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Assessing availability of wetland ecosystem goods and services: A case study of the Blesbokspruit wetland in Springs, Gauteng Province

By

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Research Report submitted in partial fulfilment of the requirements for a Masters Degree in Environmental Sciences

School of Animal, Plant and Environmental Sciences

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Johannesburg

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Plagiarism Declaration

I declare that this research is my own work except where otherwise acknowledged. It is being submitted in partial fulfilment for the requirements of the degree of Master in Environmental Sciences at the University of Witwatersrand. It has not been submitted before for any degree or examination in any other university.



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Mrs Shuvai Mharakurwa 10 October 2016

Abstract

Wetland ecosystems cover approximately 6% of the Earth's surface area and provide important ecosystems goods and services for the sustenance of human livelihoods. According to the Millennium Ecosystems Assessment, wetlands' ecosystems goods and services cover the provisioning, regulating, support of biodiversity, and wider community cultural values. However, wetland ecosystems are threatened by human interference in combination with effects of climate change, both of which might compromise the functionality of these socio-ecological systems. The study used a combination of observations, interviews and remote sensing combined with GIS to investigate evidence of change and the possible effects on the Blesbokspruit wetland's natural integrity, and thus availability of ecosystem goods and services in the wetland. Documented spatial changes in land uses were analysed to determine the extent to which land use and cover changes have affected the natural capital (i.e. ecosystem goods and services) for people. The interaction of local people with the wetland was assessed in order to establish how they use the wetland as a livelihood support system.

The study found that people from the surrounding communities both in the upper (Putfontein) and lower catchments (Marievale) are interacting with the wetland in different ways. The provisioning services from the Blesbokspruit wetland to the surrounding communities include water used for both domestic and agricultural activities. Both subsistence and commercial farming are taking place along the wetland (crop farming and livestock rearing). The wetland is therefore providing a safety net to disadvantaged households who are able to supplement their food. The wetland is also able to regulate climate change (carbon sequestration and flood attenuation) and water quality due to the presence of vegetation. The wetland also supports high biodiversity (flora and fauna) such as within the Marievale Bird sanctuary. Recreational services of the wetland come from the scenic views noted at both Marievale (picnic spots) and Putfontein (evidenced by children playing and swimming). The integrity of the wetland is primarily threatened by population increase and urbanisation. Remote sensing analyses of land use/land cover patterns between 1998 and 2015 indicate that major changes of the wetland have been due to human encroachment. Subsistence agriculture in the wetland has increased, which fuels damage to the wetland. Direct observation and interviews with female farmers showed that they compete for plot size which is proportional to the respect one farmer earns in the community. Water quality of the wetland seemed to be compromised

by industrial activities and use of fertilisers by farmers. Unlike the pristine upper part of the wetland at Putfontein, eutrophication downstream was evidenced by polluted water, algal blooms and change of water colour at Marievale – all suggesting loss of natural benefits such as high quality water.

Despite the observed threats, it is concluded that the Blesbokspruit wetland ecosystem goods and services play a significant role in supporting the well-being and livelihoods of surrounding poor communities. It is suggested that activities threatening the wetland's integrity may be managed effectively through community-based approaches for natural resource management. There is a need for all stakeholders to be equipped with proper conservation knowledge for them to appreciate the indirect (e.g. climate regulation and water quality control) as well as direct (agricultural and water provisioning) benefits of Blesbokspruit wetland. A better understanding of this socio-ecological system would benefit from comprehensive research on hydrological dynamics associated with agricultural practices within the catchment, and the development of an integrated model of natural resources management with a strong social component.

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Chapter 1: Introduction and literature review

1. Introduction

This chapter serves as an introduction to the study, highlighting background information from the literature and leading to the aims and objectives. To give a proper background to this study, literature relating to types, importance of, and threats to wetlands will be explored. The benefits that people get from wetlands also come out of the literature synthesized. This included literature that also considers relationships between human livelihoods and the natural resources provided by wetlands.

At a worldwide scale, wetlands occupy an area more than 1280 million hectares which is approximately 6.2-7.6 percent of the Earth's land surface (Melendez-Pastor *et al.,* 2010). They are considered as some of the most highly complex ecosystems in the world because of a variety of their unique conditions, whether aquatic (being inundated by flowing or non-flowing water permanently or seasonally; Ollis *et al*., 2013) or terrestrial/on land (Verones *et al.,* 2013). Peatlands, marshes, swamps, mangroves, shallow lakes with a water depth not more than 3 m, floodplains, and littoral zones are all forms of wetlands (Sarkar and Jain, 2008) as defined by the Ramsar Convention. A way to classify wetlands in South Africa on the basis of their hydrological, ecological and geological characteristics was put forward by Cowardin *et al* (1979). In their definition, wetlands could be marine (coastal wetlands), estuarine, with examples such as deltas, tidal marshes and mangrove swamps. Some are lacustrine (lakes), riverine (adjacent to rivers or streams) or palustrine wetlands such as marshes, swamps and bogs (Bassi *et al*., 2014). How the soil develops and the diversity of plant and animal life in wetlands are largely determined by water saturation levels, both aquatic and terrestrial species may be supported by wetlands. The continual presence of water allows favourable conditions in which plants that are especially adaptive to wetlands soils' characteristics can thrive (EPA, 2013). The ecosystem services they provide for human wellbeing include provisioning, regulating and supporting all social and economic aspects of human activity, as well as cultural dimensions and values (Ramsar Convention Secretariat, 2013). The global contribution of ecosystem services in monetary terms has been estimated to be around 14 trillion US dollars every year, thereby making a vital contribution to human livelihoods (Turpie *et al*., 2010). The main source of potable fresh water for human consumption is wetlands in their different forms, which serve 12 times more water than dry

lands (Millennium Ecosystem Assessment - MEA, 2005). In almost every country, wetlands in one form or another exist, some are periodically aquatic, while others periodically terrestrial, but all play a pivotal role for the sustenance of both humanity and natural biodiversity (World Wide Fund for Nature - WWF, 2011). Stressing the same view, Wray and Bayley (2006) also noted that the importance of wetlands to human life lies in their biogeochemical and biological functions, which is the ability to export and store naturally occurring chemical compounds that can significantly affect the quality of the environment (Turner *et al*., 2009) as a result of their exceptional permanent or semi-permanent flooded characteristics. By recharging groundwater, wetlands, directly supply fresh water to around 1.5 to 3 billion people as well as provide 40% and 20% of water requirements for industrial use and irrigation respectively (MEA, 2005).

1.2. Importance of wetlands for ecosystem goods and services

Wetland ecosystem goods and services refer to the benefits that people obtain from any wetland environment (MEA, 2005; Barbier, 2011; Maltby and Acreman, 2011), and these are categorised as: "provisioning services, which are products obtained from ecosystems, e.g. fresh water, food, fibre, fuel, genetic resources, biochemical, natural medicines and pharmaceuticals; regulating services, being benefits obtained from the regulation of ecosystem processes, e.g. water regulation, erosion regulation, water purification, waste regulation, climate regulation and natural hazard regulation (e.g. droughts, floods, storms), supporting services are those services necessary for the production of all other ecosystem services, including primary production, nutrient cycling and water cycling, they are indirect and often occur over a very long time; ccultural services are nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, e.g. cultural diversity, knowledge systems, educational values, social relations, sense of place, cultural heritage and ecotourism" (Russi et al., 2013). Wetland ecosystems therefore provide crucial functions, and serve essential ecosystem services such as supporting biological diversity, and also significantly provide benefits that enhance human wellbeing (Whiteoak and Binney, 2012). Wetlands are multi-functional resources which are capable of providing a variety of ecosystem services with regards to particular factors which can include their type, where they are located, prevailing conditions, or what they are used for (Dixon and Wood, 2003; Ramsar, 2013). The ecosystems goods and services are mainly determined by the ecological performance by the wetlands and the extent to which humankind yields benefits. (Whiteoak and Binney, 2012). The services that

wetlands provide for human well-being could be direct, while others maybe indirect. Turner *et al.* (2008, 34) distinguished the two;

1. Direct services and values arise from direct interaction with the wetland ecosystem. They could be consumptive such as water use, fish harvesting or they could be non-consumptive, for example recreational activities or aesthetic values.
2. Indirect values are associated with services that are provided by the wetland but do not entail direct interaction for example flood control, or removal of pollutants.

The provisions from wetlands are a multiple of products that may be harvested to support livelihoods of the local communities (MEA, 2005; Adekola et al., 2008). Wetlands provide habitat for biodiversity as well as produce valuable minerals such as peat, used for mushroom farming and flower-potting (Grundling and Grobler, 2005), and coal for electricity generation (Rich, 1982; Ramsar, 2013). The products that wetlands provide include staple foods, for example rice or fish, building materials such as timber, fuel-wood, vegetable oil, salt, medicinal plants, craft materials such fibres, as well as livestock grazing pastures (United Nations Development Programme - UNDP, 2009). These products are harvested and utilised differently, for example in a subsistence manner at household level, or extensively by commercial exploitation by multinational companies (Ramsar, 2013). It has been noted that around 150 million people especially those from developing nations consider fish provided by wetlands not only as an essential element of their diets, but also an income generating economic activity, thus contributing to 80% of the global fisheries (Wang *et al*., 2011). Provisioning services by wetlands along the Pak Phanang River Basin in Thailand were valued and it was noted that villagers in the coastal areas make a living by producing *nipa* sugar from coastal wetlands (Barbier, 2013). In some parts of the world, honey is collected from mangroves, for example in Cuba, by tracking the periodic blooming of the *Avicennia* mangrove present in coastal wetlands (Ramsar, 2013).

Scientists are in agreement that wetlands contribute significantly in maintaining atmospheric phenomena, for example, the global carbon cycle (Keller, 2011; Clarkson *et al.,* 2013). The role of providing regulation services by wetlands is realised through the ability of wetland vegetation and peatlands in enhancing carbon sequestration (Sullivan *et al*., 2008), with an estimation of global peatlands holding 540 gigatons of carbon (MEA, 2005). Peatlands are those wetland ecosystems that were formed as decomposing plant and animal remains

(organic matter) accumulated in water logged soils (Murdiyarso *et al*., 2012). Globally, peatlands cover 3% of the land, which equates to around 40,000,000 km² worldwide; they hold 30% of the world's soil carbon, while occurring in more than 180 countries with a representation of almost one third of the global wetland ecosystems (Erwin, 2008). Supporting the same claim, EPA (2001) maintained that wetlands are live carbon stores through their vegetation, as well as providing long-term storage of carbon as peatlands, thereby assist in minimising adverse effects of climate change.

Wetlands also mitigate impacts of severe weather events caused by climate change, for example, by naturally reducing peak flows from floods (Bobbink *et al*., 2006). This function is of great importance due to the fact that high numbers in human population are found in low lying areas such as floodplains that are at high risk for flooding because of the rich alluvial soils for agriculture (Keddy *et al*., 2009). Murdiyarso and Kauffman (2011) noted that, along coastal areas, mangroves have been proven to have significant values as they act as buffer zones and minimise the extent of damage or vulnerability of such areas from flooding after a cyclone or heavy storms. Shoreline stability is also enhanced as the wetland vegetation controls erosion (Sarkar and Jain, 2008). In a study of floodplains in Australia, Wang *et al*. (2011) noted that when flooding occurs after a heavy downpour, wetlands have the capability to retain some of the water until it is released downstream. The rainwater may be stored (i.e. along the floodplain), the vegetation creates friction which therefore delays water flow and allows some of it to infiltrate into the soil to become groundwater (Collins, 2005). When inter-connected floodplain wetlands play this role in a serial order, the accruing benefits become highly noticeable downstream (Ramsar, 2013). Similarly, peat swamp forests play the role of 'landscape sponges' by reducing flooding during rainy summers and releasing water during dry winters (Murdiyarso and Kauffman, 2011).

The other value of wetlands lies in their ability is control the quality of water flowing through the wetland (Sullivan *et al*., 2008). Improvement in the quality of water, drinking water included, is achieved as wetlands intercept overflow water from the landscape, then absorb nutrients and pollutants while allowing solid matter to be processed, and the sedimentation of any matter in suspension, so that it does not reach outflowing waters (EPA, 2001). As natural filters, wetland ecosystems' natural vegetation enables water purification when they trap toxicants which may be in form of silt, nitrates or phosphates as well as some heavy metals, bacteria or viruses , hence assisting in reducing eutrophication downstream (Collins, 2005).

The Ramsar Convention Secretariat (2013) also agrees that, as it leaves the wetland, water is considered to have fewer impurities than when it entered, due to the fact that wetlands tend to facilitate denitrification due to the presence of anaerobiotic and aerobiotic soils next to each other. The potential to assimilate excess nutrients in some wetlands, such as those in temperate regions, have been noted to be within the range of 1000-3000 kg N/ha/year and 60-100 kg P/ha/year (Bassi *et al*., 2014). The denitrification ability by wetland ecosystems is thus very crucial as potentially harmful nitrates to water quality are converted into a non-hazard atmospheric nitrogen (International Water Management Institute - IWMI, 2014).

Globally, wetlands can be considered as some of those ecosystems which are highly productive in terms of biological diversity (Stedman, 2002). The large amount of food products they provide make them attractive feeding grounds for all sorts of aquatic organisms as well as wildlife and birds (Barbier, 2013). It has been noted that numerous and vital food cycles or webs exist between those species which are harboured by wetland ecosystems (EPA, 2001). In a study of 1184 inland wetlands of international importance done by the Ramsar Convention, 73% were deemed significant for water birds at distinct stages of growth, while 67% are generally necessary for bird life, and 25%, 26% and 49% were essential for newts, reptiles and other creatures, respectively (Verones *et al*., 2013). Connicci *et al*. (2010) claimed that despite covering quite a small percentage of land in the globe (6%), wetlands are home to an estimated 40% of all species globally. A considerable number of wetlands are utilised by migratory birds as feeding and resting stations, for example, "two million shorebirds are estimated to visit both the Banc d'Aguin National Park in Mauritania and the Wadden Sea in northern Europe, while St Lucia, an estuary and Ramsar site in South Africa, supports 350 bird species" (Connicci *et al*., 2010).

Wetland ecosystems also hold exceptional values that are linked to cultures and indigenous beliefs of some communities (MEA, 2005). The Ramsar Convention Secretariat (2013) noted that some wetlands have a link to spiritual, universal ideologies or sacred benefits, while they also offer imaginative stimulus, some bear substantial archaeological evidence; others are reserves for flora and fauna, hence offer crucial foundations on which all elements of society, whether social, economic, and cultural traditions could thrive. There are some communities who perform rituals with water obtained from the wetlands as it is associated with supernatural powers for healing, and other important medicinal plants tend to strictly occur in the wetlands environment (Mokotjomela, 2009). Other communities also select specific

wetland sites for the purpose of performing cultural and spiritual rituals such as circumcision and prayers (Macharia *et al*., 2010). In Tanzania, collaborative studies between researchers and traditional doctors, at Muhimbili College of Health Sciences, have assessed the value of wetland trees, grass, leaves and flowers used as traditional medicines by the local people (Omari, 1993). In the Limpopo province of South Africa, Lake Fundudzi is linked to several spiritual myths orally shared from one generation to the other, as a result, it's a sacred place where the paramount chief and his kinsmen perform religious practices (Khorombi, 2000).

In Australia, wetlands have historical as well as social significance as they have contributed to opportunities that led to the growth of the interior parts of the country (Commonwealth of Australia, 2014). According to Verschuuren (2006), before the establishment of communication infrastructure such as rail lines and highways, wetlands along rivers such as the Murray, Murrumbidgee and Darling were utilised for shipping agrarian produce such as wool to market places. Products such as river red gums found in the Barmah forests along the Murray River in Millewa have been harvested as early as the 1800s to provide logs needed in construction industries, bridges and railway sleepers, and firewood for cargo boats. People in the Murray region therefore commemorate their river and wetland culture and tradition, while providing tourist and recreational facilities (Verschuuren, 2006). Wetlands are culturally valued by the Aborigines, who claim that although fish in wetlands can present a platform for considerable potential for fisheries at local subsistence or commercialized efforts; the same fish can also be significant as a sacred, totemic or emblematic species (Barber and Rumley, 2003). The opinion of one native female about leisure sport-fishing harbouring at sacred places in the Daly River reflected that, to the locals, the rivers are not merely water sources, but rather resting havens of their ancestors (Barber and Rumley, 2003). A study in Nepal by WWF (2011) also revealed that the people of the Himalayan mountains placed high cultural significance on the wetlands, considering them to be sacred.

Wetlands also provide crucial sites for scientific researches and favourable circumstances for environmental education and awareness campaigns for biodiversity conservation (Sullivan et al., 2008). The United States Environmental Protection Agency (2013) noted that some institutions actually carry out educational investigations to assess the environmental reaction by waterways, floods and ecological water provisioning by wetlands, as well as the reaction of flora and fauna in terms of breeding and abundance while using wetlands as their reference

point. This also places a lot of emphasis of how wetlands are linked to crucial a diversity of physical and biological processes.

1.3. Common threats to wetland ecosystems

In the Fifth Assessment Report on Impacts, Adaptation and Vulnerability, the Intergovernmental Panel on Climate Change (IPCC, 2014) argued that inland water bodies are some of the most likely globally endangered ecosystems. The major causes of losses in wetlands have been due to land uses such as urbanisation, drainage for agricultural purposes, development of different forms of infrastructure, industrial effluent pollution, pollution from agricultural runoff, as well as climate change and variability (Bassi *et al.,* 2014). Any perturbations in the amount of water or its characteristics by either natural or anthropogenic interference could have adverse effects on the health integrity of the wetland (Sims *et al*., 2013). Before the mid-1970s, disturbing and degrading of wetlands through activities such as water abstraction were commonplace and that resulted in their losses and alterations, thereby compromising the benefits they provide (EPA, 2001). Transformation of many wetlands by people was due to the need for expansion of agricultural activities, or growth of towns and cities, while on some, embankments were created to mitigate vulnerability to floods in coastal areas (Ramsar, 2013). As population grows, so does the demand for ecosystem goods and services, this directly trigger threats to wetlands' sustainability (MEA, 2005). For example, due to degradation, some floodplain wetlands are no longer functionally connected to the rivers systems that are supposed to supply them with water (Settele *et al*., 2014).

The main reason why wetlands are continually being negatively transformed, degraded and eventually lost together with the goods and services they offer appears to be the lack of real appreciation of their value economically so as to establish their sustainable use and management or trade-offs (McCartney *et al.,* 2010; Whiteoak and Binney, 2012). In agreement, with particular focus on Africa, Getachew *et al*. (2012) argued that another shortcoming to the sustainable utilisation of wetlands may be inadequate comprehension by stakeholders of the gains from these ecosystems, hence failure to implement sustainable utilisation approaches because stakeholders have insufficient knowledge of ecosystem goods and services. Economically, the benefits wetlands generate or and the costs incurred after their loss due to degradation are rarely acknowledged, thus this may lead to decisions that trigger wetland conversion and degradation, therefore lack of their direct market value fuel their loss (Mmopelwa *et al*., 2009). It has also been noted that wetland ecosystems and their

benefits are being lost due to the traditional perception of treating them as public goods and with open access by the public, without any enforceable property rights to curb unrestricted use of the resource (Turner *et al.*, 2009). Access to natural ecosystems, such as wetlands by local communities, can therefore be linked to 'the tragedy of the commons', implying that common resources are overexploited because of lack of known direct owners (Prato and Longo, 2012).

It was estimated that from the existing inland and coastal marshes, 56 to 65% have been converted for intense agricultural production in Europe and North America, 27% in Asia, 6% in South America and 2% in Africa (MEA, 2005). Due to anthropogenic activities such as dredging, oil spills and wetland reclamation, Africa's Niger Delta has the most exploited mangrove forest, despite being one of the most sensitive biodiversity hot spots globally (Okonkwo *et al.,* 2015). The Mesopotamian marshes of Iraq initially extended over 1.5 to 2 million hectares, however they have been highly impacted due to water extraction and development of dams along the Tigris and Euphrates rivers (FAO, 2011). Therefore the ecosystem goods and services they provide to their surrounding communities have also been deteriorating.

Global evaluations on the conditions of wetland species showed the proportion of species that are deemed endangered amongst the diverse animal classes are at: "17% of water fowl, 38% of freshwater species, 33% of freshwater fish, 26% of freshwater amphibians, 72% of freshwater turtles, 86% of marine turtles, 43% of crocodilians and 27% of coral reef-building species" (Ramsar 2013). The principal cause of wetland biodiversity loss is linked to habitat alterations as a result of wetland drainage for crop production, and other development activities, or due to climate variability, poor water quality, spreading of alien species and overuse of the natural capital (Obiero *et al*., 2012).

Reports on the state of peatlands revealed that an estimated 14-20% of the global peatlands are presently utilised for agricultural production while, peat swamp forests in South East Asia, are being rapidly transformed by draining or burning to prepare for oil palm or alternate produce and other crops as well as accidental veld fires (Settele *et al*., 2014). Land cover changes in tropical wetlands are occurring more quickly than in any other types of forests (Murdiyarso and Kauffman, 2011). Almost 45% of Indonesia's peat forests are degraded by deforestation or drained, thereby causing a change in their role as essential global carbon

stores to significant global carbon dioxide emitters (Centre for International Forestry Research - CIFOR, 2015).

The threats to wetlands are sometimes interlinked, for example, due to rising sea levels associated with climate change, wetlands at coastal areas tend to retreat inland (Ramsar, 2013). As the population continues to grow, there is also more demand for raw materials, leading to more conversion of low-lying coastal wetlands for various development activities such as crop farming, industrial growth as well as urbanisation (Dixon and Wood, 2003). As a result, wetland ecosystems are continually becoming constricted between the ocean on one side and hard, impermeable ground on the other due to port expansion and urban and industrial sprawl (Turner *et al*., 2009). As these wetlands dwindle, their functional diversity decreases, while human wellbeing is negatively impacted by sea level rise and other extreme events (Ramsar, 2013).

1.4. Socio-environmental conflict: human needs and biodiversity conservation

Socio-environmental conflicts stem from different ways through which interrelationships exist as different stakeholders strive to benefit from ecosystems (Little, 2007). According to Little (2007), this anthropological notion of conflict surpasses a concentration on political and economic endeavours combined with universal, ritual, identity and moral elements that are not often perceived in a clear manner from different perspectives. In order to strike a balance between provisioning for the needs of the current generation while considering the future generations, measures in form of conservation efforts are put in place where biodiversity is concerned (Adams *et al*., 2004). Protected areas such as national parks and game parks/reserves serve that purpose (Salafsky and Wollenberg, 2000). However it has also been noted that once a protected area has been established, local communities become marginalised and risk their livelihood needs, hence these efforts in many cases are coupled with rejection (Sanjay and Weber, 1995). Studies have shown that most of the indigenous communities adjacent to the protected areas feel negatively about national legislation and nature preservation and protection efforts (Okech, 2010). This scenario is created when the conservation efforts are implemented in a way that compromise resident communities' opportunities to benefit from ecosystem goods and services (Baker *et al*., 2013). In many cases, protected areas are created on lands that would have been legally or customarily belonging to or under the management of local people, and once in operation they have defined boundaries that deny access to unauthorised individuals (Salafsky and Wollenberg,

2000). For some communities living near natural resource banks such as forests, they tend to develop strong relationships with such ecosystems because they depend on them as their safety nets (Food and Agriculture Organisation - FAO, 1995). The challenge with conservation and management efforts, especially those imposed and outsourced from other private organisations, is that they overlook these important relationships, and thus result in conflicting agendas with local communities, for example game poaching, wild fires and snares for trapping small animals as hunting strategies (Holmes, 2007). Conservation management efforts are sometimes designed from the need to develop a natural environment, whose value is influenced by its distance from human interaction with it, mostly in areas classified as non-access (Holmes, 2007). Imperatively, where protected areas are created as zones of limited use, it often involves removing local people from such areas not just physically, but also socially and culturally (Andrade and Rhodes, 2012).

There are several reported cases where nature conservation protocols have created tension in the neighbourhood communities. For example, when the Mombasa Protected Area was established in Kenya, it resulted in adverse impacts on how people would earn a living because of a decrease in their fishing harvests due to the introduction of no-take zones where fishing is prohibited, resulting in reduced access to fishing grounds (Redford and Fearn, 2007). Exclusively setting aside grazing land for wildlife and tourism results in pastoralist communities being affected negatively, thus prompting them to question the African wildlife approach – which has in many cases resulted in 'people versus animals' conflict (Okech, 2010). As result people who live adjacent to protected areas tend to perceive nature conservation in a negative manner because of its imposed conditions and limitations on them (Kaminski, 2010).) In the Philippines and Indonesia, marine protected areas were viewed as biologically successful, while socially failing as there were limited benefits for the local people without any conflict resolution measures being successfully employed (Bennett and Dearden, 2014).

Overall, protected areas seem to represent opportunities to save endangered species (Bennett and Dearden, 2014). However, they also intensely transform the means of earning a living for some rural households, especially the indigenous communities in the periphery of such areas the world over (Andrade and Rhodes, 2012). The protection of nature in its pure unspoiled state, is a morally accepted move that sometimes legally allows communally owned rural land to be the acquired and restrict the indigenous people from using available natural

resources. However, this deliberate side lining local stakeholders is sometimes seen as a cause of degradation of the land (Kaminski, 2010). Once people are concentrated on a small area to carry out livelihood support activities, over-exploitation of resources is inevitable, leading to increased land degradation. For example, in Zimbabwe, after the introduction of legislation to stop cultivation on dambos, an increase in deforestation in the upper catchment of dambos occurred as a compensation for land lost downstream, while increased livestock grazing on the dambos was also noted (McCartney *et al*., 2010). The fact however remains that merging biodiversity conservation with poverty alleviation has proven to produce win-lose scenarios, and thus animosity might prevail where protected areas are found in proximity to communal areas (Baker et al., 2013). For example in Bwindi Impenetrable Forest, Uganda, 5% of the forest was lost due to deliberate fires, while in South Africa, illegal activities are carried out by the affected communities in an effort to retaliate to imposed conservation strategies at Tsitsikamma National Park (Andrade and Rhodes, 2012).

In many African communities, wetland resources were communally managed under the indigenous authority exercised by traditional leaders on behalf of the community (Rebelo *et al*., 2010). In Tanzania, Rebelo *et al*. (2010) discovered that, due to the socio- political changes, the management of natural resources is now the responsibility of several formal government structures put in place to make informed decisions on how to manage and monitor wetland use. It is well known that wetland cultivation makes a significant contribution to livelihood production for some rural households as they directly get a cash injection and food security (Rebelo, 2009). To millions of people in sub-Saharan Africa, wetlands are interlinked to crop farming and livestock production, this is exacerbated by the exponential population growth which has triggered a higher demand for food security, hence the inevitable need increase wetland agriculture (Rebelo *et al*., 2010). The rapid urbanisation globally is responsible for the degradation and eventual loss of urban wetlands and their riparian areas (Mhlanga *et al*., 2014). It is therefore unlikely that wetland agriculture can be prevented as long as there are no sound options of supporting households' livelihood requirements. (Rebelo *et al*., 2010). Evidence provided from a study on Ga-Mampa wetland in South Africa showed that the community witnessed the absence of wetland products which have no alternative source in the area, such as sedge and reeds, due to continued encroachment into the wetland by agricultural land conversion (Adekola *et al*., 2008). Globally, it has been projected that the demand for food and fresh water will increase, thereby causing a further decline in the benefits a large number of people, especially those

whose livelihoods directly dependent on wetlands for livelihoods sustenance (Finlayson *et al*., 2015).

1.5. Possible solutions to conflict resolution between conservation efforts and allowing communities access to ecosystem goods and services: Community-based conservation

For many developing countries that rely on agricultural and other land-based resources, population boom coupled with diminishing reliability of rainfall have resulted into expansion of livelihood activities into wetlands (Sakataka and Namisiko, 2014). Thus it becomes imperative that management of natural resources is done in a sustainable manner where clear dependence by local communities is evident. "Wetland communities are often from low income groups who have little or no land access rights. Wetlands are often common-lands under no ownership and their resources and land are relatively freely available. This serves as a big attraction to poor people in both rural and urban areas who can come to rely on them, with their welfare becoming intimately tied to the status of the wetland itself" (Wetland International, 2010, 14). It is also clear that where the resources are in an open access regime, they tend to be overexploited (Bassi *et al*., 2014) hence the need to come up with sustainable strategies of safeguarding them. According to the Ramsar Convention, sustainable use of wetlands is realised when people use wetlands in such a manner that they yield maximum benefits while maintaining the potential of the same wetlands to fulfil the needs and aspirations of future generations (Nabahungu and Visser, 2011).

Community-based conservation (CBC) entails bottom-up or local initiates which promote individual communities and environmental organisations to work together towards realising sustainable resource management (Forgie *et al*., 2001). The aim could be to conserve biodiversity through tourism or simply encouraging the sustainable use of resources so as to avoid over-exploitation. There are several advantages to CBC, for example, a scenario can be easily changed if local people identify solutions to problems that affect them, or to initiate a project. CBC encourages people to participate in achieving goals (Glew *et al*., 2010). In the long run, it becomes more sustainable since there are minimal conflicting parties, thereby saving resources (Berkes, 2007). It is also important to involve local knowledge and skills in CBC initiatives because local people may be more knowledgeable about their immediate environment than a government official from another area. A study in Kenya revealed that CBC has enhanced livelihoods by facilitating community access to public services and infrastructure, and these socioeconomic improvements have been realized in the context of

remarkable improvements to habitat conditions influenced by sustainable grazing management (Glew *et al*., 2010).

1.6. South African wetlands

According to Tooth and McCarthy (2007), wetlands exclusively occur where there are restricted but favourable shallow water availability periodically or permanently, and in particular for drylands of southern Africa, the influence of incoming water from rivers. Therefore, nearly all medium to big freshwater wetlands are connected to rivers which draw water from the interior while supplying most of the water, alluvium and nutrients (Tooth and McCarthy, 2007). A six-tiered classification system is used in South Africa to distinguish the different types of aquatic inland systems, which include wetlands by use of the functionally-oriented hydro-geomorphic approach which has a top to bottom hierarchy (Macfarlane *et al*., 2014). This classification makes use of available information about a wetland to describe a system whether it is marine, estuarine or inland at level 1. Physical and biogeographic features also help in this classification at level 2. The permanence of connection to the ocean by a wetland is also a criterion used at level 3 of the classification system. At levels 4 and 5 of the system, the hydro-geomorphic and hydrological regimes of a wetland are applied to determine its class. Level 6 assigns a description on a wetland according to the geology of the area, whether it is natural or artificial in formation, the soil type, vegetation cover as well as salinity and alkalinity levels also help determine a type of a wetland (Ollis *et al*., 2015).

There are 17 Ramsar sites in South Africa, whose classification is based on their specific importance, including biodiversity conservation, supporting endangered species as well as supporting flora and fauna at critical stages in their life cycles (Haskins, 1998). This is conditioned by those attributes of the wetland such as its hydrology, whether it is capable of supporting biodiversity all year long or seasonally, for example in the case of migrating birds. Turpie *et al*. (2010) gave an in-depth description of South Africa's wetlands (Fig. 1.1).

According to Turpie *et al*. (2010), bogs and fens are examples of seeps that are commonly found in South Africa. Bogs are peat accumulating wetlands found in isolation without any links to major streams hence they are rain and groundwater fed (Mitsch, 2001). Despite their relatively low productivity, bogs have the largest peat deposits and highest long-term carbon accumulation rates (Keddy *et al*., 2009). They are generally located on south-facing slopes which are fairly moist and with dominant vegetation being short sedges and hummock

grasses (Turpie *et al*., 2010). A fen is a peat-accumulating wetland that receives its water from surrounding mineral soil and is usually good for marsh-like vegetation (Collins, 2005). Fens on the other hand are formed on warmer, drier north-facing slopes with sedges as dominant vegetation too. They are supplied with water from streams or underground which eventually discharges downstream (Turpie *et al*., 2010). Although they also have large lawns, sedges and grasses, their source of water can be streams or groundwater which they likely release downstream (Collin, 2005). Peat and peatlands are not very common in South Africa, but where they do occur they are associated with depressions that intersect the regional groundwater table on coastal plains, or in areas with catchments of sandstone or quartzite and dolomite (Job and Ellery, 2013).



Figure 1.1. Examples of South African wetlands: A. Velddrif salt pan (http://www.trover.com/d/EMFh-velddrif-south-africa); B. Zoeitvlei pan (http://www.namakaroo.org/birdlife-of-the-high-karoo-park/); C. Goukou Peatland in the Western Cape (Grundling and Grobler, 2005); D. Barberspan in the Northwest (https://mostlybirding.com/tag/barberspan-bird-sanctuary/); E. Lake Fundudzi in Limpopo (https://tracks4africa.co.za/listings/item/w162450/viewpoint-the- sacred-lake-fundudzi/).

Floodplains are riverine wetlands that receive their water from the river during overflows, for example during a flood, which is then released into the river downstream (Erwin, 2008). Common features along floodplains are marshes and swamps which remain flooded all year round, with waterlogged soils, and also grasslands that are periodically covered with water.

Swamps and floodplains are commonly found in the Limpopo province of South Africa (Jogo and Hassan, 2010).

Pans are also common in South Africa, these are depressions with near-surface waters which gain water from surface runoff and lose it by evaporation (Collins, 2005). There are pans which are flooded all year round, while some pans only get flooded during higher rainfall, while in some dry regions pans remain without water for years, lakes are an example of permanently inundated pans (Allan *et al*., 1995). Throughout South Africa, pans are common in low-lying grasslands of the Nama Karoo and Kalahari, with a range from less than a hectare to over 1000 hectares in size, Barberspan in North West Province, being a good example (Allan *et al*., 1995). Pans can be freshwater ecosystems throughout the rainy summer and later turn into brackish ecosystems when the water evaporates in the dry season (Dini *et al.*, 1999).

1.6.1. Status of wetland ecosystems in South Africa

According to the National Biodiversity Assessment for South Africa carried out in 2011, wetlands occupy only 2.4% of the country's total area, however, 48% of the wetland ecosystem types are critically endangered, 12% are endangered, 5% vulnerable and 35% least threatened (Macfarlane *et al.*, 2014). The South African wetlands are therefore the most highly threatened ecosystems of all in the country (Driver *et al*., 2012). The launching of the Working for Wetlands Programme in June 2000 has enhanced awareness on the value of wetlands, and along with it came many environmental education campaigns focusing on wetlands (Sieben, 2011). Restoration activities include the building of gabion structures in order to minimise erosion, the construction of structures that divert the flow of water or raise the water table, as well as the plugging of artificial drainage channels, and the removal of invasive plants (DEA, 2014). Since it was established, the Working for Wetlands Programme has spent approximately R530 million in wetland rehabilitation and has been involved in over 900 wetlands, thereby upgrading or reinstating the ecological integrity of over 70,000 hectares of wetland environment (SANBI, 2014). South Africa has lost and continues to lose wetlands as a result of human activities which include dam construction, veld fires, overgrazing, pollution, crop production, urbanisation and poor management of land resources (King *et al*., 2005). Wetland ecosystems that are facing the greatest threat in South Africa are floodplains since they are localised in lands most suitable for agricultural production

(SANBI, 2013). The threats are realised in both urban and rural areas, for urban areas its urban expansion, while in rural areas agricultural activities are the main drivers of change.

1.6.2 Legislative Framework and wetlands in South Africa

All resources in South Africa are protected by certain legislation as well as parliamentary acts. South Africa is an affiliate of the Ramsar Convention of Wetlands of International Importance. By doing so as a country it has an obligation to assess, conserve and protect wetlands within its jurisdiction (DEAT, 2010). The South African government policy reflects the recognition that, "in order to be truly effective, strategies for wetland conservation need to include a combination of proactive measures for maintaining healthy wetlands, together with actions to reverse past degradation. This latter aspect forms the core business of a government-led wetlands programme" (Working for Wetlands, 2015).

Section 24 of the Constitution of South Africa states that: "Every individual person in the country rightfully has access to an environment that is not threatening to their health or well-being; and the responsibility to protect the environment, so that both present and future generations benefit from it, by means of free and fair rules and regulations and other measures to avoid polluting and degrading; but rather support conservation; and enable ecologically sustainable development and natural resource utilisation while promoting justifiable socio-economic growth by society" (South African Bill of Rights).

The following list outlines some of the legislative acts that give a framework for protection and good management of wetlands for sustainability:

- The National Environmental Management Act (NEMA) 1998 which provides principles to promote environmental management and decision-making (Government Gazette, 2014).
- The Environmental Conservation Act 1989 prohibits any form of harm to the environment (Government Gazette, 2014).
- The National Water Act 1998 promotes protection, conservation, good use and management of water bodies (Government Gazette, 2014).
- The National Biodiversity Act 2004 which provides the framework for the protection of species and ecosystems that warrant national protection. (Government Gazette, 2004).

Despite having policies and regulatory instruments to safeguard the sustainable utilisation and management of wetlands in the country, people defy them in a bid to earn a living. It was noted that farmers utilising the southern Cape palmiet peatlands consistently choose those services with immediate economic benefits rather than judiciously using the natural resources to ensure long term provision of diversified benefits (Job and Ellery, 2013). South Africa is faced with a growing population, this results in higher demand for the available land such as wetlands as they are mostly freely accessed by the public. Lack of alternative sources of income therefore force local communities to resort to overexploitation of ecosystems such as wetlands (Adekola et al., 2012).

1.7. Rationale of the study

The value of wetland ecosystems to humans and the major threats to the normal functioning of wetlands are well-known globally (MEA, 2005; Turpie *et al*., 2010; IPCC, 2014), but there is a gap in assessing the potential of wetland ecosystems to contribute goods and services to human settlements, especially in the developing world where use of wetland ecosystem services is particularly important. For example, natural environments tend to be threatened by different pressures, such as urban sprawl, and pollution from human settlements and thereby compounding conservation problems of already threatened wetland ecosystems (WWF, 2011), which may also change their function. Thus, it is imperative that the inter-connections between wetlands, and their functions, and services they offer are understood (Whiteoak and Binney, 2012) in order to find effective ways of conserving the natural capital and adapting to the negative effects of climate change. This can be partly achieved by studying impaired wetlands in order to establish which functional losses and gains have occurred over time, and whether changes have negative or positive impacts on the natural wellbeing of the wetlands and thus for local communities. This knowledge would enhance decision-making in context-based conservation and natural resources management plans. For example, current research developments emphasise the need for community-based conservation initiatives to optimise stewardship.

In view of these issues, it is suggested that a four-point scale of provisioning, regulating, supporting, and cultural role (MEA, 2005) could provide a relatively effective assessment of the overall change in functioning of the wetlands, and how pertinent changes has affected the ability for an ecosystem to provide goods and services. Two major reasons for prioritising

this research focus are, the evidence that climate change is impacting negatively on the livelihoods of marginalised communities that rely primarily on natural capital (Shackleton and Shackleton, 2004; IPCC, 2014). Also, high levels of poverty within these communities means they are quite susceptible to the negative conditions triggered by climate change as a result of their limited adaptive capacity (IPCC, 2014). Local people might depend on wetlands as safety nets during droughts (Turyahabwe *et al*., 2013). Models suggest that due to climate change, availability of freshwater is going to be negatively affected (IPCC, 2014). This might heavily impact on food security in areas of rain-fed agriculture (United Nations High Commissioner for Refugees - UNHCR, 2015). It is therefore imperative that conservation of ecosystems such as wetlands become national priorities as they offer safety nets by providing some goods and services that might help mitigate the impacts of climate change on marginalised communities.

By adopting a holistic and integrated approach, this study intends to provide conservation guidance and scientific knowledge of the wetlands ecosystems through demonstrating the importance of ecosystem goods and services of un-impacted wetlands. The study assesses the ability of a wetland to provide ecosystem services despite known threats, and identifies factors that might have led to deteriorated functions of the wetland. Based on the findings, practical and context-based conservation and sustainable wetland natural resource use, recommendations can be made, which will lead to the more sustainable use of natural resources found on wetlands. The results of the study may be integrated into conservation policy, at any level, and may contribute to positive changes in resource management, which makes it possible to achieve sustainable development of wetlands. In the face of global climate change, use of natural resources associated with wetlands can help rural human communities to adapt.

1.8 Aims of the study

This study aims to assess how local communities interact in terms of acquiring ecosystem goods and services, focusing on the Blesbokspruit wetland in Gauteng Province, South Africa. The impacts of anthropogenic environmental changes on the ability of this wetland to provide ecosystem goods and services to poor communities in the vicinity are also examined**.**

1.8.1. Objectives of the study

1. To assess whether the Blesbokspruit wetland is effectively providing ecosystem goods and services to neighbouring communities.
2. To determine the human interactions with the Blesbokspruit wetlands as the main drivers of ecosystem change.
3. To use remote sensing and GIS to assess physical changes that occurred on Blesbokspruit wetlands due to interactions with human beings over the period 1998-2015.

1.8.2. Report outline

Following the introductory chapter 1, chapter 2 will consist of the description of the study site of Blesbokspruit wetland including the methods and materials used to gather primary and secondary data in the field. Chapter 3 will focus on the results entailing analysis of data and presentation of the major findings. In chapter 4, the findings of the study and their discussion will be presented.

Chapter 2: Methods and materials

2. Introduction

This chapter outlines the materials and methods used to gather data used to achieve the study objectives. The Blesbokspruit study site will be described in terms of its geographical location and ecological status. Data collection techniques that were employed in the field will also be described and justified. In particular, the methods involved semi-structured interviews, direct field observations and participant observations. Remote sensing and GIS technologies will also be discussed as data gathering method used during land use classification.

2.1. Study site

The study was conducted in the Gauteng Province of South Africa, at Blesbokspruit wetland which is a peri-urban wetland (Figure 2.1). The upstream part of the wetland is at Putfontein (26°7'00"S; 28°24'00"E) where it can be described as being in a fairly pristine condition with insignificant alteration by human activity (King *et al*., 2005). From there it stretches for a distance of about 21 km while covering an area of approximately 1858 km^2 (du Plessis *et al*., 2014). The delineation of the study area ends at the R42 road, the location of the Marievale Bird Sanctuary (26°21'00"S; 28°30'00"E) near Nigel, which is conserved by the Department of Agriculture and Rural Development. The Blesbokspruit wetland is surrounded by five towns in the East Rand region; Springs, Boksburg, Benoni, Brakpan and Nigel, and enclosed by large areas of formal and informal urban developments (du Plessis *et al*., 2014; Ambani and Annegarn, 2015). The wetland covers approximately 45% of the Putfontein catchment. Blesbokspruit wetland is a permanently flooded and reed-dominated wetland whose reed beds are probably supported by its nutrient-rich eutrophic status (South African Wetlands Programme, 1999). It could also be described as a non-forested peatland that has freshwater marshes and swamps on inorganic soils, comprising emergent vegetation in waterlogged conditions most of the growing season (South African Wetlands Programme, 1999; Ramsar, 2013; Ollis *et al*., 2015). Figure 2.1 below is showing the position of the wetland's catchment relative to the South African provincial map.

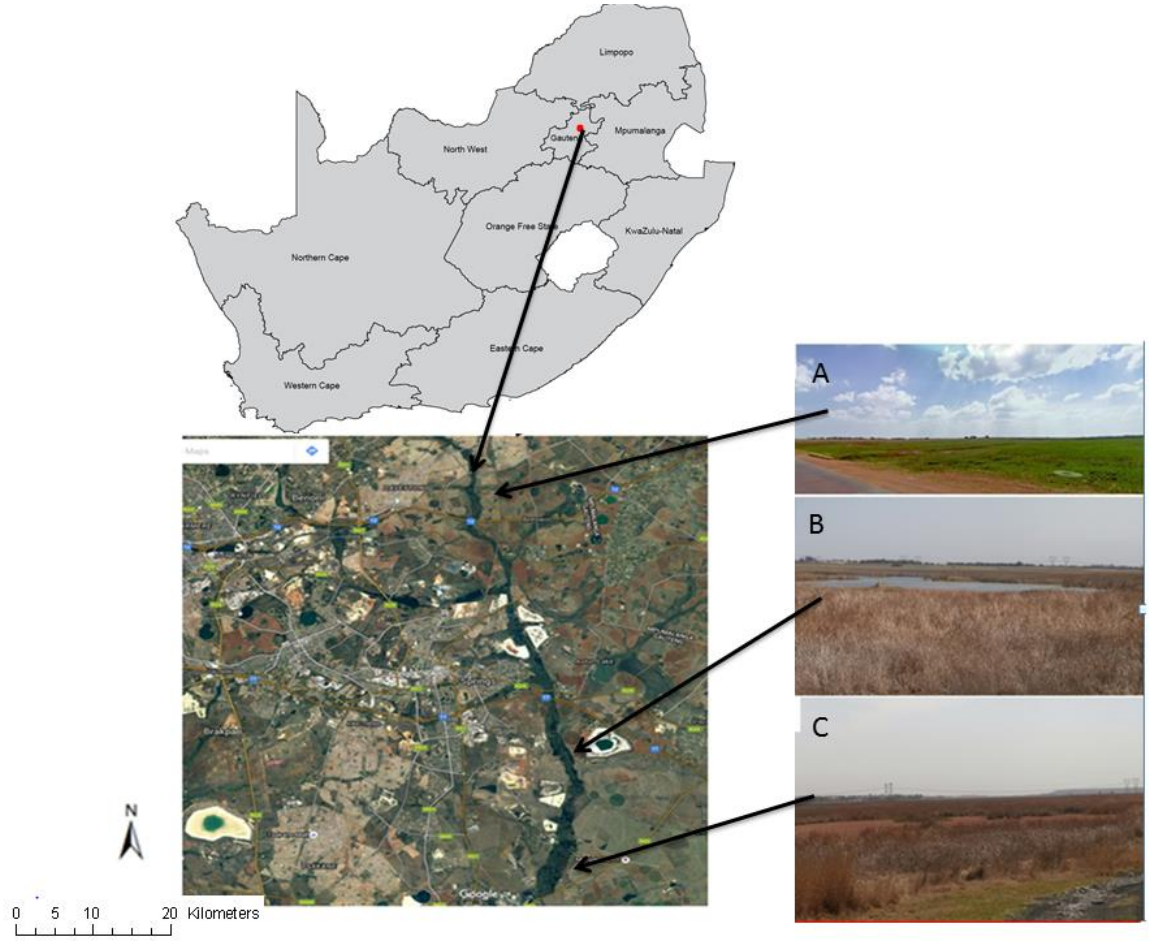


Figure 2.1. Map showing the study site, Blesbokspruit wetland catchment area in Gauteng, South Africa (Source: Google Earth); (A), the upper catchment of the wetland in a near pristine condition (B), the middle part of the wetland without water pollution (C), and the lower part of the wetland near Marievale affected by water pollution. Images A, B and C were taken during fieldwork of this study (June, 2015).

The development of Blesbokspruit wetland is linked to anthropogenic activities that took place due to the discovery of gold in the Witwatersrand in the 1930s. As mining operations were developed, a number of embankments were built across the Blesbokspruit for roads and pipelines, rock dumps and slime dams were built to store mine waste (Haskins, 1998). In 1995, what was once a stream was turned into a wetland as mines within the catchment pumped out excess underground water and discharged it into the stream as a measure to prevent underground flooding, thereby creating large flooded areas but with shallow water levels (de Fontaine, 2013; Ambani and Annegarn, 2015). The wetland can therefore be termed anthropogenic in part; in other areas it can be termed a floodplain whose flooding fluctuates seasonally especially following closure of some of the mines within the catchment.

Since October 1986, Blesbokspruit wetland was designated a Ramsar site (Ramsar, 2013). This gives the wetland international status as a conservation site according to the Ramsar Convention of 1971 (Haskins, 1998; Ambani, 2013). The "mission of the convention is to promote the conservation and sustainable use of all wetlands through local and national actions as well as international cooperation, as a contribution towards achieving wider sustainable development" (Ramsar, 2013). The wetland is also a tributary of the Vaal River which supplies portable water to the highly industrialised and populated Gauteng province (Ambani, 2013). The wetland is home to 250 water birds species while it is a biodiversity hub with some species being in South Africa Red Data Book (du Plessis *et al*., 2014). In terms of water quality, the Blesbokspruit catchment has been deteriorating rapidly due to surrounding socio-economic activities, especially mining (du Plessis *et al*., 2014). In 1996, the wetland was placed on the Montreux Record (Ambani and Annegarn, 2015), which is a global list of ecologically threatened wetlands (Swanepoel, 2009). Since then, a number of stakeholders have been trying to bring about change of this status. For example, a study by Ambani and Annegarn (2015) considered surface water quality of the Blesbokspruit wetland which revealed that, after the underground mine-water pumping operations stopped, mineralisation of the Blesbokspruit showed a noticeable stepwise decrease as a result of the closure of the pulping plant at Sappi Enstra paper mill in Springs, and the cessation of mining operations by Grootvlei Mine in 2011. The closure of the mine and paper plant meant a reduction in pollutants being discharged into the Blesbokspruit water system (Department of Water Affairs, 2013).

It is therefore against this background that this study focuses on assessing what ecosystem services the Blesbokspruit wetland still provides. It is important to find out if people are fully benefiting by having full access to the ecosystem goods and services offered by the wetland, especially in those areas where it is under conservation management by external authorities. Most community members are non-skilled labourers who seek employment in nearby commercial farms and industries. The residential areas are mixed and thus reflect the socio-economic differences of the community. There is a formal housing section surrounded by informal settlements developing adjacent to the wetland. Other stakeholders within the Blesbokspruit wetland catchment are private landowners practicing commercial agricultural activities and recreational activities such as game ranging (Ambani, 2013). In terms of ethnicity, there is a diversity of South African languages, with some foreign nationals from Mozambique and Zimbabwe. Almost all the East Rand townships in Gauteng Province are

surrounded by informal settlements, revealing ongoing social issues of homelessness coupled with the failure by many local governments to provide proper housing for the increasing urban population (Malinga, 2000). It is therefore, necessary to conserve wetland ecosystems that provide goods and services that are beneficial to people in the context of current socio-economic challenges.

2.2. Data gathering methods

The research design was a semi-qualitative study in which an investigation of an existing phenomenon is carried out within its real-life context, and in which multiple sources of evidence were used to substantiate the observed patterns (Kohlbacher, 2005). The principle of case study research methods is triangulation, which is the art of making use of more than one technique for data gathering for the purpose of ensuring research validity (Johansson, 2003). The use of research triangulation was found to be essential; it was very helpful in offsetting some expected limitations by providing complementary and supplementary information (Adekola et al., 2008). Data acquisition was achieved by a combination of methods such as document reviews, interviews, direct observation, targeting different sources of relevant information.

2.2.1.1. Semi-structured interviews and questionnaire use

Semi-structured interviews consist of a variety of key questions which would assist in defining the themes to be explored, while also allowing the interviewer or interviewee room to diverge where more clarity is required (Gill et al., 2008). A total number of 34 household members from the surrounding communities were randomly interviewed. This allowed any individuals working on the wetland an equal opportunity to be selected as part of the sample. Of these, 18 were from the upper catchment near Putfontein, and 16 from the lower catchment near Marievale. Interview questions were structured to complement a questionnaire and were administered concurrently. The questionnaire was designed to gather data on the demographic and socio-economic attributes of the respondents. This included the number of years respondents have been resident in the community, their access to the wetland as well as their opinions on which services they valued most. Semi-random sampling of the respondents was employed based on their willingness to talk to the researcher. In order to gather enough information, the first day was a ground truthing day during which the researcher familiarised themselves with the two study sites and the catchment in before doing any interviews or questionnaire administration. Three more visits per site were then made to

the different households at Putfontein and Marievale, participants were those who interacted with different parts of the wetland. Semi-structured interviews in this case proved to be most appropriate because of the variety of statuses of the respondents (Appendix 1). The researcher had the ability to rephrase a question in a manner that would suit the different respondents.

A semi-structured interview may provide a more relaxed sense of feeling in the informant during collection of information; and individual respondents might feel more comfortable having an open conversation than giving out personal information on a questionnaire (Woods, 2011). Semi-structured interviews could be made up of a number of questions in order to assist in the definition of focal areas while also allowing the interviewer or interviewee a little divergence so that a response could be pursued fully until satisfying details are obtained (Reeves *et al*., 2008). This approach is also quite flexible, allowing for the identification or clarification of information that is crucial to respondents which may have not been considered as initially appropriate (Gill *et al*., 2008). However, the limitation that this approach had during the study was the issue of language barrier. To overcome this limitation, an interpreter was engaged to translate from English to the local languages used by respondents. Interviews were not recorded. The researcher wrote notes, highlighting the main points made by the respondents.

Prior telephonic notice was given to a conservation officer and the reserve manager at Marievale Bird Sanctuary, before interviewing them as key informants. They were considered for these roles because they offered both general and more advanced knowledge in terms of peoples' interactions with Blesbokspruit wetland, as well as conservation concerns. The reserve manager was a source of in-depth knowledge about the dynamics of management plans and status of the Blesbokspruit wetland, such as the Montreux Record.

Written notes were made while the interviews were being conducted and where necessary, photos showing the respondents interacting with the wetland were taken on the individual copy of questionnaire per head basis. Thus, notes were recorded on separate questionnaires consisting of open ended as well as closed questions with the information of each interviewee per encounter included. This approach allowed a careful management of the sample size and the diversity of information as well is its classification to determine the patterns. The responses were categorised according to the key questions, while each respondent's questionnaire was coded; P1-P18 for Putfontein respondents, and M1-M16 for Marievale

respondents. The number of respondents per category were totalised to be used as the data to be presented from the questionnaires and semi interviews.

2.2.1.2. Direct field observations

Direct field observations were also employed to document evidence on the impacts of interactions between people and Blesbokspruit wetland (Whitehead, 2005). Visits to the sites were done during four different week days and one weekend. These visits took place from mid-morning to late afternoon to allow the researcher to be at the sites at the times when most people carry out their daily activities. One of the research objectives was to identify drivers of environmental change on the wetland and direct observations allowed collection of accurate data. The researcher documented the different activities undertaken by local people on the wetland at both sites by making field notes for later reference as well as in the form of photography. Direct observations allowed the researcher to gather more realistic data because it was possible to capture some of the details that the respondents might have omitted during interviews. Therefore, this method has been used as a supplementary technique to the interview approaches. Sometimes during fieldwork, a researcher may incidentally get answers to unanticipated questions; and during observations the mind to come up with such questions (Whitehead, 2005). As a data gathering approach, direct observation method is popular and it has been used in several studies as a data collection instrument involving people, processes, or cultures particularly in qualitative research (Kawulich, 2005). Written notes were also made to back up the photographic evidence. All photos showing people were taken with their consent. Photographs also played a role of being a data gathering technique because they represent visual and permanent evidence especially for instances where textual data only may not give a fully-detailed description of a phenomenon (Patton, 2002). Using photography in research is essential in the sense that photos enhance interpretation of what might have been said in an interview (Schwartz, 1989). Permission was first granted to the researcher before photographing took place.

2.2.2 Deriving land use/land cover classifications using Landsat images

Research in environmental change often focuses on evaluation of variables within a Geographic Information System (GIS) (Schlagel and Newton, 1996). By definition, GIS is a system of computer hardware and software that can be used to capture, store, retrieve, manipulate, analyse, and display geographically referenced spatial data to assist in the management of natural resources (Mallupattu *et al*., 2013). GIS has been used in combination

with Remote Sensing (RS) to assess land cover change (Xiao *et al*., 2006). In addition, RS can provide large amount of data of the whole earth while GIS is capable of analysing huge quantities of data in a short period of time (Patra, 2011). GIS and RS data have been used as the effective tools to monitor wetland distribution area and spatial-temporal dynamics because they provide information on surrounding land use and their changes over time (Ghobadi *et al*., 2012). Since traditional wetland ground surveys may require a lot of time and resources, remote sensing imagery can therefore be a time and cost effective alternative especially in developing countries since they operate under minimal and strict budgets (Sarkar and Jain, 2008). The data on wetland distribution, land use, and wetland losses is limitedly available (Droj, 2008; Allen *et al*., 2011). Murungweni (2013) noted that, as a tool to assess changes on wetlands, GIS is capable of overlaying themes from different time periods to produce a detailed description of land use change. It is also possible to monitor wetland coverage changes by comparing colour infrared photographs with other imagery from different time periods (Sarkar and Jain, 2008). Therefore, GIS and RS make it possible to detect if there are any changes in size, vegetation cover or land use at or around the Blesbokspruit wetland, and thus help identify the main possible drivers of the observed changes and their impacts on the wetland.

A classification of land use/land cover was constructed from Landsat TM 5 images acquired for the years 1998, 2004, 2009 and 2015, which were downloaded from the USGS website. Pre-processing of the images involved radiometric calibration for the purposes of compensating for errors from sensor defects, variations in scan angle as well as noise so that the images represented true spectral radiance at the sensor. Atmospheric correction was then done using FLAASH with the images cropped to the region of interest.

A number of approaches to the classifications of the Landsat images were pursued, including unsupervised and supervised methods, but the heterogeneity in the land surface produced unsatisfactory classifications. The final classifications were derived by digitising polygons over homogeneous features in the Landsat images using colour, tone and texture changes to define boundaries. To confirm and interpret the Landsat images, prior ground-truthing was done by taking transect walks along the catchment area of the wetland. For each of the predetermined land use/land cover types, ENVI 5.3 was used for training sample selection by delimiting polygons around the representative sites to minimise confusion on the final map output (Butt *et al*., 2015). Using the maximum likelihood supervised method, the catchment

was classified into 10 land use/land cover classes, namely wetlands, croplands, residential, roads, mining areas, industrial, water bodies, woodlands, open grasslands, and bare soil. Once all polygons had been identified, the classification was repeatedly processed to remove slivers and overlaps with a final step to calculate areas for each class of land use using ENVI 5.3. A confusion matrix was then used to calculate the percentage change for each of the 10 selected land use classes for the period 1998-2015, based on the ground truth region of interest.

Chapter 3: Results and data analyses

3. Introduction

The focus of this chapter is to present all the data collected to determine whether the communities surrounding the Blesbokspruit wetland are benefiting from any ecosystem goods and services that it is providing. This will include data on participants from the two study sites, their responses to the key questions, results from the researcher's direct and participant observations, as well as the overall opinions of the interviewees regarding the importance of the Blesbokspruit wetland. Data obtained through remote sensing and GIS will also be presented for analysis.

3.1. Sample description

The respondents' backgrounds were derived from the data collected through a questionnaire and semi structured interviews and field observations at both sites. The average size of the families ranged from 4 to 8 individuals in a single household. In terms of their gender, more women than men were found to be carrying out economic activities on the wetland, especially at Putfontein. Of the total respondents (N = 34; Table 3.1), 19 were females. The socio-economic background such as education level and employment status of respondents was also an influence on whether people depended on the wetland for livelihood support.

3.2 Interviewing the communities along the Blesbokspruit wetland

A summary of the responses to key questions which were used during interview sessions is provided. It was revealed from the responses that acquiring a portion of land on the wetland was on the basis of one having stayed in the local area for a reasonable time period. One of the respondents from Putfontein, P5, revealed that "I have been staying here long enough, so I decided to supplement food at home by doing farming here, we don't pay for this land you know'. The wetland is freely accessed by the public in those areas where it is not fenced off as private property. A woman respondent, P15, who was found on her plot preparing it for the planting season, gave the need for food security in the home as her motivation to take up wetland farming: "I am not educated, but I have children to feed. God gave me hands, I will use them, at least if I start planting now, by December I will have something to put on the table". Socio-environmental education naturally takes place among the crop farmers as was revealed by one respondent, P13, "We start digging to prepare the fields early so that by the

time rain comes our crops have already germinated and growing. They are not affected by too much water. We also leave a way for the water to flow through and protect the crops". It also came out from talking to the community members that the wetland is a safety net for the needy households, M9 for instance noted that, "instead of stealing, we grow our own food and make an extra income from selling the fresh vegetables". The official name of the wetland, Blesbokspruit, is not popular among the communities at all they only refer to it as a wetland in their vernacular languages: (*ixhaphozi*-Zulu; *mmgxobholo*-Xhosa, *mohlaka*-Pedi; *mokhoabo*-Sotho and *mogobeng*-Tswana). In its upper catchment the wetland is easily identified as it is a floodplain along a stream, while at the site in the lower catchment, Marievale reserve is well known. About whether access to the wetland to the wetland by the members of the community, the reserve manager at Marievale pointed out that, "the fence does not mean total access denial at all. People from the community could still get a permit from the Department of Agriculture to come inside and harvest grass for thatching or mulching". However it was also indicated from interviews with the reserve manager that although it is free to access the wetland at the bird reserve, certain rules have to be followed or else he chases the rule breakers away. In particular while inside the reserve, people have to observe a certain level of noise or else birds will fly away from the viewing spots.

Table 3.1. Description of the respondents included in questionnaire analysis during this study (N= 34)

	Site A (Putfontein)	**Site B (near Marievale)**
Gender		
Male	7	8
Female	11	8
Level of education		
Matric	5	7
No matric	13	9
Age		
18-25	6	3
26-40	6	11
41 and above	6	2
Occupation		
Formally employed	1	6
Unemployed	17	10
Marital status		
Married	8	8
Single	10	8

3.2.1 Overview of responses about ecological services

The questionnaire and semi structured interviews were used to gather data on questions such as, whether respondents were happy with the status of the wetland, to which all 34 answered,

yes. Reasons that were given for that response ranged from the wetland being a source of water and grazing pasture for livestock such as cattle and goats, by 18 respondents, to it providing moist and fertile soils for crop farming for crops such as maize, potatoes, pumpkins, beans and tomatoes (22 respondents), 8 respondents revealed that they were able to grow enough to feed their families while they had surplus to sell and supplement other household needs. The benefits obtained from the wetland also became the reasons why people visited the wetland, at Marievale, recreation services were realised by 8 respondents who appreciated the scenic beauty of the wetland and went there for picnics or walks. The respondents were also asked if they believed the wetland supported livelihood strategies, all the 34 respondents noted that by being a source of water, fertile soils and being freely accessed, the wetland was playing that role. In particular, traditionally, having a herd of cattle or other livestock gives one a certain respect in the local community, 12 of the respondents were owners of herds of livestock, (cattle, goats or sheep).

It was also revealed through interviews and questionnaires that the local communities are aware of what kind of threats the wetland is facing. At Putfontein, conversion of more land for crop farming was noted by 9 respondents, with 5 of them, P1; P12, a Mozambican man; P14, 15, and P18, worried about land shortage as more people compete for the available land. At Marievale, dumping of garbage on the wetland and change of colour on the water surface were noted by 5 and 8 respondents respectively. Responding to the questionnaire on what the community could do to conserve Blesbokspruit wetland, it was indicated that quite a number (16) have witnessed an outbreak of a veld fire because they mentioned avoiding outbreaks as a conservation strategy.

3.2.2 Key informants' responses to key interviews and questionnaires

Two officials, a conservation officer and a reserve manager, were consulted as key informants during data gathering for the study. The officer had been working at the site for 12 years while the reserve manager had 6 years' experience working at the Marievale reserve. Asked about the benefits they witnessed the communities gaining from the wetland, both officials mentioned the ability of the wetland to support agriculture (crop farming and livestock grazing), availability of water, and biodiversity support and recreation facilities as the main ones. Harvesting of wetland products such as reeds and grasses were said to be permitted provided the bearer obtained a licence from the Department of Rural Development and Agriculture. Both officials also emphasised that the harvesting is free of charge.

The officials also both agreed that there were notable changes to the quality of the surface water in the wetland. The existence of both subsistence and commercial farmers and other industrial and mining activities within the wetland's catchment was given as the main factor compromising water quality. Asked whether enough measures have been put in place as conservation strategies, both officials agreed and mentioned the existence of the Blesbokspruit Forum. This is a group of individuals who are lobbying for the delisting of the wetland from the Montreux List of ecologically threatened wetlands. Activities such as physical inspections are done along the wetland and its catchment and public awareness campaigns were described as some of the efforts being made.

Another response obtained from the officials was on what the surrounding community could do to help conserve the wetland. The conservation officer mentioned the 'polluter pays' principle because source polluters were well known to them. In agreement, the reserve manager believed it was the mining and farming activities within the Blesbokspruit catchment that compromised the surface water within the wetland. Awareness campaigns were agreed upon as the best strategy to save the wetland from further degradation.

3.2.3 Peoples' opinions on the importance of conserving Blesbokspruit wetland

During the interviews, respondents were asked to outline the benefits which they understood to be offered by the Blesbokspruit wetland. Figure 3.1 shows the different perceptions held by the people in the surrounding communities on which benefits they get from the Blesbokspruit wetland.

All, of the respondents (N=34) agreed that the wetland supported human livelihoods in one way or another. The provisioning services associated with the wetland being a source of water and grazing pastures for livestock were recognised as the most important benefits (30 respondents). The ability of the wetland to provide rich soils for crop production, thus becoming a source of human livelihoods was ranked second (29 respondents), followed by recreation services and aesthetic values (14 respondents). The fact that the wetland plays an important role as breeding grounds for aquatic life such as fish and other small animals was confirmed by 10 of the respondents. In terms of direct provisioning for food, 6 respondents valued the wetland for that service, 2 and 4 from Putfontein and Marievale respectively. Overall, the community at Putfontein benefit more from direct services from the wetland such as farming activities, while at Marievale more people than at Putfontein value the wetland's indirect services such support of biodiversity and recreation. This difference in the type of services obtained is also largely due to more open access to the wetland at Putfontein, while the security fence at Marievale restricts access to directly utilise the wetland.

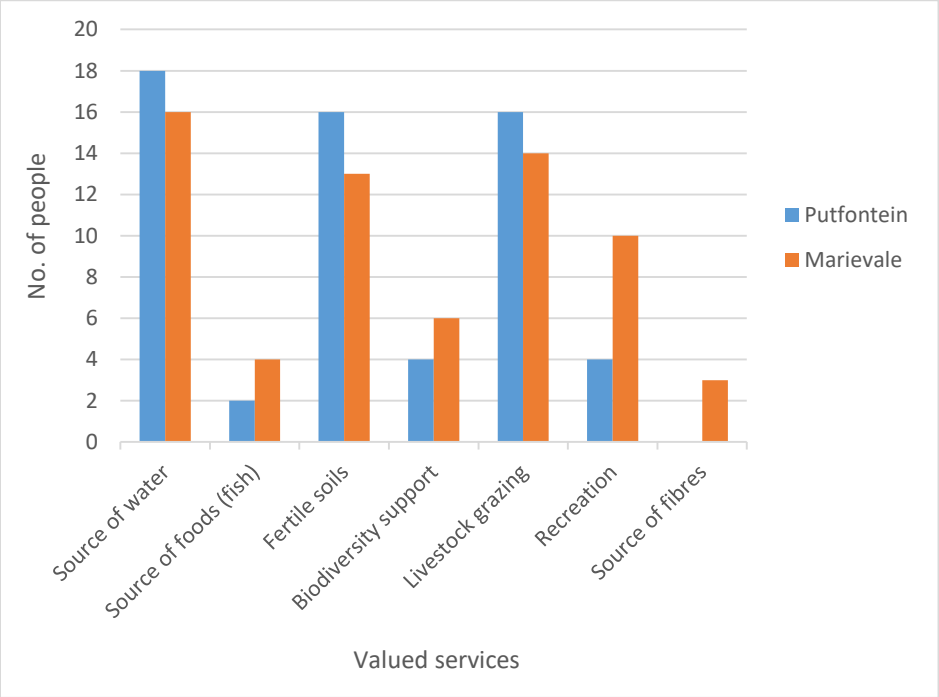


Figure 3.1. The direct ecosystem services valued by the Blesbokspruit community.

3.2.4 Community management of Blesbokspruit catchment

The interviews and questionnaire responses showed that there is no structured communal effort aimed at ensuring the sustainable use of the wetland by those who interact with it. Despite that, different suggestions by individuals reflected that, although at a small scale,

wetland users were aware of that they could do to conserve the integrity of this ecosystem. Avoiding outbreaks of veld fires and not ploughing too close to the water channel were highlighted as conservation strategies. At Marievale, the conservation officer mentioned the Blesbokspruit forum as a platform where concerned stakeholders meet quarterly to discuss the state of the catchment. The forum is made up of different stakeholders from the government, local authorities, the private sector as well as the public at large. The role of the forum is mainly to advocate for the sustainable use and management of the whole catchment, for example alerting responsible authorities in the event of an outbreak of a veld fire or when there is dumping on the wetland. The fact that no community members mentioned this forum may suggest that it is not very effective or does not communicate very well.

3.2.5. Direct observation - Observed ecosystem goods and services

The site visits to the wetland revealed that there are several ecosystem goods and services that Blesbokspruit wetland is providing to the surrounding communities. At both sites, neighbouring communities benefitted from water supply for drinking, agricultural irrigation, livestock drinking water, grazing grounds and fertile soils for crop production. Direct food products obtained by Marievale communities are restricted because the wetland is under national and international protection at this site. Neither fishing nor hunting within the reserve is allowed, however where there is free access, respondents practise fishing. At its upper catchment at Putfontein young boys were observed making an attempt to fish while others acknowledged that they hunted for small mammals in the wetland.

The transect walks and direct observations, showed the floodplain nature of the wetland, and therefore it may also offer climate regulating services such as flood attenuation during the rainy seasons. The gentle slope of the wetland also helps to reducing water velocity after heavy storms. The wetland vegetation may be playing a huge role in absorbing pollutant chemicals in the water thereby purifying it. For example at Marievale, as soon as the water leaves the wetland, women were seen doing for domestic laundry downstream (field observation). Carbon sequestration takes place as the wetland vegetation and peat soils absorb carbon dioxide through the process of photosynthesis as well as sedimentation. Consequently, the fertile soils are also suitable for crop production, such as been noted at Putfontein (Figure 3.2A). The Blesbokspruit wetland also supports biodiversity by providing a habitat to aquatic life as well as foraging grounds for several small mammals. The wetland also offers rich grazing grounds for livestock such as cattle, sheep and goats at both

Putfontein and Marievale (Figure 3.2B). Also, Marievale Bird Sanctuary supports bird diversity serving as a recreational facility for bird watchers (Figure 3.2C). However, because of the fencing, within the reserve the wetland does not support subsistence agricultural activities at Marievale as opposed to those observed at the upper catchment at Putfontein.



Figure 3.2. Observed ecosystem goods and services available at Blesbokspruit wetland: A - Fertile soils for crop production, B - Grazing pastures for livestock, C - Provision of water and habitat for aquatic life, D - Recreation functions such as natural swimming pools for local children.

Recreation services derived from the Blesbokspruit wetland at Putfontein included a football playground for the children, especially the boys who also look after the livestock. From interview conversations and direct field observations, the young boys enjoy playing in the lush open soft grounds of the wetland. Other activities that the young boys enjoy are swimming in some of the ponds (Figure 3.2D). Marievale as a bird reserve offers recreational and aesthetic services to the surrounding community.

3.3. Land use patterns and change detection at Blesbokspruit wetland

To determine land use patterns and spatial changes within Blesbokspruit wetland catchment, remotely sensed data using Geographical Information System was generated. The land use

classifications were used to assess which activities were responsible for the spatial changes which may also have been threats to the integrity of this natural ecosystem. Figure 3.3 is showing remotely sensed imagery for the years 1998, 2004, 2009 and 2015, showing the land uses within the Blesbokspruit catchment.

Using the remotely sensed images for the years 1998, 2004, 2009 and 2015, Table 3.2 shows the total area each classified land use covered. The total land surface covered by the catchment generated from the satellite images is 95 484 ha. The land cover classified as the wetland was approximately 11 312 ha in 1998 and decreased to 4681 ha in 2004, however the area increased to 13 683 ha by 2009 with a small decrease to 12 465 ha by 2015. In 1998 the open grasslands covered the biggest area of the wetland and its catchment of 20 433 ha, followed by croplands covering approximately 19 866 ha, with land used for industrial and residential purposes covering 14 912 ha and 13 018 ha respectively. There was a notable change in the area covered by the different land use classes as reflected by both the images (Figure 3.3 and Table 3.2). The open grasslands and woodlands showed significant reduction in size as compared to other land uses, while residential areas and roads have shown a clear increase in their size from 13 018 ha to 37 546 ha, and 3 094 ha to 11 989 ha for the years 1998 and 2015 respectively. There has been some fluctuation in terms of the total size of the wetland itself from 1998-2004, 2009- 2015. In 1998 the wetland covered an estimated 11 312 ha which decreased to 4 681 ha in 2004 and rose to 13 683 ha in 2009 and slightly reduced to 12 465 ha in 2015.

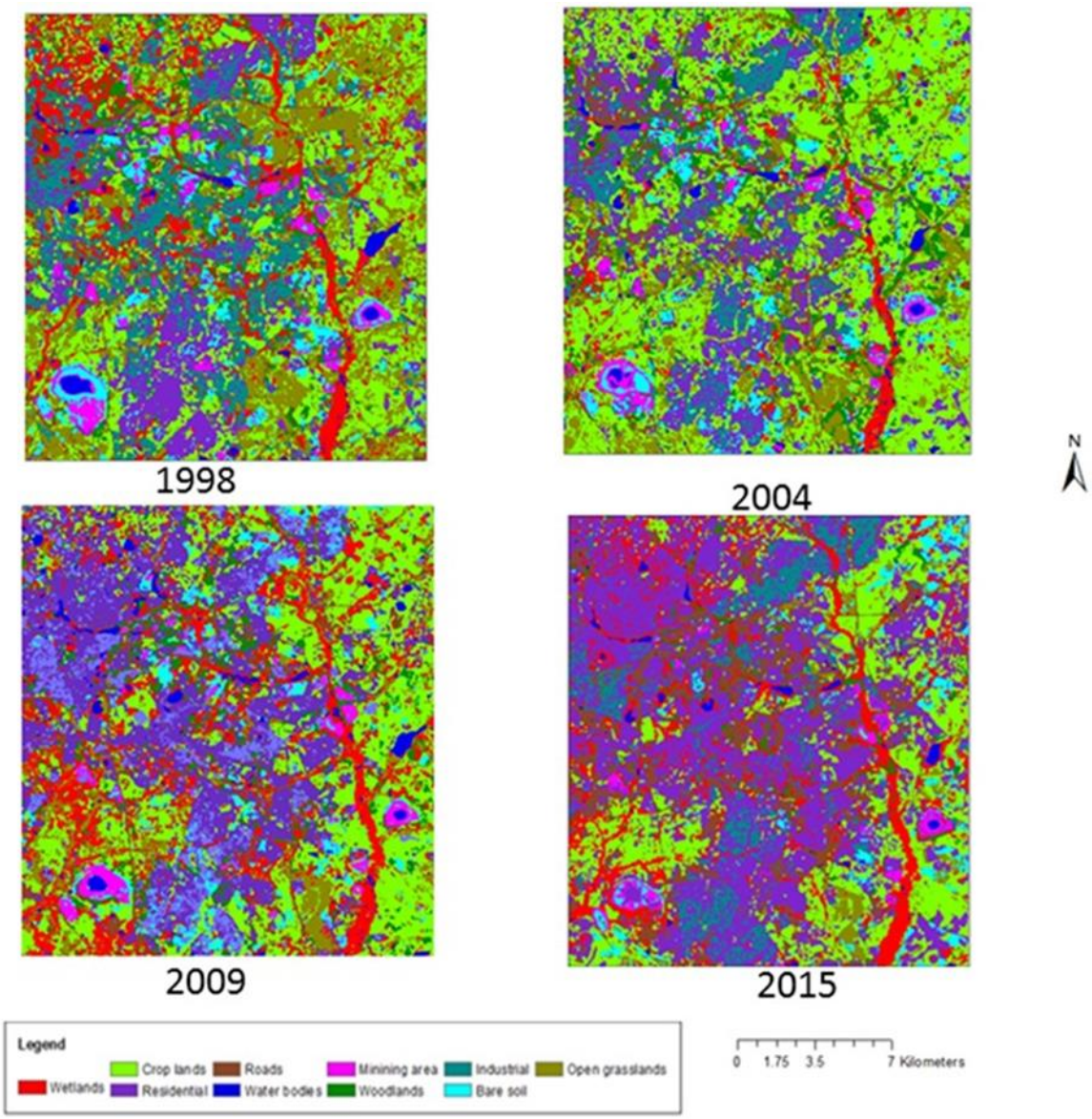


Figure 3.3. Showing classified land uses within the Blesbokspruit wetland catchment derived from remotely sensed images for the years 1998, 2004, 2009 and 2015 (prepared by Rueben Lembani).

Table 3.2. Showing area in hectares covered by different land uses within the Blesbokspruit catchment for the years 1998, 2004, 2009 and 2015.

	1998	2004	2009	2015
Land cover				
Wetlands	11312,73	4681,08	13683,6	12465
Croplands	19866,51	33504,12	23208,12	18023,4
Residential	13018,14	15574,68	25681,95	37546,74
Roads	3904,02	5149,8	5981,49	11989,35
water bodies	1218,06	1200,42	1855,89	746,1
Mining area	2534,67	2144,25	1882,08	1112,58
Woodlands	4042,35	7442,91	5354,55	1684,17
Industrial	14912,37	8180,91	5945,31	6318
Bare soil/land	4241,88	4334,31	3756,24	3040,92
Open grassland	20433,51	13271,76	8135,01	2557,98
Total Area (ha)	95484,24	95484,24	95484,24	95484,24

Table 3.3. Showing % change for landuse classes between periods 1998-2004; 2004-2009; 2009-2015 and overall from 1998-2015.

Land cover	**% Changes**			
	1998-2004	**2004-2009**	**2009-2015**	**Total (1998-2015)**
Wetlands	-7,039539	9,522535	-1,276232	1,206764
Croplands	14,376833	-10,877188	-5,429922	-1,930277
Residential	2,677447	8,766505	14,244685	25,688637
Roads	1,304697	0,871023	6,291991	8,467711
Water bodies	-0,018468	0,686469	-1,162276	-0,494275
Mining area	-0,408884	-0,274569	0,805892	-1,489345
Woodlands	3,561347	-2,187125	-3,843964	-2,469742
Industrial	-7,049812	-0,522558	-1,428455	-9,000825
Bare soil	0,096802	-0,605409	-0,74915	-1,257757
Open grasslands	-7,500452	-5,379684	-5,840786	-18,720922

Of all the 10 classified land uses within the Blesbokspruit catchment, residential areas showed a steady increase in the percentage of total area they covered. Its total increase as a percentage from 1998-2015 was 25,6% followed by roads which had increased by 8,5% in 2015. The increase in human-induced land cover may have attributed to negative changes in the physical classified land uses such as open grasslands and woodlands which showed a negative 9% and 2,5% change, respectively, between the same time period. A significant negative change that may have been influenced by growth of residential areas was noted on land used by industries, with a 9% reduction.

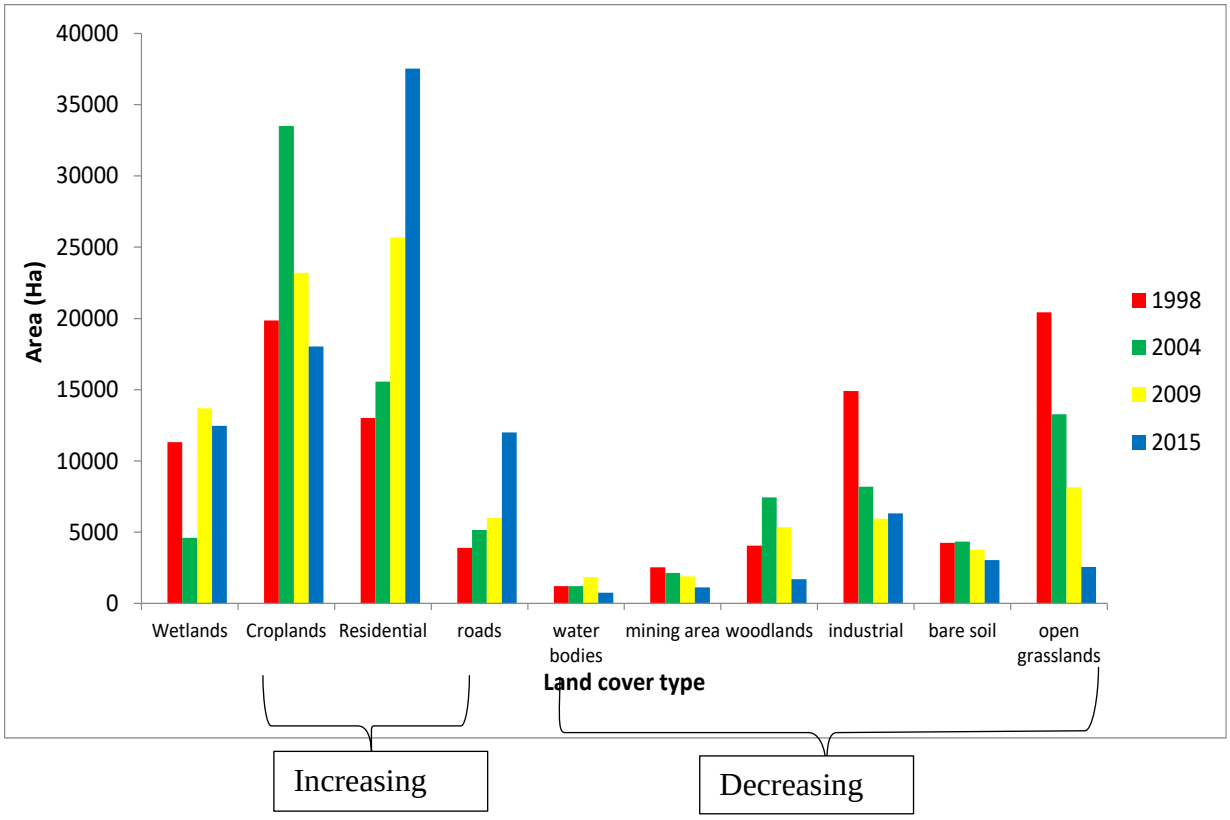


Figure 3.4. Bar graph showing the classified land uses within Besbokspruit wetland catchment and the area they covered in (ha) for the years 1998, 2004, 2009 and 2015.

The land use and land cover changes taking place within the Blesbokspruit wetland catchment for the years 1998, 2004, 2009 and 2015 are presented in Figure 3.4. There is a clear indication that open grasslands and industrial activities covered more land area compared to the other classified land uses. In 2004, croplands dominated as the highest landuse in terms of total area coverage. Land cover such as open grasslands and bare soils as well as mining activities decreased in total area from 2004 until 2015. Residential areas as

well as roads showed an increase throughout. The size in total land area for the wetland itself showed a fluctuation for the period of study, with a notable decrease for the year 2004.

3.3.1 Observed threats to the integrity of the Blesbokspruit wetland

The anthropogenic activities that are threatening the wetland and have been the main drivers of change to Blesbokspruit wetland from classified RS images and GIS processed data are shown on Figures 3.3 and 3.4 and Table 3.2. Direct observation from transect walks at the study sites are shown in Figure 3.5, to highlight some of the threats to the integrity and health of the wetland. It was noted that land uses such as residential, roads, industrial and croplands has been causing change within the wetland's catchment. Urban expansion is negatively impacting the wetland in the sense that as more people seek cheaper accommodation, open spaces such as those at the edges of the wetland are targeted (Figure 3.5A).



Figure 3.5. Observed threats at the two study sites (A, B, D at Putfontein, and C, at Marievale) along the Blesbokspruit wetland visited during the study: A - Encroachment by human settlement, B - Conversion of wetland to agricultural land, C - Eutrophication and D - Exposure of land to erosion after veld fires (Source, field observations).

Encroachment on to the wetland by subsistence farmers and also housing were observed, especially at its upper catchment at Putfontein (Figure 3.5A, B). Land uses associated with human settlement such as residential areas showed an increase while croplands fluctuated. Eutrophication in open water bodies such as natural ponds (Figure 3.5C) due to activities such as solid waste dumping as well as discharge of sewerage by several industries along the wetland was also documented, while direct observations revealed that solid waste dumping on the wetland takes place at both Putfontein and Marievale. Evidence of prior veld-fires (Figure 3.5D) was also noted to be a problem along the wetland, thereby compromising its integrity.

There were some changes in the amount of land used for some activities, which could all be attributed to an increase in human settlements along the Blesbokspruit wetland. Fluctuations were noted on land used for crop production. For instance, the total area for 2009 was 23 208 ha, but has been reduced to 18 023 ha by 2015. Other prominent land use changes associated with expansion of human settlement were changes in open grasslands and woodlands.

Through direct observations, the observed threats were documented at both sites and are listed in Table 3.3. The main threats observed at Putfontein are encroachment onto the wetland by settlements and wetland conversion to agricultural land, followed by veld fires and solid waste dumping. At Marievale, eutrophication, veld fires as well as dumping also pose some threats to the wetland's health.

Table 3.3. Observed threats to the natural integrity of the two study sites at Blesbokspruit wetland

Site A – **Putfontein**	**Site B** – **Marievale**
1. Encroachment by agricultural activities	1. Eutrophication
2. Urban expansion/human settlement	2. Evidence of earlier veld fires
3. Evidence of earlier veld fires	3. Dumping
4. Dumping solid waste	
5. Over-exploitation	
6. Eutrophication in water bodies	

Chapter 4: Discussion and conclusions

4. Introduction

This chapter focuses on the discussion of the results obtained from the analysed data from the interviews, field observations as well as data generated from remotely sensed imagery. Findings from similar studies will be reviewed to contextualise the results of this study. Conclusions reached by the findings will also be drawn to indicate whether Blesbokspruit wetland still offers ecosystem goods and services, despite the documented threats.

4.1. Interview responses and people's opinions on the importance of Blesbokspruit wetland

It was noted that there were more women (19) interacting with the wetland than men (15) as shown on Table 3.1. Aside from sampling bias, more women taking a leading role in wetland utilisation might be due to the fact that traditionally it is the role of the females to prepare meals for the family. Thus when faced with the challenge of food insecurity, women go out of their way to come up with alternatives (Karl, 2009; Asian Development Bank, 2013). One female respondent from Putfontein stated this as the reason she decided to take up wetland crop farming. In a synthesis of reports on gender and food security, FAO (1998) also noted that women in sub-Saharan Africa contributed up to 80% of the labour (e.g. ploughing, sowing, weeding, and fertiliser application) required for food production to meet family consumption requirements, as well as surplus. For Blesbokspruit communities, most households depended on manual labour for crop production while others pool their resources to hire tractors for land preparation. A study on the contribution of wetland agriculture to the farmers' livelihoods in Rwanda by Nabahungu and Visser (2011) found similar results. Due to low socio-economic status such as lower educational levels and being unemployed (Table 3.1), the wetland appears to be a safety net for many respondents, in producing extra food crops such as leafy vegetables, maize and potatoes. Total dependency on wetlands was also realised by Turyahabwe *et al.* (2013) for wetlands in Uganda, where local people use them as a sole source of water and moisture for crop production especially during droughts.

The number of years that a respondent has spent living within the vicinity of the wetland was considered important for their personal viewpoints on the value of the wetland. While some people have been staying in the area for only six months, others have been there for nearly 23

years. The opinions of those respondents who have known the wetland for longest were considered to be quite reliable. For example in Ethiopia, changes in water quality of the wetland was only noted by those who were interacting with the wetland over long time periods (Malatu *et al.*, 2015), while for wetlands in Uganda, Turyahabwe *et al*. (2013) only used data from respondents who had lived within 5 km of the wetland for 24 years.

The two officials at Marievale reserve were considered as key informants on the overall well-being of the Blesbokspruit wetland. Their working experience and social knowledge about the surrounding communities were valuable in this study to corroborate some of the data gathered from community members. Both the conservation officer and reserve manger agreed that the wetland is still providing important ecosystem services to the local people.

According to the questionnaire and interview responses, water use is the most valued service provided by the Blesbokspruit wetland, with 100% of the respondents having that opinion. Similarly, 100% of respondents expressed that water provisioning was the main reason they gave for conserving Mutubuki wetland in Zimbabwe (Zinhiva *et al*., 2014). There are more people valuing direct ecosystem services such as water, fertile soils and grazing grounds than those that consider indirect services like biodiversity support and recreation (Nabahungu and Visser, 2011). In some case studies, communities would usually focus on realising only those services that they directly benefit from. For example, Turyahabwe *et al*. (2013) highlighted water and household food security as the main reasons why value was placed on wetlands in Uganda. It is therefore clear that communities around Blesbokspruit wetland still derive some benefits from the wetland, despite having different opinions on which benefits are available and most valuable.

4.2. Observed ecosystem goods and services at Blesbokspruit wetland

This study has confirmed other findings (e.g. Rebelo *et al*., 2010; Sakataka and Namisiko, 2014) that wetlands provide livelihood support strategies through a range of provisioning, regulating and supporting services. It was observed that Blesbokspruit wetland provides ecosystem goods and services to surrounding communities, despite its being listed as threatened on the Montreux Record (Ambani and Annegarn, 2015). The four categories of ecosystem goods and services presented in the MEA (2005) are provided by Blesbokspruit wetland. These are: provisioning of water and food products; regulating of climate conditions as well as of water quality by wetland plants; supporting of biodiversity; and recreational

services. Of the different goods and services, some benefit human wellbeing directly while others do so indirectly (Turner *et al*., 2008).

4.2.1 Wetland provision of water and fertile soils

The Blesbokspruit wetland is directly providing water and fertile soils for crop farming to the surrounding communities (Figures 3.1, 3.2A). In Uganda, Kakuru *et al*. (2013) carried out a study on economic value of wetland products and services which also revealed that communities located adjacent to wetlands realised higher yields from wetland agriculture as a result of moisture availability during the drier seasons. Furthermore, ongoing fertility restoration of wetland soil comes from sedimentation and siltation from wetland biomass (Lannas and Turpie, 2010; Kakuru *et al*., 2013). This confirms that wetlands can reliably support livelihoods of the surrounding peri-urban communities. A study by Macharia *et al*. (2010) in Kenya confirmed that even in peri-urban settings, wetlands have abundant natural resources which support a variety of economic activities such as farming and fishing. Thus, wetlands perform a crucial function in sustaining human wellbeing and as such should be given priority conservation consideration by stakeholders especially under climate change. It is possible that loss of such water systems may have far-reaching negative impacts both on biodiversity in general, and on downstream human communities whose water systems dependent on catchments such as the Blesbokspruit wetland.

4.2.2 Grazing pastures for livestock

It was noted that the Blesbokspruit wetland is also rich grazing for livestock owned by households both at Putfontein and Marievale (Figure 3.2B). Similarly, a study whereby the value of two contrasting wetlands was compared, one in rural Lesotho highlands and the other in peri-urban Cape Town, South Africa (Lannas and Turpie, 2009), confirmed that wetlands provide grazing and foraging grounds for both domestic cattle and wildlife during seasons when surrounding grasslands become dry. Corroborative results on wetlands, providing attractive grazing grounds for local livestock resources, were realised from a study on two wetlands in Kenya (Macharia *et al*., 2010). By virtue of providing a rich and reliable grazing pasture for the livestock, the Blesbokspruit wetland is therefore directly contributing to the socio-economic wellbeing of surrounding households, because the livestock can either be slaughtered to provide food or could be sold.

4.2.3 Support of biodiversity

The Blesbokspruit wetland also support plant species (reeds; *Typha* and *Phragmites*, sedges and bulrushes; *Typha latifolia*) that can be harvested for fibres and building materials (Haskins, 1998). Plants with medicinal properties (*Aloe ecklonis* and *Erythrina zeyheri*) are also part of the biodiversity of this wetland. The wetland supports different species of fish, amphibians and reptiles, rodents and crustaceans (Haskins, 1998). These in turn are a source of food to some small mammals and water birds, thereby supporting different food webs. The fact that it supports biodiversity (Figure 3.2C), also gives Blesbokspruit wetland the opportunity to offer recreational, cultural and tourist services within the nature reserve. This has also been noted as one of the reasons why the wetland is of international importance as a Ramsar site (Ambani and Annegarn, 2014). The wetland also becomes a source of livelihood for surrounding communities through utilising fish, small mammals or birds. This is in line with the findings of Shackleton and Shackleton (2004) who showed that 85% of low income groups, especially in rural areas, harvested biological resources. Several ponds are found along the Blesbokspruit wetland, providing a habitat for fish that could be caught to supplement dietary needs (IWMI, 2014; FAO, 2014). In places where there is open access to the wetland, some young boys were doing some net fishing at Putfontein (Figure 3.2D).

The importance of a wetland's direct provisioning of food products has been noted in a number of studies. In Uganda, a study on economic values of wetlands revealed that fish from wetlands provide up to 50% of all animal protein for the local people, while those who feed their livestock realised enhanced milk production, thereby becoming food secure (Kakuru *et al*., 2013). Another study on the economic value of the Zambezi Basin wetlands (Barotse, Zambia; Caprivi, Namibia; Shire, Malawi) also revealed that local communities were highly dependent on wetland biodiversity for livelihood sustenance, with fish providing a source of income as well as nutrition (Turpie *et al*., 1999). It therefore becomes apparent how Blesbokspruit wetland could be playing a crucial role in directly contributing to food security through fertile soils for agriculture as well as direct food resources.

4.3. Major threats and drivers of change in Blesbokspruit wetland

The land use classification from RS images (Figure 3.3), as well as those from direct observations (Figure 3.5), suggests that the main threats facing Blesbokspruit wetland are encroachment by settlements, conversion of wetland to agricultural land, veld fires, solid waste dumping and eutrophication of water bodies. The demand for more land as the urban centres within the catchment have grown (Ambani and Annegarn 2015) has been the driver

for most of the detected land use changes. According to Lamsal *et al*. (2015), population growth and associated anthropogenic interferences have the tendency to deplete resources and reduced the rates of flow of ecosystem services. The attempt by low income groups to make a living, especially where livelihoods depend on natural capital (Shackleton and Shackleton, 2004), may create threats that could trigger loss of ecosystems goods and services (Adekola *et al*., 2008). In Zimbabwe, Zinhiva *et al*. (2014) noted that overexploitation of a rural wetland has led to negative ecological impacts, such as loss of biodiversity as well as socio-economic impacts (through lower yields) to the community. Naturally conversion of wetlands into agricultural lands starts with loss of biodiversity, followed by an exposure of the ground to surface runoff, with less infiltration, and less groundwater recharge, then sedimentation of the wetland. All these processes affect the wetland water table which eventually results in less water available for downstream users, or a complete drying up of the wetland (Zinhiva *et al*., 2014). There was more settlement encroachment (Figure 3.5A) and wetland conversion to agricultural land at Putfontein than at Marievale, which could be attributed to the fact that the lower catchment is protected from public access by the reserve itself, private commercial farms and game reserves (Ambani, 2013).

Data obtained through RS and GIS for this study (Figure 3.3, Table 3.2) also indicate that land use/land cover changes have occurred for the period 1998-2015. Human-related land uses such as croplands, residential areas, roads, industrial and mining have taken up 78% of the total area of the catchment (95 488 ha by 2015) as compared to the same land uses covering 56.7% in 1998. The increase in human interference in the catchment has also led to a decrease in the natural land cover (open grasslands and woodlands). The total land area covered by grasslands was reduced by 88% from 20 433 ha in 1998 to 2 557 ha by 2015, while woodlands show a reduction from 4 042 ha, to 1 684 ha (60%) for the years 1998 and 2015 respectively. It is therefore imperative that further development along the wetland must be done with full considerations of its impacts on the integrity of the wetland, so that ecosystem services (both direct and indirect) are not lost.

Worldwide, agricultural activities pose the greatest threat to the existence of wetlands in their natural state (IWMI, 2014). At both Putfontein and Marievale, direct agricultural activities such as crop farming and cattle grazing (Figure 3.5B, C) may pose the same threat to Blesbokspruit wetland. Adjacent to the wetland, both subsistence and commercial farming

are practiced, with data from RS and GIS (Figure 3.3) indicating that although land under crop production has been showing negative fluctuations, by 2015, approximately 19% of the total area of the catchment was still under crop production. In this case, some of the agricultural land may have been taken up by settlement in the form of housing and roads, because change detection indicates a continuous increase in these two land use classes. Findings by Adekola *et al*. (2008) during their study of the Ga-Mampa wetland, also in South Africa confirmed that agricultural encroachment into the wetland was its major threat, which halved its size between 1996 and 2004. Extreme flooding led to the conversion of a bigger part of the wetland for crop production thereby decreasing its size (International Water Management Institute - IWMI, 2014). In comparison, the difference in the causes of changes in total land area under crop production between Ga-Mampa and Blesbokspruit could be attributed to the former being rural and the latter being surrounded by urban areas. At Marievale, land conversion to crop farming is limited, which may be due to limited access at Marievale by protective fencing, while part of the wetland at Putfontein is openly accessed by the public. Similar observations were reported for wetlands in central Kenya by Macharia *et al*. (2010) and in Nigeria by Ajibola *et al*. (2012). These two studies noted that lack of government intervention to regulate use and management wetlands leads to the overexploitation and degradation of some wetlands. In Rwanda, efforts from the national government to encourage sustainable use of wetlands were noted by Nabahungu and Visser (2011) where zero-grazing is encouraged. Dumping of solid waste, excessive draining of water, encroachment of wetland for commercial and residential needs, overgrazing and illegal wildlife hunting are the main drivers of degradation of the Manguo and Ondiri wetlands, mainly because there is open access to these wetlands by the public and minimal intervention from the government (Macharia *et al*., 2010). This shows that the proximity of any form of settlement to a wetland in many cases may trigger different threats to the integrity of the ecosystem. Therefore, wetland ecosystem protection policies should aim to minimise possible negative impacts and encourage sustainable use of wetlands from the onset, when human activities occur in the vicinity of the wetland.

Water quality on the wetland (Figure 3.5C) may also be compromised by different industrial activities as well as subsistence and commercial agriculture within the catchment, as shown by the RS images and data (Figure 3.3, Table 3.2). Water from the wetland flows to the Suikerbosrand River and later to the Vaal River, which supplies the whole of Gauteng with potable water (Swanepoel, 2009; Ambani, 2013). This is a national challenge because South

Africa is a water-scarce country. Therefore, natural reservoirs such as the Blesbokspruit wetland should be given priority for conservation. In a synthesis on human wellbeing and the reliance on wetland goods and services, the MEA (2005) also notes that degradation and loss of inland wetlands and dependent species has been mainly a result of infrastructure development, land conversion, water abstraction, pollution, overharvesting, and the introduction of invasive alien species. These factors have exerted influence on the change of structure and functions of Blesbokspruit wetland (Ambani and Annegarn, 2015), thereby reducing wetland ecosystem goods and services (Bassi *et al*., 2014).

Evidence of earlier veld fires, for example to rejuvenate grazing pastures (Collins, 2005), were also observed as a threat to the health of Blesbokspruit wetland. Figure 3.5D shows ground that is now partially bare due to a past fire at Putfontein. Although some fires are started accidentally, some are started by the farmers with the intention of rejuvenating grazing pastures for their livestock. As land is stripped of its cover it becomes prone to erosion by wind and rain, leading to wetland siltation and drying out of the wetland during some seasons. Data from RS show a consistent reduction in the total land area classified as woodlands and open grasslands between 1998 and 2015 (Figures 3.3, 3.4). When wetland vegetation is destroyed by fire, it leads to the release of carbon back into the atmosphere which can contribute to global warming (Kotze, 2010).

Veld fires also lead to a loss of habitat for small mammals which may trigger other biodiversity losses. Results from a study on the effects of bushfires on small mammals on wetlands in Ghana revealed that more rodents were captured on unburnt plots than on burnt ones (Attuquayefio and Wuver, 2003). Reduced biodiversity after fire is attributed to lack of food and nesting material which impedes females from breeding (Hogan, 2012), while high temperatures, toxic smoke and lack of oxygen during a fire outbreak can lead to mass deaths or physical impairment (Engstrom, 2010). Loss of biodiversity on the wetland eventually results in diminishing provision services, hence a threat to livelihoods. Also, depending on the intensity of veld fires, the heat may penetrate into the soil (Forsyth *et al*., 2010). Consequently, once the soil profile has been disturbed by fire, and with continued overgrazing, it becomes weak and susceptible to erosion. Fertile soil can be lost and sedimentation of the wetland downstream occurs, resulting in changes in hydrology (Forsyth *et al*., 2010). Thus while the community is trying to get optimal benefits from the wetland,

they also need to do that in a sustainable manner to avoid a complete loss of ecosystems goods and services.

4.4. Community management of the Blesbokspruit catchment

Although the community members found interacting with the wetland had a general idea about what to do or not to do so as to conserve the integrity of the wetland, no formal structures were found in place to manage the use of the wetland. Wetlands are often common-lands under no clear ownership and their resources and land are viewed as relatively freely available. This serves as a big attraction to poor people in both rural and urban areas who can come to rely on them, with their welfare becoming intimately tied to the status of the wetland itself (Wetland International, 2010). It is clear however that individual users have some knowledge on how the conservation of the wetland could be achieved. This is a good thing because sustainable use of wetlands is realised when people use wetlands in such a manner that they yield maximum benefits while maintaining the potential of the same wetlands to fulfil the needs and aspirations of future generations (Nabahungu and Visser, 2011). The forum that exists seems not to cater for people at grassroots level as none of the respondents were aware of it. There is however a potential therefore that such initiatives could in future be implemented by the communities along the Blesbokspruit catchment and actually yield positive results.

4.5. Conclusions

This study was carried out to assess the ecosystem goods and services that prevail at the Blesbokspruit wetland, a Ramsar site despite its being listed on the Montreux Record of wetlands under ecological threat. It was found that the wetland has been impacted by a variety of anthropogenic interferences in both its upper and lower catchment at Putfontein and Marievale respectively. More respondents at Putfontein than at Marievale valued the wetland for direct services to support their livelihood needs through agriculture (crop production and livestock rearing) because of its fertile grazing grounds and provision of water. At Marievale more respondents than at Putfontein valued indirect services derived from the wetland, such as supporting biodiversity (different aquatic species and water birds, also including migratory birds). Another objective of this study was to find out if people have access to ecosystem goods and services where the wetland is under conservation by a national authority. The ability of the wetland to regulate water quality and climate change lies in the presence of a variety of wetland vegetation which absorb pollutants and captures carbon

dioxide during green plant growth, especially where it is under protection. It can therefore be concluded that, despite being fenced off from direct access by the public in some parts of its catchment, Blesbokspruit wetland can still provide indirect regulating services for the benefit of all.

The wetland is however not free from threats which are exacerbated by the expansion of urban settlements due to the increase in population within the catchment. It is under threat from subsistence as well as commercial agriculture in both its upper and lower catchments. Encroachment by expansion of residential areas, and different forms of pollution from solid dumping and industrial effluent, are also anthropogenic activities that negatively impact on the wetland's ecological integrity. Social factors such as low levels of education resulting in the failure to secure formal employment for some people are also leading to more pressure being put on the wetland, as people compete for land to produce food. Wetland degradation associated with human/anthropogenic activities and poverty can easily lead to loss of ecosystem services, pushing people further into poverty. Growing populations account for further conversion of the wetland to other forms of land uses, such as agriculture which may lead to change in hydrology such that the wetland may eventually dry up (Ramsar, 2013). In this way, people are indirectly reducing some of its ecological functions.

Despite all the major threats to the health and integrity of Blesbokspruit wetland, the flooded area has been fluctuating in size in the period 1998-2015 (Table 3.3, Figure 3.4), from 11 312 ha in 1998, to 4681 ha in 2004, which by 2009 had increased to 13 368 ha and showed a minimal decrease to 12 465 ha in 2015. The extreme decrease in size of the wetland in 2004 has been attributed to a severe drought in the southern African region at this time (Rouault and Richard, 2005). The continuous presence of surface water thereafter may have been due to pumping of underground discharge water from several mines and other industrial effluent within the catchment into the wetland. This implies that while human settlement and subsistence agriculture have been on the increase, industrial activities have been benefiting more from the water purification services provided by the wetland. It may therefore be concluded that with sustainable wetland use management, there is a possibility to restore Blesbokspruit as a wetland of international importance and eventually allow its delisting from the Montreux Record.

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Appendix 1 - Questionnaire

Title: Assessing changes in the Wetlands' Ecosystem Services in the peri-urban environment: The Case Study of the Blesbokspruit Wetland, Springs

Part 1: Questionnaire for Blesbokspruit community

Age …….. Sex…….

Level of Education……

1. For how long have you been staying in this area?

2. Do you know the name of the wetland?

3. Do you ever visit the wetland? Why?

4. Are you happy with the state of the wetland? Why?

5. In your opinion is this wetland important for human wellbeing at all?

6. Give reasons for your opinion.

7. Have you noted any changes in the nature of the wetland as a resident of this area? Please list them in order of importance.

8. If yes can you explain the changes and their impacts on the nature of the wetland……

9. What does the community do to protect the wetland?

Part 2: Questionnaire for Blesbokspruit Officials

Period of work……..

Level of Education……..

1. What is your role in the Blesbokspruit Nature Reserve?
2. In your own opinion are there benefits provided by this wetland to the people located in the neighborhoods? List them.
3. Is the community still allowed to access the wetland for their benefit?
4. Are there any changes that you have noted at the wetland while working here?
5. What are these changes
6. What are the causes of the observed changes?
7. What are the impacts of the changes on the nature of the wetland?
8. Are there any control and containment measures of the impacts of the changes on the wetland?
9. Do these measures involve the neighborhood community? And how?
10. Do you think Blesbokspruit Nature Reserve authority is doing enough to protect this wetland?
11. What do you think could be done to improve the state of the wetland?

Appendix 2: Human Research Ethics Clearance Certificate

Research Office

HUMAN RESEARCH ETHICS COMMITTEE (NON-MEDICAL)
R14/49 Mokotjomela

CLEARANCE CERTIFICATE	**PROTOCOL NUMBER: H15/05/26**
PROJECT TITLE	Sustainability of water-use in agricultural food production systems by small-holder farmers under climate change
INVESTIGATOR(S)	Dr T Mokotjomela
SCHOOL/DEPARTMENT	GAES- GCSRI/
DATE CONSIDERED	22 May 2015
DECISION OF THE COMMITTEE	Approved unconditionally
EXPIRY DATE	10 June 2017

DATE 11 June 2015 **CHAIRPERSON** (Professor T Milani)

cc: Supervisor: N/A

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to completion of a yearly progress report.**

Signature Date

PLEASE QUOTE THE PROTOCOL NUMBER ON ALL ENQUIRIES

Ethics clearance for this project was granted under the overarching project run by Dr Mokotjomela, above.