only in rural areas, but across the three identified types of SES.

Next to the theoretical interest an analysis of a waning agricultural transition evokes regarding the behavior of social and ecological variables, the adopted and extended approach of Hamann et al. (2015a) has clear potential to inform spatially targeted policy making. Not only can the identification and the mapping of the characteristic bundle of direct ES reveal hotspots of human well-being, social deprivation, ecological footprints or differing human-nature relationships and thus serve as a basis for spatially targeted policy interventions, but also can this approach turn disciplinary-bounded science upside down and reframe it in a transdisciplinary approach that integrates theories and methods of both natural and social sciences to resolve the pressing sustainability issues of present generations.

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8 Annex

Annex I. Linkages between Ecosystem Services and Human Well-being

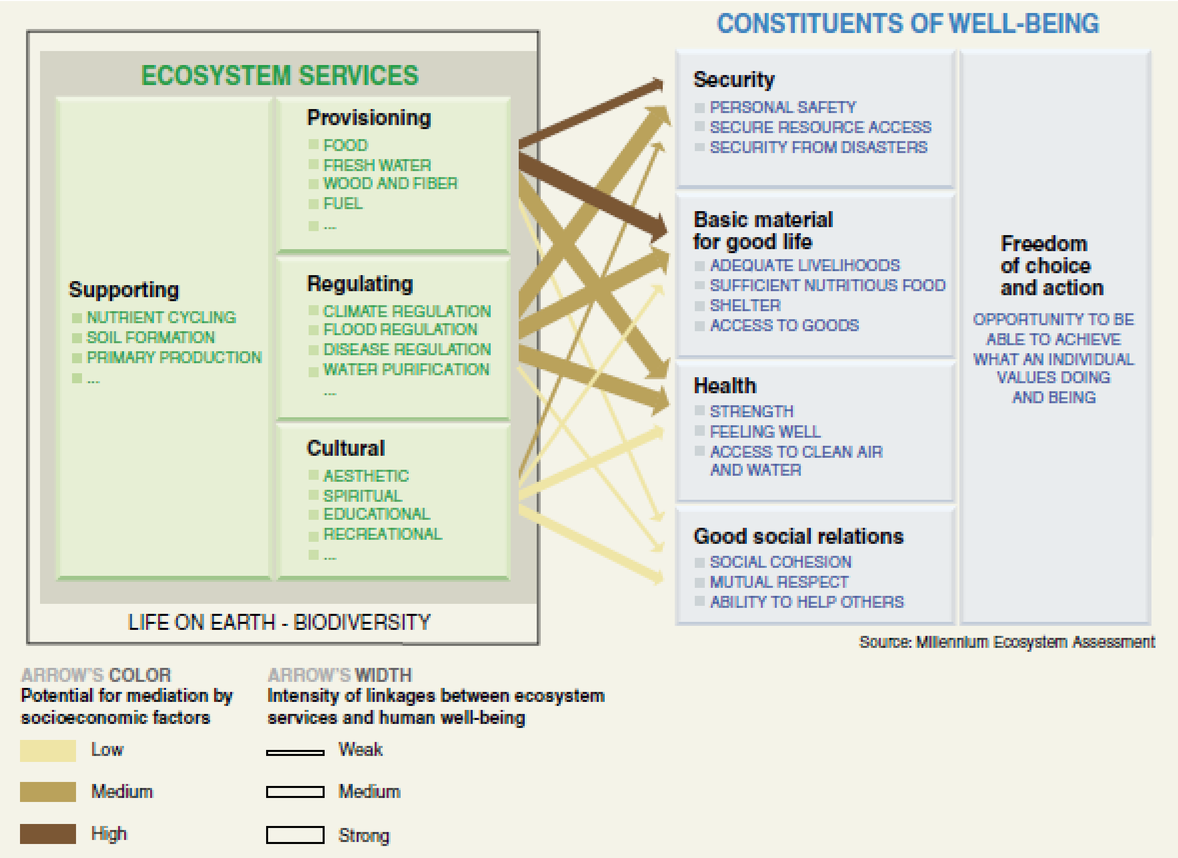

Figure A. 1 - Linkages between ecosystem services and human well-being. Source: Millennium Ecosystem Assessment (2005a, p. vi).

Annex II. Full survey questions for the construction of the characteristic bundle of direct

Variable	Question	Chosen response variable	Other possible responses
ES_water	(2.2) What is the source of water used most often in this household for things like drinking or bathing and washing clothes? **(SINGLE MENTION ONLY)**	Flowing river/spring; Protected spring	Piped – internal; Piped - yard tap; Water carrier/tanker; Piped - public tap/kiosk (free); Piped - public tap/kiosk (paid for); Borehole; Rainwater tank; Dam/stagnant water; Well (non-borehole) Other (specify)
ES_wood	(3c)[7] Average number of trips per week >= 1	# of trips ∈ {1:19}	# of trips ∈ {0}
ES_materials	(2.1) Type of dwelling	Traditional dwelling (hut)[8]	Shack; House/Part of a house; Maisonette; Flat; Hostel; Outbuilding; Combination of buildings
ES_crops	(8.5.1.1)[9] What crops, if any, did the household harvest in the past year? **(Write down the relevant name and record the code from the box for each crop harvested.)**	# of crops ∈ {1:22} [01= Maize Grain 12=Millet 02= Maize Fresh 13=Madumbe/Other Tubers (Specify) 03= Sorghum 14=Peanuts/Nuts 04= Wheat 15=Tomato 05= Potato 16=Onion 06= Orchard Fruit 17=Sugar/Cane 07= Bananas 18=Other Vegetables 08= Grapes 19=Pasture Crops (e.g. lucerne) 09= Dry Beans 20=Commercial Flowers	# of crops ∈ {0};

[7] At least one household member. Variable does not change if multiple household members carried out multiple trips per week.
[8] Stats SA define a traditional dwelling as "A dwelling made primarily of clay, mud, reeds or other locally available natural materials. This is a general term that includes huts, rondavels, etc. Such dwellings can be found as single units or in clusters" (Stats SA, 2012b, p. 19).
[9] If household did not grow any crops (question 8.5-1a), NA was set to {0}.

		10= Pumpkin/Squash 21="Imifino", "Morogo" berries, mushrooms 11= Green Vegetables 22=Other (Specify)	
ES_anim	(8.5.1.2) Does the household own or farm with any animals or poultry of any kind?	# of animals ∈ {1:5} [cattle, sheep, goats, pigs, poultry]	# of animals ∈ {0}

Table A. 1 - Full survey questions and answer categories KIDS data 1993-2004 for the characteristic bundle of direct ES.

Variable	Question	Chosen response	Other possible responses
ES_Water	What is the this households main source of water for household use?	River/stream; spring	Regional/local water scheme (operated by municipality or other water provider); Borehole, Rain water tank, Dam/pool/stagnant water; water vendor; water tanker/other
ES_Wood	What type of energy does this household mainly use for cooking/heating/lighting? (Note: Wood cannot be indicated for lighting usage).	Wood for cooking, wood for heating	Electricity, gas, paraffin, coal, candles, animal dung, solar, other, none
ES_materials	Type of main dwelling	Traditional dwelling/hut/structure made of traditional materials	House, flat, cluster house, townhouse, semi-detached house, house/flat/room in backyard, informal dwelling (in backyard), informal dwelling (as a squatter or settlement on a farm); room/flat on the property of a larger dwelling, caravan/tent, other
ES_crop	What are the kind of agricultural activities the household is involved in? (More than one can be chosen)	Vegetable production, other crops or fodder	Other, none
ES_anim	What are the kind of agricultural activities the household is involved in? (More than one can be chosen)	Livestock production; Poultry production;	Other, none

Table A. 2 - Full survey questions and answer categories Census data 2011 for the characteristic bundle of direct ES.

Annex III. Technical note KIDS data

The exact definition of a core member is if he/she is (University of KwaZulu-Natal, 2004):

- The self-declared head of household from the 1993 survey
- A spouse/partner of the self-declared head of household (from the 1993 survey)
- Lives in a three-generation household and all of the following are true:
- Child of the self-declared household head, son/daughter-in-law of the
- household head, or niece/nephew of self-declared head
- At least 30 years old
- Have at least one child living in household
- Spouse/partner of person satisfying criterion.

Annex IV. District municipalities and corresponding local municipalities.

eThekwini Metro	Amajuba	Harry Gwala	Ilembe	King Cetshwayo
Durban metropolitan municipality	Dannhauser; eMadlangeni; Newcastle	Dr. Nkosanzana Dlamini Zuma; Greater Kokstad; Ubulebezwe; uMzimkhulu	KwaDukuza; Ndwedwe; Mandeni; Maphumulo	uMhlathuze; Umlalazi; Nkandla; Mthonjaneni; Umfolozi
Ugu	**Umgungundlovu**	**uMkhanyakude**	**Umzinyathi**	**uThukela**
Ray Nkonyeni (used to be Ezinqoleni and Hibiscus Coast); Umzumbe; uMuziwabantu Umdoni	Msunduzi; uMshwathi; uMngeni; Richmond; Mkhambathini Mpofana; Impendle	Jozini; Umhlabuyalingana; Mtubatuba; The Big 5 Big Five Hlabisa	Msinga; Nqutu; Umvoti; Endumeni	Alfred Duma (used to be Emnambithi/Ladysmith and Indaka); Okhahlamba; Inkosi Langalibalele (used to be Imbabazane and Umtshetzi)
Zululand				
Ulundi; Nongoma; Abaqulusi; uPhongolo; eDumbe				

Table A. 3 - Full list of local municipality names and corresponding district municipalities in KZN. Administrative classification as of 2016. Data: South African Demarcation Board (2016a and b).

Annex V. Distribution of former homeland areas in South African and KZN

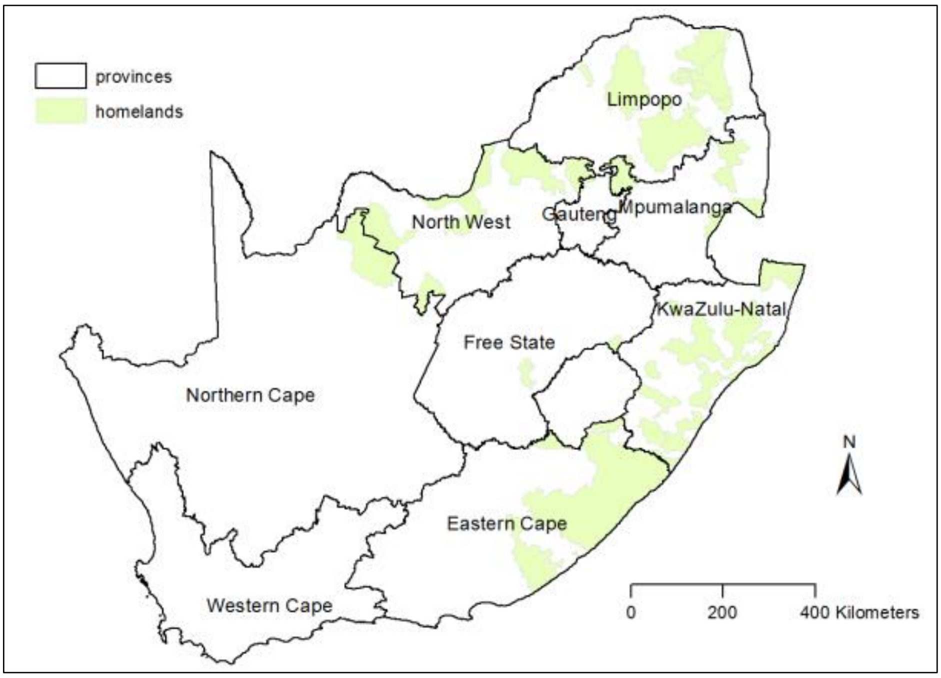

Figure A. 2 - Distribution of former homeland areas in South Africa. Source: Hamann et al. (2015b)

Annex VI. Structure of the dataframe KIDS and census

Snapshot of the KIDS-dataframe (consisting in total of 4067 rows as unique household observations per wave and 46 columns as variables):

	hhid	year	cluster	esd_name 93: ESD Name	md_code 93: Magisterial District Code	md_name 93: Magisterial District Name	metro	ES_water
1	590010	1993	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	
2	590010	1998	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	
3	590010	2004	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	
4	590020	1993	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	
5	590020	1998	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	
6	590020	2004	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	
7	590030	1993	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	
8	590030	1998	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	
9	590030	2004	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	
10	590040	1993	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	
11	590040	1998	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	
12	590040	2004	59	ST. WENDOLINS, SAVANNAH PARK	221	PINETOWN	3	

Figure A. 3 - Snapshot of the KIDS-dataframe.

Snapshot of the census-dataframe (consisting in total of 260.229 rows as unique household observations and 34 columns as variables):

	hhid	H11_ENERGY_HEATING Energy or fuel for heating	H_PROVINCE Province	H_DISTRICT District	H_MUNIC Municipality	Weight	ES_water	ES_wood
1	10842477879	1	5	521	503	10.23112	0	
2	10842477782	1	5	521	503	10.23112	0	
3	10842479722	4	5	521	503	10.23112	0	
4	10842480013	1	5	521	503	10.23112	0	
5	10842479819	1	5	521	503	12.49888	0	
6	11028984629	1	5	521	503	10.23112	0	
7	11028984047	1	5	521	503	10.80881	0	
8	10842478849	4	5	521	503	10.76381	0	
9	11028983562	1	5	521	503	10.76381	0	
10	11028386624	1	5	521	503	18.00086	0	
11	11028445212	4	5	521	503	10.76381	0	
12	10811669321	4	5	521	503	10.23112	0	

Figure A. 4 - Snapshot of the census-dataframe.

Annex VII. R-Code

The scripts created for the empirical sections of this thesis is available under the following link. The relevant questionnaires and coding manuals are included as well.

https://1drv.ms/f/s!AnzstWb00cHFu2R29VBn8N033T6C