An assessment of the implications of involving local communities in biodiversity conservation: A case study of Blouberg Nature Reserve in Limpopo, South Africa

by

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DISSERTATION

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DECLARATION

I declare that the An assessment of the implications of involving local communities in biodiversity conservation: A case study of Blouberg Nature Reserve in Limpopo, South Africa hereby submitted to the University of Limpopo, for the degree of Master of Science in Geography has not previously been submitted by me for a degree at this or any other university; that it is my work in design and in execution, and that all material contained herein has been duly acknowledged.

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Rampheri, MB **Date**

Abstract

This work aimed at assessing the implications of involving local communities in biodiversity conservation in Blouberg Nature Reserve (BNR) in Limpopo Province, South Africa. To achieve this objective, firstly biodiversity status before and after involving local communities in conservation initiatives was assessed using multi-temporal medium-resolution Landsat series data and species diversity indices. The results showed that there were significant variations ($\alpha = 0.05$) in tree species diversity in BNR for before and after involving local communities. For example, tree species diversity was low after involving communities particularly for the years 1996 and 2019. Secondly, benefits and costs of involving local communities in biodiversity conservation as well as their investigate views, perceptions and attitudes BNR management were assessed. The study demonstrated local communities do not obtain sufficient benefits or incur numerous costs from the nature reserve. Despite this, there was considerable support for biodiversity conservation (84.2%) since household respondents still held positive attitudes towards biodiversity conservation in the reserve. For, example most of them indicated that they would report illegal activities to the authorities. However, despite lack of participation by the majority of the household respondents (89.6%) in biodiversity conservation, they demonstrated understanding of the relevance of nature conservation. In contrary, the BNR Manager stated that the local communities received benefits in the form of fuel-wood for special occasions such as funerals and bush meat sold at treasury approved tariffs during culling. However, illegal activities like poaching are still experienced in the nature reserve. Thus, the study underscores the relevance the integrating satellite data and qualitative information in assessing the ecological condition of PAs. Such information can help in biodiversity monitoring and decision-making on conservation of biodiversity.

Keywords: biodiversity conservation; community-based natural resource management approach; ecological status; mapping; satellite data; spatial characterisation; species diversity; statistical analysis.

Publication and manuscripts

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Dedication

To my mother and family for all their inspiration, support, love, patience and encouragement.

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1. Chapter one

Background and context

1.1 Introduction

People rely on natural resources like water, trees, soil, animals, grass and minerals for their general livelihoods (Shackleton *et al*., 2001; Rankoana, 2016). The establishment of Protected Areas (PAs) isolated people from nature and compromised the goals and objectives of conservation (Poirier and Ostergren, 2002; West *et al*., 2006). PAs have restricted people from entering and accessing natural resources through the creation of fences and legislations (West *et al*., 2006). Andrade and Rhodes, (2012) and Ayivor *et al*, (2013) emphasize that the restriction of access to natural resources in PAs resulted in conflicts between people and parks management, which in turn accelerated illegal activities like poaching and overharvesting of natural resources by local communities. For instance, Andrade and Rhodes, (2012) found that in Tsitsikamma National Park in South Africa, indigenous people practice unlawful engagements by means of revenge through poaching, which significantly affected wildlife population and hindered conservation.

Nature conservation experts have attempted to restore the relationship between people and nature to enhance conservation through the Community-Based Natural Resource Management (CBNRM) approach. CBNRM approach allows nearest communities to benefit socially and economically from their participation in the PAs while conserving nature (Mahumuza and Balkwill, 2013; Milupi *et al*., 2017). People obtain benefits amongst others include, revenue from tourism, meat from culling and knowledge enhancement, while PAs acquire benefits such as reduction in illegal activities such as poaching (Mahumuza and Balkwill, 2013). By benefiting from nature, people’s custodianship is enhanced. For example, in Okavango Delta, Botswana, local people are engaged in conservation activities where their knowledge was enhanced and get benefits including income from tourism and this has led to a decrease in poaching statistics, as they become custodians of the Delta and community (Mbaiwa, 2004).

Even though CBNRM is seen as a solution to the conflict between nature and people, and enhance nature, there are still areas of failures where they are facing challenges, such as poaching and illegal harvesting of natural resources that hinder the effectiveness and successful biodiversity conservation through CBNRM. Rechlin *et al*., (2008) and Huynh *et al*., (2016) point out that the ineffectiveness and failure of CBNRM are due to inactive community participation, lack of partnership, inequity in distributing benefits among participants and poor monitoring. There is, therefore, a need to study and understand the root causes of the intrinsic problems hindering the success of CBNRM as well as to assess and examine the state of the biodiversity in PAs. Thus, this study aims to assess the implications of involving local communities in biodiversity conservation in BNR in Limpopo Province, South Africa.

1.2 Problem statement

People and nature have co-existed for ages. People rely on natural resources like water, trees, soil, animals, grass, and minerals for their general livelihoods (Shackleton *et al*., 2001) while through the exploitation of natural resources, nature is enhanced. Russell-smith *et al*., (1997) established that Aboriginal people in Australian harvest yam species that occur in floodplains and woodland habitats where they leave some part of yam, especially the jungle yams to the ground to regenerate.

The advent of Protected Areas (PAs), which restricted people access to natural areas, isolated people from nature (Weber and Vedder, 2001). People were restricted access to natural areas through the creation of fences. The isolation of people from nature brought hardships to the people. People, therefore, resent PAs because of hardships, which lead to conflicts between people and nature. Conflicts encourage people to engage in unsustainable activities such as poaching and illegal harvest of natural resources which eventually lead to the ineffectiveness of PAs (Poirier and Ostergren, 2002; West *et al*., 2006). Besides hardships, resentment, and unsustainable activities, indigenous knowledge systems are also broken through this isolation (Ayivor *et al*., 2013).

Community-Based Natural Resource Management (CBNRM), which was introduced in the 1980s, aimed at recreating the relationship between people and nature has provided people with opportunities to participate in conservation activities (Mahumuza and Balkwill, 2013). Through CBNRM, people receive benefits such as access to natural resources and incentives from tourism that enhances their livelihoods (Bajracharya *et al*., 2005). Milupi *et al*., (2017) further observe that hardships, resentments, conflicts and unsustainable activities are reduced through CBNRM. In addition, people's knowledge of nature has been enhanced. Nevertheless, in some cases, CBNRM has not fully realized its intended goals and objectives. There are some cases of poaching and illegal harvesting of natural resources in PAs and communities do not get benefits (Rechlin *et al*., 2008). According to the literature, CBNRM resulted in mixed results. Thus, the study intends to assess the implications (i.e. benefits and challenges) of involving local communities in biodiversity conservation in Blouberg Nature Reserve in Limpopo, South Africa.

1.3. Aim and objectives of the study

1.3.1. Aim

The aim of the study is to assess the implications of involving local communities in biodiversity conservation in the Blouberg Nature Reserve in Limpopo Province, South Africa.

1.3.2. The objectives

Objectives of this study are to:

I. Assess the state of tree species diversity before and after involving local communities in biodiversity conservation in Blouberg Nature Reserve in Limpopo Province, South Africa.
II. Identify and assess benefits and costs of involving local communities in biodiversity conservation in Blouberg Nature Reserve in Limpopo Province, South Africa.
III. Investigate the views, perceptions and attitudes of local communities towards Blouberg Nature Reserve management in Limpopo Province, South Africa.

1.4. Research questions

i. Is tree species diversity conserved since the involvement of local communities in biodiversity conservation?
ii. Is communities' involvement enhancing biodiversity conservation in Blouberg Nature Reserve?
iii. Is communities' participation improving the views, perceptions and attitudes of local communities towards conservation?

1.5. Significance of the study

Identification of benefits and costs of involving local communities in biodiversity conservation in the protected area will assist in the suitable policy changes to obligingly address the existing problems associated with CBNRM to both local communities and PAs, to pursue conservation goals. Moreover, the results of the study will provide a baseline for future research on a similar and related topic. In addition, the results of the study will help to answer the question as to whether community involvement is making a difference in biodiversity conservation.

1.6. Ethical considerations

The study deals with people; therefore, an ethical clearance certificate was applied to Turfloop-Research Ethics Committee (T-REC). Objectives and expected outcomes were explained to every approached research participant to check if they are interested or not. Collected information was treated confidentially were respondents remained anonymous.

1.7. Study area

1.7.1. Experimental Site

The study was carried out in Blouberg Nature Reserve (BNR). The area is situated within latitudes of S 23° 01' 04" and longitudes of E 29° 04' 09" in Blouberg Local Municipality within Capricorn District Municipality of Limpopo Province, South Africa. BNR covers a total area of approximately 9 348 hectares. It is located approximately 34 km from R521, south-west of the Langjan Nature Reserve (Limpopo Department of Economic Development, Environment and Tourism, 2013). The reserve was established in 1983 (Constance, 2014) and started involving local communities in biodiversity conservation in 1992. It is surrounded by villages including, Edwinsdale, Indermark, Ga-Moyaga, and Glenfernes (Figure 1.1) (Limpopo Department of Economic Development, Environment and Tourism, 2013). According to Blouberg Municipality, (2017) majority of people (10231) from surrounding villages are unemployed, 1578 have higher education qualification and 2036 people did not go to school.

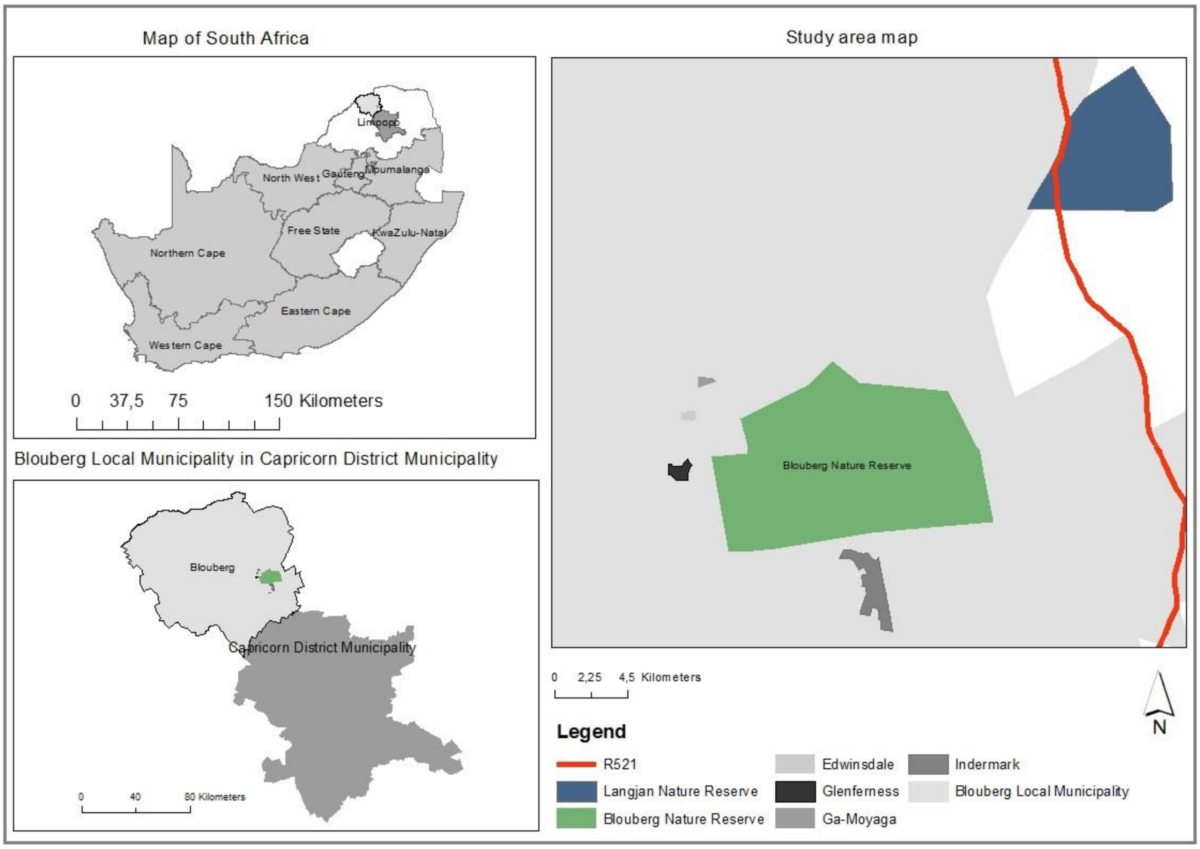


Figure 1. 1: The location of the Blouberg Nature Reserve and its local communities in Limpopo, South Africa.

1.7.2 History

BNR is situated on the land formerly occupied by the Hananhwa tribe in the early 1820s (LEDET, 2013). According to LEDET, (2013) people living near BNR still maintain a traditional lifestyle. The nature reserve land was purchased from white farmers and designated as one of the Limpopo's PAs. After 1994 democratic election, the nature reserve was merged in newly formed Northern Provincial Government now known as the Limpopo Provincial Government. The nature reserve is run by Limpopo Environmental Management: Protected Areas Act (Act 57 of 2003) (LEDET, 2013; Constance, 2014). It was established with the purpose to: a) protect its natural landscapes, indigenous fauna and flora and biotic communities; b) promulgate scarce and endangered species of fauna and flora and c) sustainably use the area for scientific, educational and ecotourism purposes (Constance, 2014).

1.7.3 Climate

Rainfall and temperature

BNR is located in a semi-arid area, with a warm and dry summer starting from October to March and a dry winter season starting from April to September (Constance, 2014). It receives an average annual rainfall of 410 mm per year during the summer months (LEDET, 2013). The area experiences orographic rainfall due to the east-west positioning of the Soutpansberg Mountain (Mostert, 2006). The area experiences seasonal droughts that occur between May and October (Constance, 2014). Temperature ranges from 16 - 40ºC and mild winter months with temperatures ranging from 12 - 22ºC (Mostert, 2006).

1.7.4 Flora and fauna

The nature reserve boasts a rich diversity of plant life including 1600 plant species, which provide habitat to the animal species (Van Wyk, 2002). Dominant vegetation types within the reserve include Soutpansberg Summit Sourveld, amongst others dominated by *Combretum molle* and *Englerophytum magalismontanum*; Limpopo Sweet Bushveld, which include *Acacia robusta* and *Dichrostachys cinerea*; Roodeberg Bushveld, mainly *Sclerocarya birrea* subsp and *Kirkia accuminatum*; and woody species namely *Elephantorrhiza* species and *Burkea African*; grass species such as *Trichoneura grandiglumis* and *Digitaria eriantha*; and herbaceous species such as *Cheilanthes involute* and *Cyperus angolensis* (Mostert, 2006). There are also Species of Conservation Concern that include *Cineraria cyanomontana*, *Isoetes transvaalensis*, *Justicia montis-salinarum* and *Drimia altissima* (LEDET, 2013). According to LEDET, (2013), even though BNR is rich in plant species, alien species such as Prickly Pear (*Opuntia ficus-indica*) do occur although in low density.

The nature reserve is endowed with variety of animal species, about 50 reptiles namely Bibron's Stiletto Snake, Southern African Python and the endemic Common Flat Lizard *Platysaurus intermedius parvus*. There are also about 25 species of amphibians and 21 Bat species (LEDET, 2013; Constance, 2014). The nature reserve is also rich with Avifauna species (128), of which some of them (16) occur on International Union for Conservation of Nature (IUCN) Red List of Threatened Species The nature reserve also supports a variety of mammals including grazers such as bushbuck (*Tragelaphus sylvaticus*), mixed feeders such as Impala (*Aepyceros melampus*) and browsers such as Giraffe (*Giraffa camelopardalis*) (Constance, 2014).

1.7.6 Geology and soils

Geologically, the area is dominated by a variety of geological formations that in conjunction with soil type explain the spatial distribution of vegetation in BNR. The area is associated with rock such as gneisses and metasediments and soils including limestone layers in Limpopo Sweet Bushveld. In the Southpansberg Mountain Busveldock, the area is associated with rocks such as sandstone and siltstone, and soils including acidic dystrophic to mesotrophic sandy to loamy. In the Rooderberg Bushveld, the area is associated with rock such as sandstone and conglomerate, and mesotrophic soils, whereas rocks such as quartzite and shale and extremely shallow, leached, acidic, coarse sand of the Glenrosa and Mispah soil forms in the Soutpansberg Summit Sourveld (LEDET, 2013).

1.7.7. Population and settlements

BNR is surrounded by villages amongst them include Edwinsdale, Indermark, Ga-Moyaga, Glenfernes, Ga-Maphotho and Kroemhoek. The villages constitute of 7 510 out of 41 723 households and 14 210 out of 162 629 population of Blouberg Municipality (StatsSA), 2019. The villages comprised of Black African, Coloured, Indians and Whites population group of which Black Africans are the dominant which constitutes 98%. The most common language spoken is Sepedi followed by Sesotho, Setswana, Tshivenda, Xitsonga and isiZulu (Blouberg Municipality, 2017). The above mentioned villages are located within 3 km radius of the reserve.

1.8 Structure of the research

This dissertation consists of five chapters. Chapter 1 provides a general overview of the research background and context of the research as well conceptualizes the problem statement, the aim of the study, research objectives and questions. Meanwhile ethical consideration was also included since this study has certain aspects of ethical concern.

Chapters 2, 3 and 4 are stand-alone chapters. Chapter 2 reviews available literature, in terms of theories and practices, and legislation. In addition, this chapter provides a detailed overview of the implications (i.e. benefits and costs) of involving local communities in the conservation of PAs and examines how geospatial techniques have been embraced in nature conservation considering its spatial explicit nature. Furthermore, the study highlighted gaps and possible future knowledge gaps on the potential use of remote sensing techniques to estimate tree species diversity in PAs that involve local communities in biodiversity conservation.

For chapter 3 focuses on the use of geospatial techniques and biodiversity indices in tree species diversity estimation before and after involving local communities in biodiversity as an indicator of biodiversity conservation in BNR. Then Chapter 4 outlines the benefits and costs of involving local communities in biodiversity conservation as well as views, perceptions and attitudes of local communities towards BNR management.

2. Chapter two

Local community involvement in nature conservation in protected areas under the auspices of Community-Based Natural Resource Management (CBNRM): A review of literature

Abstract

Biodiversity conservation has been addressed in various ways and the socioeconomic impacts of Protected Areas (PAs) have been recognized and documented by conservationists and decision makers. This has resulted in various policies and laws e.g. the Community-Based Natural Resource Management (CBNRM) drafted to ensure a systematic involvement of local communities in conservation. As such, numerous calls were made to explore community involvement strategies and associated socio-economic impacts in nature conservation. Most studies and reports emanating from such calls demonstrate cases of failure of *inter alia* including poaching. This work, therefore, provides a detailed synthesis of the implications of involving local communities in conservation in PAs and further examines how spatial explicit methodologies could be harnessed in enhancing nature conservation. Overall, the study has shown that community attitudes and perceptions towards nature conservation in PAs point towards the failure of the CBNRM approach. Weak, conflicted and sometimes-corrupt governance and poor institutional arrangements seem to have contributed towards its failure. Overall, the review further indicates that most studies on community involvement in nature conservation have not fully considered spatial dimension and this has hampered holistic and effective monitoring and assessment of biodiversity in PAs to ensure sustainable management and the possible implications of such an approach towards conservation. This work, therefore, recommends a shift towards collaborative modelling or transdisciplinary monitoring and assessment approaches to improve biodiversity conservation as well as to determine the success and limitations of the CBNRM approach in Africa and the world-over.

Keywords: cost-benefit analysis; costs; community-based resource management; conservation; geographic information system; remote sensing

2.1 Introduction

Communities from predominantly African rural areas; rely on natural resources, like water, soil and animals to sustain their livelihoods (Fabricius, 2013; Makindi, 2016). Most of these areas have since been designated as Protected Areas (PAs) (Chowdhury *et al*., 2014). Vodouhê *et al*., (2010) pointed out that in Africa; PAs are the pillar of biological conservation. Over the past years, biodiversity conservation mostly depended on national PAs controlled by central governments, through the central approach (Vodouhê *et al*., 2010). The approach isolates people from nature as it restricts access to natural resources. Further, this isolated them from key decision-making initiatives concerning natural resource management in PAs (West *et al*., 2006). The approach created conflicts between communities and PAs management resulting in resentment over PAs. There was also an acceleration of costs in PAs, which include poaching (Andrade and Rhodes, 2012). Moreover, Makindi (2016) added that the exclusion of rural communities from PAs resulted in animosity and negative attitudes towards wildlife and conservation agencies.

Responding to conflicts between communities and PAs management, the CBNRM approach emerged as the most possible solution and has since evolved over the past three decades. The CBNRM aimed to conserve nature while taking local peoples' needs and aspirations into consideration (Vodouhê *et al*., 2010). Through CBNRM, local communities are involved in decision making in the management of PAs and benefit from natural resources (Vodouhê *et al*., 2010; Mahumuza and Balkwill, 2013). According to Méndez-López *et al*., (2014) and Makindi, (2016), local communities' play an important role in the implementation of management plans, development, decision-making and conservation activities of PAs. This is because most of the indigenous have vast knowledge and experience on how to manage natural resources and ensure the protection of both wildlife and human.

PAs have been strategically set aside from human exploitation. They have increasingly been recognized that they play a significant role in sustaining the livelihoods of adjacent local communities through CBNRM (Vodouhê *et al*., 2010). Even though CBNRM is considered suitable for enhancing biodiversity conservation while benefiting local communities, it has also experienced failure. The effects of nature conservation in PAs can include both costs and benefits to local communities (Segage, 2015) or PAs. Participating local communities in biodiversity conservation in PAs acquire socio-economic benefits that enhance their livelihoods (Lepetu *et al*., 2008), while biodiversity conservation in PAs is enhanced through the decrease in illegal activities (Mbaiwa, 2004). On the other hand, both parties also incur the costs. According to Andrade and Rhodes, (2012) and Vodouhê *et al*., (2010), the costs to PAs arise when PAs fail to observe other important factors such as social, cultural, traditional and political issues. The costs, therefore, result in local people resenting PAs, developing negative perception and attitudes towards biodiversity conservation in these areas (Andrade and Rhodes, 2012).

For better CBNRM approach management, benefits and costs of involving local communities in biodiversity conservation need to be studied with integration of spatial explicit techniques. This will help in identifying the opportunities or problems and diagnosing fundamental solutions for developing appropriate policies for biodiversity conservation (Rechlin *et al*., 2008). GIS and remote sensing techniques offer a unique opportunity to monitor and manage natural resources at multi-temporal, multi-spectral and multi-spatial resolution (Kumar *et al*., 2015). For instance, the study in Sumatra and Kalimantan in Indonesia show the power of integrating geospatial and social analysis techniques (Dennis *et al*., 2005). According to the study, the long-term land-cover change trends show forests being replaced by burn scars, with 9% appearing as recent burn scars between 1985 and 1994, where human activities were one of the main drivers. This approach provides a rich record of where, when and magnitude of fires have occurred and the associated effects to the environment (Dennis *et al*., 2005). However, Dennis *et al*., (2005), indicated that so far, very few studies tempted to explore the integration of social science and remote sensing to understand the cultural dimension of fires. In addition, Sibanda *et al*., (2016), showed that limited work has been done to understand the spatial trends of illegal activities like poaching using GIS and remotely sensed data. This work, therefore, focusses on (i). understanding the role of PAs in biodiversity conservation; (ii). CBNRM approach and associated benefits and costs in biodiversity conservation; (iii). knowledge, perceptions and attitudes of local communities towards PAs management; and (iv). the application of GIS and remote sensing in biodiversity conservation in the international context.

2.2 The role of PAs in biodiversity conservation

PAs are described as the central part of global, regional and national conservation strategies for the long-term preservation of biodiversity (IUCN and UNEP-WCMC, 2014; Mucova *et al*., 2018). The main objective of PAs is to effectively and sustainably protect, develop and maintain the existing biodiversity (Vodouhê *et al*., 2010). The number of PAs globally has doubled since 1992, covering above 12% of the Earth’s land in 2014. Although the number of PAs has increased, their effectiveness in biodiversity conservation remains questionable. In agreement, Coad *et al*., (2008) highlighted that the effectiveness of PAs is determined by their ability to reduce illegal activities and to conserve biodiversity. These studies have shown that there are problems in PAs, including continued overexploitation of biological resources, local extinction of fauna through illegal poaching, over harvesting of forest resources, intensified livelihood conflicts with local communities, the lack of scientific research and increased ecological separation (Mucova *et al*., 2018). For example, Mucova *et al*., (2018), using GIS and remotely sensed data, demonstrated that Quirimbas National Park lost about 301,761.7ha of land cover between 1938 and 2017, corresponding to 41.67% of the land area. Illegal exploitation of forest resources and mining inside of the park was among the main causes..

2.3 Community-Based Natural Resource Management in an international context

There has been a massive shift in nature conservation from a centralized system to Community-Based Conservation approaches (CBC). Most of the African countries endorsed the CBNRM approach. They recommend it as strategy for promoting the local community's stewardship and involvement in natural resource management while integrating development and conservational goals (Lepetu *et al*., 2008; Fabricius, 2013; Segage, 2015). As an emerging international model for natural resource management, CBNRM, is regarded as a win-win conservation framework (Dabo, 2017). The approach considers communities as the owners and managers of natural resources, hence the need for their involvement in PAs management. The approach was introduced in the 1980s by IUCN with a clearly outlined involvement and engagement guidelines in place to promote a participatory approach in nature conservation (Segage, 2015).

2.3.1 Community involvement and participation in PAs pathways

According to Whande, (2007) and Lepetu *et al*., (2008), CBNRM is promoted through a wide range of projects and programmes. They include *inter alia* partnerships (co-management agreements), integrated conservation and development programmes, CBC (Whande, 2007), PAs outreach programs and Community Wildlife Management (CWM) (Alberts, 2010). The main purpose of CBNRM related projects and programmes is to ensure that local communities and PAs build resilient relationships and partnerships. It also aims to ensure that communities play their role in the management of natural resources in the PAs while getting socio-economic benefits from wildlife-based activities, also ensuring sustainable utilisation of natural resources (Mbaiwa, 2004).

A partnership is a formal agreement upon standards, in which two or more stakeholders cooperate to solve issues, or to achieve a specific policy framework (Lepetu *et al*., 2008). In partnership management, there are compromises and sacrifices involved to advance in conservation efforts (Segage, 2015). This reinforces intimacy and erodes instability among key stakeholders. There is, therefore, is a need to identify common interests among the different stakeholders involved and benefits for all. Segage, (2015) states that through the partnership strategy, expected conservation outcomes can be realized when management is cognizant of the diverse nature of stakeholders and expectations. These can include, but not limited to the diversity of skills, expertise and knowledge that are valuable to conservation.

2.3.2 Benefits of involving local communities in biodiversity conservation

Through CBNRM, communities involved in PAs have access to socio-economic benefits, while ensuring sustainable use of natural resources (Lepetu *et al*., 2008). The PAs acquire ecological benefits that enhance biodiversity conservation through a reduction in illegal activities such as poaching, the setting of fires, and overharvesting of natural resources, among others. Mbaiwa (2004) mentioned that participating communities in biodiversity conservation in PAs attain benefits including *inter alia* incentives from tourism, employment opportunities, ecosystem goods and knowledge enhancement. Snyman (2014) added that when communities receive benefits from PAs and ecotourism that exceeds the costs incurred, they tend to hold positive attitudes and perception towards biodiversity conservation. In agreement, Bajracharya *et al*., (2006); Rechlin *et al*., (2008) highlighted that community involvement results in strong partnership and high participation rates, which lead to effective and successful biodiversity conservation.

2.3.3 Costs of involving local communities in biodiversity conservation

To date, studies have explored the effectiveness of CBC, through different initiatives and schemes, such as ecotourism in providing tangible community benefits and enabling conservation (He *et al*., 2008; Rechlin *et al*., 2008). It was found that despite promises, CBC schemes have not been rigorously evaluated since they are still associated with costs (Rechlin *et al*., 2008; Mutanga *et al*., 2017). These costs affect both local communities' livelihoods and the conservation of PAs. The costs faced by the local communities include human-wildlife conflicts, unequal distribution of benefits from PAs (Mbaiwa, 2004; Stone, 2007), and entrance fees into PAs (Vodouhê *et al*., 2010).

Further, costs faced by PAs in the conservation of biodiversity include *inter alia*, lack of understanding of the CBNRM by local communities, illegal hunting, fence destruction, overharvesting of natural resources and poaching amongst others, which hinder successful and effective conservation in PAs (Mbaiwa, 2004). The cost faced by PAs can indirectly be traced using spatial explicit techniques. For instance, Sibanda *et al*., (2016) used GIS and remotely sensed data integrated with spatial logistic regression to understand the spatial distribution of elephant poaching activities in the Mid Zambezi Valley safari areas. The work showed that the majority of poaching activities occurred in the woodlands, closer to the water holes, especially in autumn season. They concluded that the integration of spatial explicit methodologies provide optimal and cost effective tools for understanding the spatial distribution of elephant poaching activities in Southern Africa.

2.4 Knowledge, perceptions and attitudes of local communities towards PAs

The level of biodiversity conservation in PAs varies from place to place depending on the social context and governance dynamics. Amongst the social context, knowledge, perceptions, and attitudes towards PAs are the key determinants. The local people's perceptions influence the way they interact with PAs and determine the effectiveness of conservation (Vodouhê *et al*., 2010; Andrade and Rhodes, 2012; Chowdhury *et al*., 2014). Perceptions and attitudes of local communities are influenced by several factors. Amongst them include, the history of park management, the degree of awareness of PAs existence, education level, ethnicity and gender (Vodouhê *et al*., 2010; Chowdhury *et al*., 2014). According to Bonilla-Moheno and García-Frapolli (2012), the interests of stakeholders, which include the benefits they receive from the PAs, influence biodiversity conservation in PAs.

Local communities often develop positive perceptions and attitudes when they receive more benefits than the costs they incur. Adams *et al*., (2004) added that for CBNRM programmes to be successful, they must offer more benefits to the community to balance the expected demands and compromises agreed on. On the other hand, local communities develop negative perception and attitudes towards PAs when the management does not factor in their socioeconomic and cultural needs (Vodouhê *et al*., 2010). Perceptions and attitudes of local communities towards PAs, therefore, need to be explored for better management of PAs. This is because the socioeconomic needs of the surrounding communities affect the conservation management (Chowdhury *et al*., 2014).

2.5 CBNRM vs. Governance and institutional arrangements

Natural resources in CBNRM can be governed by several institutions, including local institutions controlled by traditional leaders and local community committees, as well as external institutions, such as local and central government agencies (municipality and tourism agencies) and Non-governmental organizations (NGOs) (Mbaiwa, 2004; Lepetu *et al*., 2008; Marambanyika and Beckedahl, 2016). According to Nxumalo, (2010), there are many institutional rules and policies governing the CBNRM in South Africa. For example, Section 24 of the Bill of Rights and National Environmental Management Act (NEMA) or institutional frameworks define the rights and duties in which CBNRM initiative operates. The role of local institutions, particularly the one controlled by traditional leaders were found to be effective (Dimbi, 1998), however, weakened by interference and institutional disruptions initiated by colonial governments. Colonial legacy largely ignored indigenous knowledge and common practice (Marambanyika and Beckedahl, 2016).

Due to colonial legacy, Galvin *et al*., (2018) indicates that in most of the cases, the establishment of CBCs in Africa resulted in a mixture of positive and negative socioeconomic outcomes, while ecological outcomes have been largely positive. Amongst the negative socioeconomic outcomes, unequal distributions of benefits to CBC members and households have been noted. He *et al*., (2008) found that in China, the distribution of economic benefits such as employment were unequally distributed among the rural residents in Wolong Nature Reserve for Giant Pandas. Additionally, human-animal conflicts are among most reportedly negative social impact.

Positive social outcomes include financial incentives. Bajracharya *et al*., (2006) indicated that 14.9% of the participating local people in forest conservation in Annapurna Conservation in Nepal received income from tourism revenue. Local people also get employment opportunities, for instance, Gandiwa, (2013) found that the Communal Areas Management Programme for Indigenous Resources (CAMPFIRE) programme in Gonarezhou National Park, Zimbabwe created employment opportunities for 114 adjacent and neighboring communities. Developmental support is also among the positive social outcomes. The most reported ecological outcomes include enhanced species diversity. For example, Nelson *et al*., (2016) established that in community conservancies in northern Kenya, elephant-poaching statistics have decreased and the number of lions has increased over the past decade because of the establishment of joint venture conservancies between local landholders and private tourism operators. Institutional governance is amongst the reason behind those results.

Literature demonstrates that governance institutions, particularly local, have been unable to curb the loss of natural resources (Marambanyika and Beckedahl, 2016; Mosimane and Silva., 2015). For instance, Mosimane and Silva, (2015) found that local governance institutions in Uibasen conservancy in Kunene region and Mayuni conservancy in Namibia have not developed adequate benefit-sharing systems. Mosimane and Silva, (2015) suggested that local governance structures require more external support and oversight in designing and implementing methods for distributing benefits to community members. Brooks *et al*., (2012) emphasised that relatively few studies have scrutinized the institutional factors that can help improve social and ecological outcomes of CBCs in Africa.

2.6 Integration of spatial explicit methods in biodiversity conservation

For decades, GIS and remote sensing techniques have been found to provide advanced environmental assessment tools that can help analyze, characterize, profile and monitor ecosystem patterns; processes and status of biodiversity; as well as the associated environmental parameters (Wang *et al*., 2010; Haque and Basak, 2017). Remote sensing has capabilities of providing a reliable and spatial explicit long-term Earth observation data at different scales. Moreover, remote sensing is not labor-intensive and time-consuming, when compared with other conventional techniques, like ground-based monitoring frameworks (Wang *et al*., 2010). They provide information on key habitat or ecological parameters, such as land cover and species composition among others. In addition, remotely sensed data can be modeled to estimate potential spatial and temporal species range and richness (Wang *et al*., 2010). Cohen and Goward (2004), observed that an integration of GIS, remote sensing data and modelling techniques in ecological research provides a better understanding of biodiversity patterns and improves conservation efforts.

Remote sensing allows for the detection and classification of individual species with varied success. According to Heumann *et al*., (2018) and Shoko *et al*. (2016), the identification of species requires a reliable unique spectral characteristic that sets it apart from the other objects on the environment. Wang *et al*., (2010); Shoko *et al*. (2018; 2019) further observed that the capabilities of remote sensing application on environmental components is determined by the instruments and techniques used. Most commonly and advanced instruments used include high spatial resolution, hyperspectral, medium resolution satellite remote sensing platforms and LIDAR sensors, while techniques include classification algorithms and variables amongst others. Moreover, the instruments and techniques also depend on the scale of application.

There are, however, a couple of remote sensing related studies, which have reported on different characteristics of a landscape. Most of these studies have applied freely available remotely sensed products and have regarded these as cost-effective (Prasad *et al*., 2015). Freely available satellite data are known to be associated with insufficient spatial resolution as such medium resolution satellite platforms while commercial high spatial resolution satellite imagery, with pixel sizes of 2-5 m are associated with a fine spatial resolution (Nagendra *et al*., 2010). However, there are some pitfalls for every platform, for instance even though medium resolution satellite remote sensing platforms like Landsat collect data at 30 m it, however, some instances results in fundamental information being masked out. Nagendra *et al*., (2010) argues that Landsat data have been used for plant diversity estimation in the past with moderate success. More importantly, it provides archival data over longer periods than other remote sensing platforms (Nagendra *et al*., 2010; Prasad *et al*., 2015). In contrary, high spatial resolution satellite remote sensing platforms like IKNOS have challenges in the provision of consistent historical data required for tracking ecosystems and environmental changes over time at landscape scale (Nagendra *et al*., 2013).

Landsat is the most commonly used imagery that provides terrestrial observations in support of services such as forest monitoring, landcover change detection and natural disaster management (Cohen and Goward, 2004). Landsat data is more affordable, and it has the ability to acquire and analyze large volumes of observations than other data (Cohen and Goward, 2004). Cohen and Goward, (2004), added that Landsat data has been used for mapping land and vegetation cover changes and it continues to become commonly used in ecology. For instance, Landsat 7 showed the potential applicability and usability in mapping vegetation in Delaware Water Gap National Recreation Area in the United States of America; producing an overall accuracy of 82% and a Kappa coefficient of 0.80% (de Colstoun *et al*., 2003). In addition, Cohen and Goward (2004), further stated that of all remotely sensed data, those acquired by Landsat sensors have played the greatest crucial role in spatial and temporal scaling. Nonetheless, the challenge with Landsat is that it has a medium spatial resolution of 30m, which makes it difficult to be applied on a smaller scale (Pape, 2006). This is, however, now compensated by the introduction of the 10 m Sentinel 2 multispectral instrument at a 5-day interval and a global footprint (Sepuru and Dube, 2018; Thamaga and Dube, 2018).

Various classification approaches have been developed and widely used to derive thematic land cover maps for environmental management purposes from remotely sensed data (Wang *et al*., 2010; Al-doski *et al*., 2013). Classification techniques are used to extract and spatially characterize the landscape from the satellite images. In literature, image classification techniques have been recognized as the most effective means to classify different types of land-use and land-cover since the mid-1800s (Wang *et al*., 2010; Al-doski *et al*., 2013) and result in improved classification accuracies (Lu and Weng, 2007). Broad commonly used types of image classification techniques in remote sensing included supervised image classification, unsupervised image classification, and hybrid classification (object-based image analysis) (Al-doski *et al*., 2013).

Supervised classification is the technique in which the analyst selects representative samples for each land cover class. Then, the software uses those training sites and applies them to the entire image (Liu, 2005). In supervised classification, different algorithms such as the maximum likelihood and minimum-distance classification are available and the maximum likelihood is commonly used. The maximum likelihood procedure discovers the value of one or more parameters for a given statistic, which makes the known likelihood distribution a maximum (Ahmad and Quegan, 2012).

Unsupervised classification is the process by which the analyst groups pixels with similar spectral values based on their characteristics (Liu, 2005; Phillips *et al*., 2007). For the analyst to create clusters, they use image-clustering algorithms. There are two most frequent clustering methods used for unsupervised classification and these are the K-means and Iterative Self-Organizing Data Analysis Technique (ISODATA) (Al-doski *et al*., 2013). The advantage of using unsupervised classification techniques is that they do not require the analyst to specify training data, but broadly accessible in image processing and statistical software automatically translates raw image data into useful information. However, the disadvantage of using unsupervised classification is that the computer determines the spectrally separable class and then defines their value (Al-doski *et al*., 2013) and this can compromise the accuracy for biodiversity assessment.

Al-doski *et al*., (2013) added that besides the other classification procedure having more advantages over the other, scientists have realized that there are many limitations for both major classification methods (supervised and unsupervised), hence the development of a new classification approach called hybrid classification method (object-based image analysis). Hybrid classification methods, take both the advantages of the supervised classification and unsupervised classification techniques (Al-doski *et al*., 2013). The combination of different classification approaches have shown to be helpful for the improvement of classification accuracies by many researchers (Mucova *et al*., 2018). Mucova *et al*., (2018) used the Object-Based Image Analysis in their study to assess land use and land cover and the overall classification map was successful. These methods, therefore, provide unique opportunities for assessing biodiversity in protected areas and this information can be useful in making informed management decisions that can be beneficiary to CBNRM implementation.

According to Lu and Weng, (2007) and Al-doski *et al*., (2013) image classification process is influenced by a variety of factors and these can be linked to the availability of remotely sensed data, landscape complexity, image band selection, the classification algorithm used, the analyst's knowledge of the study area, and experience with the classifiers used amongst others. Therefore, it is better to combine the classification methods for better classification results if our understanding for biodiversity in PAs is to be fully understood.

2.7 Vegetation characterization using remotely sensed derivatives: Spectral vegetation indices

Over the years, many Vegetation Indices (VIs) have been developed and used for determining the vigor and vegetation health. Xue and Su (2017) emphasize that VIs particularly those derived from remote sensing data collected over plant canopies are relatively simple and applicable for quantitative and qualitative assessment of vegetation cover, vigor and growth dynamics for each pixel in a satellite image. These indices are influenced by factors such as soil background reflectance, atmosphere and vegetation density. In other works like that of Mróz and Sobieraj, (2004), it was demonstrated that VIs are also related to vegetation type, leaves characteristics, pigment concentration and geometry of the sun between the target feature and sensor. For instance, in terms of soil properties, some studies have shown that dark soils result in higher VIs values when compared with bright soil, using the Normalized Difference Vegetation Index (NDVI) (Mróz and Sobieraj, 2004).

VIs can be classified into the following groups: a) Slope-based, b) Distance-based, c) Orthogonal transformation and d) Red Edge Inflection Point (REIP) (Silleos *et al*., 2006). However, most of the authors including Silleos *et al*., (2006) categorize these VIs into two groups, namely, Slope-based and Distance-based. Slope-based VIs are indices that record the difference between response configurations of vegetation in the Red and Near-Infrared (NIR) portions of the electromagnetic spectrum (Mróz and Sobieraj, 2004; Silleos *et al*., 2006). Slope-based VIs indicate both the status and richness of green vegetation cover and biomass, which is helpful in conservation. The slope-based vegetation indices include a) Ratio Vegetation

Index (RATIO); b) NDVI; c) Transformed Vegetation Index (TVI) and d) Thiam's Transformed Vegetation Index (TVI) (Mróz and Sobieraj, 2004; Silleos *et al*., 2006). For example, researchers emphasize that NDVI has been successfully used to assess the risk of fire, detection and monitoring of fire, mapping burnt areas, monitoring vegetation recovery for conservation purposes (van Leeuwen *et al*., 2010; Yengoh *et al*.,2014), as well as a proxy for mapping the coverage of surface floating aquatic weeds (Dube *et al*., 2014).

2.8 Species diversity indices as proxies for vegetation species monitoring and assessment

Species diversity indices are a qualitative measure that reflects different types of species within a community or sample, and how common or rarely are they from each other. There are different diversity indices that are widely used to evaluate, survey and help understand and conserve ecosystems, especially in PAs (Dogan and Dogan, 2006). Most commonly used species biodiversity indices include the Shannon-Wiener Diversity Index (H′), Species richness (S) and Simpson Diversity Index (D) (Dogan and Dogan, 2006; Madonsela *et al*., 2017), Pielou Diversity Index (J) and Margalef Diversity Index (dma) (Peng *et al*., 2018). A number of reasons have been put forward for the common use of the Shannon-Wiener index. The fundamental reason being that it is less affected by the presence of rare species and it emphasizes the richness component of diversity, whereas Simpson's index is known to emphasize the evenness component (Dogan and Dogan, 2006). These species diversity indices are known to produce best results when working with other remote sensed indices (Madonsela *et al*., 2017) making them more relevant for conservation-related assessments and efforts.

For instance, Madonsela *et al*., (2017) using regression analysis, established a significant positive relationship ($p < 0.05$) between VIs and measures of tree species diversity in savannah woodland belt. The Simple Ratio Index (SRI) derivatives (standard deviation and the range) had the highest relationship with H' (r^2 of 0.36 and 0.34 respectively), D_2 (r^2 of 0.41 and 0.38, respectively) and S (r^2 of 0.24 and 0.22) when compared to other remotely sensed data i.e. NDVI and related derivatives. Similarly, Peng *et al*., (2018) used the stepwise linear regression to assess plant species diversity based on hyperspectral-derived indices at a fine scale in Hunshandak Sandland, in China. The results showed that the first-order derivative value (FD) can accurately estimate the D_2 with an r^2 of 0.83, J with an r^2 of 0.87and H' with an r^2 of 0.88.

2.9 The integration of remote sensed derivatives and species diversity indices

Remotely sensed indices are amongst the important diversity indicators for the management and conservation of ecosystems from local to regional scale (Mutowo and Murwira, 2012;

Mapfumo *et al*., 2016; Rocchini *et al*., 2016). According to Mapfumo *et al*., (2016), modeling the relationship between remotely sensed data and species diversity indices could advance the capability to map diversity at large spatial extents. Remotely sensed data, such as NIR, middle infrared and thermal infrared bands have been strongly recommended for discriminating species diversity (Peng *et al*., 2018). For example, Arekhi *et al*., (2017) in the Gönen dam watershed area, Turkey, found the NDVI to have the highest significant and positive correlation with tree richness (2× 2 pixels) and H' calculated from basal area (3 × 3 Shannon Index Basal Area (SIBA)) with r of 0.59 and r of 0.69, respectively. Similarly, Mohammadi and Shataee., (2010) modeled S using the band set of ETM5, ETM7, Derived Vegetation Index (DVI), wetness and variances of ETM1, ETM2 and ETM5 and their results demonstrated an r^2 of 0.59 and RMSE of 1.51 in the Hyrcanian forests of Iran. Moreover, Metternicht, (2010)'s analysis of the review on land degradation in America and the Caribbean reveals that Landsat series data (MSS, TM, ETM+) are the most commonly used data sources, with 49%s. Madonsela *et al*., (2017), stated that satellite images remain useful in estimating tree species diversity for conservation research particularly in Savannah woodland.

However, the results of the combined indices are influenced by several factors including plant condition (e.g. disturbance like logging) (Mapfumo *et al*., 2016) and amount of rainfall received (Madonsela *et al*., 2017). Therefore, it is important to check the relationship between remotely sensed indices and species diversity indices in order to choose the relevant and appropriate ones for better results, since ecosystems occur in different conditions. Mapfumo *et al*., (2016) added that it is essential to develop models that can be applied usually across several ecosystems regardless of their conditions. In addition, Dagan and Dogan, (2006) emphasize that choosing appropriate methods and tools, give the indices the potential to map diversity which can help to assess the ecosystems integrity, degradation levels and for conservation purposes. This information can be beneficiary in understanding the possible impacts of community involvement in PAs.

2.10 Limitations of spatial explicit methods in biodiversity assessment and monitoring

Shortcomings of integrating remote sensing in ecological monitoring are that some of the ecology experts are rarely exposed to remote sensing applications and terminology (Wang *et al*., 2010), while on the other side remote sensing experts are not exposed to fundamental ecological concepts. Data and systems accessibility is another factor inhibiting the initiation of more teamwork between the remote sensing and ecology communities.

Another limiting factor for applying GIS and remote sensing in conservation is that some datasets are expensive to acquire from commercial satellites, particularly images with a high spatial resolution (Wang *et al*., 2010). Environmental factors are also among the limiting factors, since they interfere with remotely sensed data. For instance, Madonsela *et al*., (2017) realized that the incorporation of remotely sensed variables with environmental variables such as rainfall and geology could result in better results for species diversity. This was realized when their study results, explained only 41-42% variability in tree species diversity, due to interference from environmental factors and remotely sensed data in Savannah woodland. They, therefore, recommended future research to combine Landsat-8 variables with environmental variables which are known to impact tree species distribution. Tree species distribution is affected by several factors amongst them include temperature, rainfall, vegetation structure, soil composition and land use (Seitz., 2017; Yilmaz *et al*., 2017). For example, Yilmaz *et al*., (2017) found that bedrock type and precipitation during the wettest month affect the distribution of *Muscari latifolium.*

2.11 Conclusions

Community involvement in the conservation of biodiversity in PAs plays a crucial role since most of these areas involve many stakeholders with varying and conflicting interests. Literature shows that local and adjacent communities are involved in the conservation of biodiversity in PAs as well as their management. However, for effective and full participation of local and adjacent communities in the conservation, people should get more benefits than the costs they face. When people get more benefits than the costs they incur, they tend to develop positive perceptions and attitudes towards conservation and results in effective participation. Biodiversity plays an important role, in both the environment as well as sustaining human-livelihoods. Community involvement was found to be an effective tool to tackle conservation issues. Moreover, the integration of spatial explicit methodologies with diversity indices can provide an operational framework or tools to monitor, assess and understand biodiversity condition and status, which are the ingredients that can help enhance conservation across Africa. Further, adopting collaborative modelling or transdisciplinary approaches through the integration of qualitative and spatial explicit techniques is recommended to monitor and assess biodiversity status in PAs and above all, to inform policy and decision making. The use of spatial explicit methods for species mapping and trend analysis at a landscape can provide the baseline information required for past, current and future monitoring, as well as an ecological basis for land management, conservation and decision-making.

3. Chapter three

Estimating tree species diversity as an indicator of biodiversity conservation in Blouberg Nature Reserve

Abstract

We use remotely sensed data to estimate species diversity in Blouberg Nature Reserve (BNR) in the Limpopo province, South Africa to understand the state of biodiversity since the local communities' involvement in biodiversity conservation initiatives. To achieve this objective, Landsat series data collected before and after the community involvement was used in conjunction and selected diversity indices i.e. Shannon-Wiener Index (H') and Simpson Index (D). 15m × 15m field plots (n = 30) were adopted and all trees within each plots were identified, with the help of Botanists. Regression analysis was applied to determine relationship between satellite derived tree species diversity and field observations. The results of this study demonstrated a significant ($p < 0.5$) variation in tree species diversity from 1990 to 2019. The highest relationship was obtained between H' and the combined remotely sensed spectral data and Vegetation Indices (VIs) when compared to other derived satellite data. Further, the results showed positive significant relationship ($p < 0.05$) between combined remotely sensed data and observed H' index with ($r^2 = 0.36$) and ($r^2 = 0.34$) for before and after involving local communities in biodiversity conservation respectively. Thus, the findings of the study indicate that the ecological condition of the reserve was slightly affected since the involvement of local communities in biodiversity conservation. Overall, findings of the study underscore the relevance of remotely sensed data in assessing the ecological condition of protected areas and this information can help in decision-making.

Keywords: ecological status, mapping, species diversity, satellite data, statistical analysis, spatial characterisation

3.1 Introduction

Tree species plays an important role in the functioning of an ecosystem and productivity in general (Cleland, 2011; Arekhi *et al*., 2017). Tree species form the basis of the food chain, providing food base and habitat, which boost ecological diversity of an area (Xie *et al*., 2008; Cleland, 2011). However, tree species diversity loss and disturbance are accelerating worldwide due to human disturbance (Cleland, 2011; Marcon, 2013; Sieber *et al*., 2013; Thant,

2017) and global climate change (Khare and Ghosh, 2016; Li *et al*., 2018). Tree species loss could threaten the stability of the ecosystem services on which humans depend (Cleland, 2011). Among the main human threats to biodiversity loss, deforestation (Li *et al*., 2018), bush encroachment, pollution (Thant, 2017) and management practices are the key drivers (Oli *et al*., 2015; Paudel and Sah, 2015). Landscape patterns related to disturbance, fragmentation and land cover change have been shown to affect the abundance of rare and endangered species as well as biodiversity. Amongst other indicators for tree species loss include functional diversity loss, habitat loss, population declines and species invasions (Wang and Gamon, 2019).

This ongoing biodiversity and ecosystem loss instantly requires assessment techniques that could quickly identify and monitor degradation hotspots (Krishnaswamy *et al*., 2009; Khare and Ghosh, 2016; Rocchini *et al*., 2019) especially in PAs. PAs are the cornerstone of global conservation efforts, therefore, requires long-term monitoring in order to maintain species integrity value (Vodouhê *et al*., 2010; Sieber *et al*., 2013). A halt of biodiversity loss is one of the Sustainable Development Goals of the United Nations' goal (Rocchini *et al*., 2019). Thus, to plan, manage and reduce biodiversity loss in an effective and sustainable way, it is essential to understand tree species diversity and composition of the ecosystems (Arekhi *et al*., 2017).

Traditionally, biodiversity has been monitored using field surveys, literature reviews, map interpretation and collateral as well as ancillary data analysis (Xie *et al*., 2008). This traditional in situ biodiversity monitoring is usually costly and time consuming (Krishnaswamy *et al*., 2009; Arekhi *et al*., 2017; Wang and Gamon, 2019; Rocchini *et al*., 2019). Additionally, in most of the cases do not allow to get temporal replicates (Rocchini *et al*., 2019). Moreover, species sampling in the field was found to have several challenges, amongst them include, observer bias, spatial errors, and historical bias on species distribution records (Rocchini *et al*., 2013).

Some studies that applied remote sensing in biodiversity estimation mostly focused on mapping habitat through land cover classification without providing detailed verification of the habitat or tree diversity. For instant the study by Arraut *et al*., (2018) produced vegetation structure map of Hwange National Parkin Zimbabwe using Landsat 8-Operational Land Imager (OLI). Thus, the development of satellite remote sensing has provided an opportunity to determine species diversity and other biodiversity at large spatial extents (Nagendra *et al*., 2010; Rocchini *et al*., 2016; Arekhi *et al*., 2017; Thamaga, 2018; Shoko *et al*., 2019). Remote sensing techniques provide an advanced, effective and practical method of obtaining accurate information on tree species diversity in a range of ecosystems (Wang and Gamon, 2019) and their changes over time (Rocchini *et al*., 2019).

Comparatively, remote sensing can cover a large area over a short period, whereas field based methods are restricted to small areas (Rocchini *et al*., 2019). In addition, the emerging remote sensed data allows spatial representation of species diversity, which could not be achieved using other methods. It assesses biodiversity through tree characters or spectral information content (Wang and Gamon, 2019). Remote sensed data has also been used to understand the distribution of biodiversity to better identify high priority areas for conservation (Araújo *et al*., 2019; Marcon, 2013; Rocchini *et al*., 2019), help maintain essential ecosystem goods and services (Wang and Gamon, 2019) and ecological restoration efforts (Champagne *et al*. 2004). Furthermore, derived tree diversity maps from remote sensing and GIS data play an outstanding role in effective management and decision-making for vegetation pattern (Zhang *et al*., 2013; Arekhi *et al*., 2017). Premised on this background, this study seeks to estimate species diversity in Blouberg Nature Reserve (BNR) in the Limpopo province, South Africa to understand the state of biodiversity since the local communities' involvement in biodiversity conservation initiatives.

3.2 Materials and methods

3.2.1 Remote sensed data acquisition and pre-processing

Four Landsat satellite images were downloaded from United States Geological Survey (USGS) through Earth Explorer online search tool (https://earthexplorer.usgs.gov/). Satellite images used in this study are detailed in table 3.1. These images were collected in different years in order to examine the change in diversity within the reserve since local communities were involved in biodiversity conservation. Out of four collected Landsat satellite images, three were Landsat-5 Thematic Mapper (Landsat-5 TM) captured in 1990, 1996 and 2009, whereas one was Landsat-8 OLI captured in 2019. The selection of years was determined by the availability of free imagery from Earth Explorer. The collected images cover the whole area of the study area. The collected Landsat-5 TM and Landsat-8 OLI images have a spatial resolution of 30m and a revisit aptitude of 16 days. Furthermore**,** the images have 7 and 11 bands with only 6 and 8 bands having multi-spectral data in the visible, Near Infrared (NIR) and Shortwave Infrared (SWIR) regions of the electromagnetic spectrum respectively (Madonsela *et al*., 2017). Overall, Landsat data is freely available, and it has the ability to acquire large volumes of observations than other data. Moreover, it has been used for mapping land and vegetation cover changes and it continues to be commonly used in ecology (Cohen and Goward, 2004). Landsat satellite images were downloaded during clear and sunny day with the cloud cover of less than 30. Only Landsat-8 OLI was atmospherically corrected using the Dark Object Subtraction (DOS1) model under Semi-Automated Classification (SCP), which masks out clouds and shadows, among other non-target effects.

Furthermore, spectral reflectances from Landsat images for different years were then extracted corresponding to each collected tree species coordinates points. The extracted spectral reflectances were then used to calculate selected Vegetation Indices (VIs) (Table 3.2). The VIs were used in this study were selected based on their well performance of compensating soil background influences and atmospheric effects in biodiversity conservation. Remote sensed variables in conjunction with field based diversity indices were then used to determine the best model to map tree species diversity in XLSTATS software, using simple and multi-linear regression analysis. The best developed model was then used to estimate tree species diversity across different years in a GIS environment.

Table 3. 1: Landsat-8 (OLI) spectral bands description

Landsat-8 OLI	Band #	Band name	Wavelength (µm)	Resolution
	1*	Coastal/ Aerosol	0.43-0.45	30
	2*	Blue	0.45-0.52	
	3*	Green	0.53-0.60	
	4*	Red	0.63-0.68	
	5*	Near Infrared (NIR)	085.-0.89	
	6*	Short-wave Infrared (SWIR)1	1.56-1.66	
	7*	Short-wave Infrared (SWIR)2	2.10-2.30	
	8	Panchromatic	0.50-0.68	15
	9*	Cirrus	1.36 -1.39	30
Thermal Infrared Sensor (TIRS)	10	Long-wave Infrared (LWIR) 1	10.30-11.30	100
	11	Long-wave Infrared (LWIR) 2	11.50-12.50	
Landsat-5	1*	Visible Blue	0.45 - 0.52	
	2*	Visible green	0.52 - 0.60	
	3*	Visible Red	0.63 - 0.69	

	4*	Near Infrared (NIR)	0.76 - 0.90	30
	5*	Short-wave Infrared (SWIR)1	1.55 - 1.75	
	6	Thermal	10.40 - 12.50	120
	7*	Short-wave Infrared (SWIR)2	2.08 - 2.35	30

*-used spectral bands

Table 3. 2: Vegetation indices used in the study and their equations

Vegetation Index	**Equation**	**Reference**
Normalized Difference Vegetation Index (NDVI)	$NDVI = \frac{NIR - RED}{NIR + RED}$	Rouse *et al.* (1974)
Soil-adjusted vegetation index (SAVI)	$SAVI = \frac{NIR - RED}{(NIR + RED + L)} * (1 + L)$	Huete (1988)
Enhanced Vegetation Index (EVI)	$EVI = G * ((NIR - RED)/(NIR + C1 * RED - C2 * BLUE + L))$	Huete *et al.* (1999)
Simple Ratio Index (SRI)	$SRI = \frac{NIR}{RED}$	Tucker (1979)

L is a soil fudge factor that varies from 0 to 1 depending on the soil the coefficients adopted in the MODIS-EVI algorithm are; L=1, C1 = 6, C2 = 7.5, and G (gain factor) = 2.5.

3.2.2 Tree species data

3.2.2.1 Sampling and tree species data collection

The tree species sampling for data collection purposes was performed in 30 plots of 15m × 15m each. Work by Mutowo and Murwira, (2012) and Mapfumo *et al.*, (2016), have shown that sampling plot sizes widely used ranges between 25 and 200m^2 in tall shrub communities and 200-25000 m^2 for trees in woods and forests. The statement guided the selected plot size for this study and it falls within the range. Simple random sampling was used to define the placement of sampling plots (Oli *et al.*, 2015), with a minimum separation of 200m to avoid overlapping sampling plots (Paudel and Sah, 2015). All tree species type per plot were identified and recorded. The coordinates of each identified tree species were recorded, using Global Positioning System (GPS). 488 tree species belonging to 19 families were recorded. The collection of tree species data was conducted in April 2019.

3.2.2.2 Measuring diversity of tree species

In this study, we used the most frequently used diversity indices to quantify diversity in each plot i.e. Shannon-Wiener Diversity Index (H') and Simpson Diversity Index (D) (Table 3.3). Madonsela *et al*., (2017) and Peng *et al*., (2018) confirmed that H' and D, are the frequently used diversity indices in ecological literature. H' is a qualitative measure that reflects different types of species within a community or sample, and how common or rarely are they from each other (Mutowo and Murwira, 2012; Ifo *et al*., 2016; Mapfumo *et al*., 2016; Madonsela *et al*., 2017). H' ranges from 0 to 5, usually between 1.5 and 3.5 but reaches 4 in rare cases (Türkmen and Kazanci, 2010). The D is generally influenced by the abundance in the distribution of tree species (Mutowo and Murwira, 2012). It ranges from 0 to 1 where high scores, i.e. close to 1 indicate high diversity whereas low scores, i.e. close to 0 indicate low diversity (Türkmen and Kazanci, 2010; Mapfumo *et al*., 2016). These indices were used in this study because they consider both species richness and abundance when measuring species diversity (Madonsela *et al*., 2017). Furthermore, H' is less affected by the presence of rare species (Dogan and Dogan, 2006; Mapfumo *et al*., 2016; Rocchini *et al*., 2016). H' and D were calculated as indicated in Table 3.3.

Table 3. 3: Summary of diversity index and their expression

Species diversity index	Equation	Reference
Shannon-Wiener Diversity Index (H')	$H' = -\sum_{i=1}^{S} Pi \ln Pi$	Shannon and Wiener (1949)
Simpson Diversity Index	$D = 1 - \frac{\sum_{i-1}^{n} ni(ni-1)}{N(N-1)}$	Simpson (1949)

Where, H' is index of species diversity, Pi is the proportional abundance of *i*th species is the number of individuals of all the species, ln is natural logarithm, *ni* = number of individuals of each species, *N* = total number of individuals of all species.

3.2.3 Relationship between tree species diversity indices and remote sensed data

The relationship between species diversity indices as a response variable and spectral data as predictor variable was investigated using simple and multi-linear regression analysis techniques to determine species diversity. The relationship was determined between most commonly used diversity indices (Table 3.3) and remote sensed data. The Root Mean Square Error (RMSE), Coefficient of determination (r^2) and corrected Akaike's Information Criterion (cAIC) of the linear regression guided the selection of the most appropriate model to map tree species diversity.

The best fitting model was selected using the following conditions: 1. the smallest RMSE and cAIC, and 2. the highest r^2. The RMSE measures how close the model could predict field measurements; r^2 measures the proportion of the variance in the dependent variable that is predicted from the independent variable, whereas cAIC estimates the quality of each model, relative to each of the other models. Peng *et al*., (2018) added that the objective of cAIC is to select the best approximating model.

Further, the Shapiro Wilk test was used in this study to investigate normality of the data in order to fulfil the requirements of linear regression analysis. According to Mutowo and Murwira, (2012), linear regression requires that data are normal distributed. In addition to normality, Pearson‘s correlation coefficients were used to evaluate the correlation between the variables. Moreover, P-value was used to check the significance of the correlated variables.

3.2.4 Environmental variables

In addition to diversity indices and remote sensed data, environmental variables such as rainfall, temperature, Digital Elevation Model (DEM) and evapotranspiration were used in this study (Table 3.4) since they are known to affect species diversity pattern (Zhang *et al*., 2013; Imani *et al*. 2016; Sainge *et al*., 2019; Shoko *et al*., 2019). Rainfall, evapotranspiration and temperature were averaged annually. A DEM at a spatial resolution of 30m was also used to derive the relief of a surface. Evapotranspiration was also integrated in this study to understand the water lost from the tree since it might influence species diversity (Silva *et al*., 2017; Li *et al*., 2019). Further, according to Liu and El-Kassaby, (2018), Species richness is best predicted by climatic variables such as evapotranspiration and asserted that evapotranspiration may greatly impact tree height since it uniquely link water cycle, energy cycle, and carbon cycle. Data were used to show the general pattern of the used environmental variables variations and how they might likely have affected the diversity within the study area. Thus, the relationship between species diversity and environmental variables was also explored based on tree species data collected from the field. The selected environmental variables were used in this study because they are amongst the most significant factors affecting species diversity and the woody vegetation (Nguyen *et al*., 2015).

Table 3. 4: Environmental variables that were used in this study.

Variable	Definition	Source
Rainfall	Mean annually total in millimetres (mm)	https://wapor.apps.fao.org/catalog/1
Evapotranspiration	Mean annually total, in millimetres (mm)	
Temperature	Mean annually total, in degrees Celsius (°C).	
DEM	Relief in meters (m)	http://srtm.csi.cgiar.org/

3.3 Results

3.3.1 Tree species in BNR

Four hundred and eighty-eight tree species belonging to 19 families were recorded within 6750 m^2 of the BNR. Predominant tree species are from Fabacea, followed by Malvaceae and Boraginaceae with tree species of 200, 126 and 50 respectively. Malvaceae, Fabacea, Combretaceae and Rubiaceae are the only families with more than one type of tree species (Table 3.5). Two commonly used diversity indices, H' and D were used in this study to see the variation in tree community among the plots. The tree species varied in few plots across the study area. The lowest value obtained from the used diversity indices was from plot 25 with (H' = 0.15; D = 0.29) whereas the highest value was obtained in plot 3 (H' = 3.14) and plot 11 (D = 0.88). Plot number 25 was noted with weakest tree species diversity, with the lowest richness of 2 amongst other plots. The number of tree species found in each plot mostly influenced the results. The information on tree species can therefore provide baseline information for conservation of the biodiversity particularly in PAs.

Table 3. 5: Tree species lists and their frequencies of the study area

Family	Names	Number of trees	Total
1. Malvaceae	*Grewia flava*	80	126
	Grewia flavascenes Juss	46	
2. Phyllanthaceae	*Pseudolachnostylis maprouneifolia*	43	43
3. Burseraceae	*Commiphora Jacq. tree*	3	3
4. Asteraceae	*Tarchonanthus camphoratus L.*	3	3
5. Fabaceae	*Philenoptera violacea (Klotzsch) Schrire*	9	200
	Dichrostachys cinerea (L.) Wight & Arn	119 38	

	Acacia nigrescens Acacia Nalatica	34	
6. Rubiaceae	*Vangueria infausta Burch. subsp. Infausta*	4	13
	Plectroniella armata (K. Schum.) Robyns	9	
7. Loganiaceae	*Strychnos spinosa Lam.*	6	6
8. Anacardiaceae	*Sclerocarya birrea*	7	7
9. Combretaceae	*Combretum imberbe Wawra*	5	9
	Terminalia prunioides M.A.Lawson	4	
10. Brassicaceae	*Boscia albitrunca (Burch.) Gilg & Gilg-Ben.*	5	5
11. Kirkiaceae	*Kirkia acuminata Oliv.*	2	2
12. Euphorbiaceae	*Spirostachys africana Sond.*	6	6
13. Ebenaceae	*Euclea undulata Thunb.*	12	12
14. Phyllanthaceae	*Flueggea virosa (Roxb.ex Willd.) Voigt*	1	1
15. Solanaceae	*Lycium ferocissimum Miers*	3	3
16. Boraginaceae	*Ehretia rigida (Thunb.) Druce*	25	50
	Cordia grandicalyx	25	
17. Rhamnaceae	*Ziziphus mucronata Willd. subsp. mucronata*	7	10
	Berchemia zeyheri (Sond.) Grubov	3	
18. Combretaceae	*Terminalia sericea Burch. ex DC.*	4	4
19. Burseraceae	*Commiphora mollis (Oliv.) Engl.*	5	5
Total			488

3.3.2 Correlation between H' and VIs, and Spectral data

In this study, correlation between the variables was evaluated using Pearson where H' for 2019 demonstrated negative correlation with spectral bands except with band 9 and all VIs. Overall, VIs had a positive correlation with H' over period when compared to the use of the raw Landsat derived spectral data (Table 3.6). To fulfil the linear regression, normality for the data was tested using Shapiro Wilk test. The findings of the study indicated that data does not statistically deviate from the normal distribution, i.e. the data does not follow normal distribution for all used years with (p = < 0.0001). The findings of the study demonstrated negative correlation between H’ and Landsat spectral data over period. The correlation was significant over period except in 1996 (Table 3.6).

Table 3. 6: Correlation between H' and remote sensed data

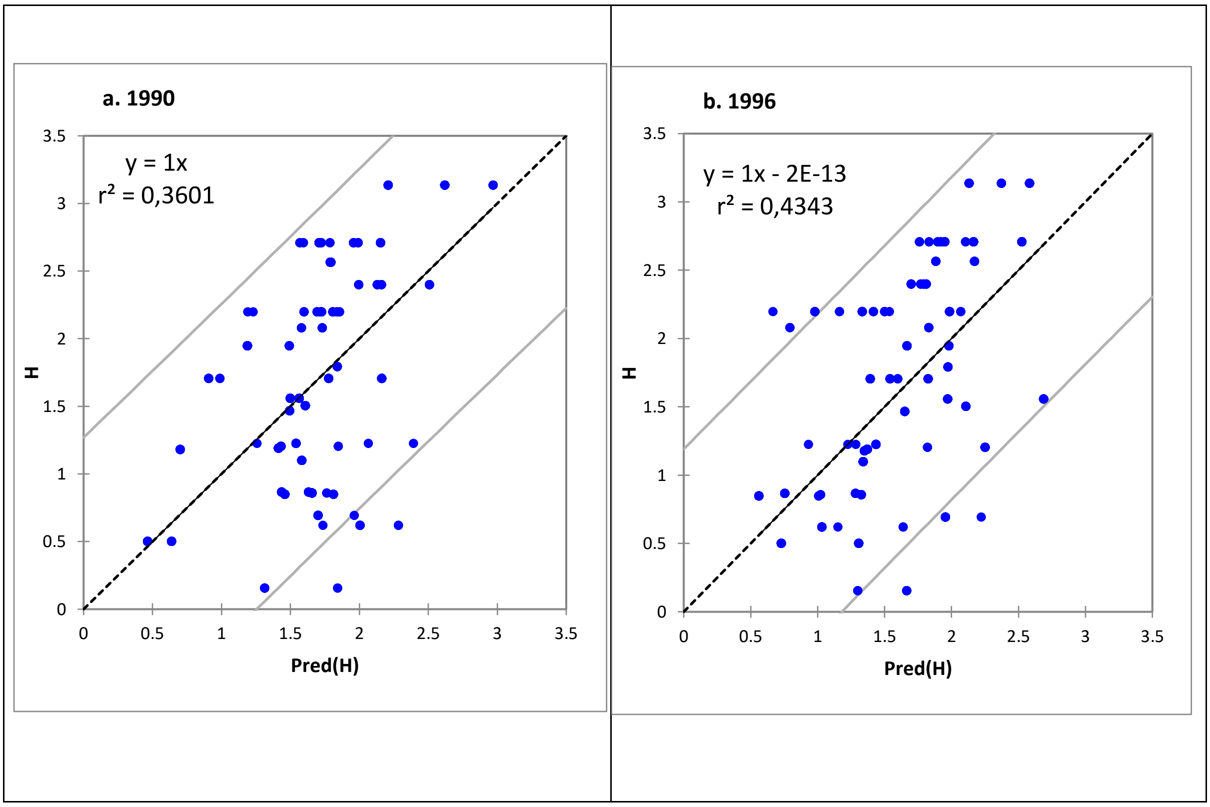
	2019		2009		1996		1990	
	Correlation to H’	P-value	Correlation to H’	P-value	Correlation to H’	P-value	Correlation to H’	P-value
Band 1	-0.10	**0.02***	**-0.12**	**0.01***	-0.03	0.55	-0.25	**0.00***
Band 2	-0.12	**0.01***	-0.07	0.11	-0.06	0.19	-0.17	**0.00***
Band 3	-0.22	**<0.0001***	**-0.12**	**0.01***	0.03	0.54	-0.06	0.16
Band 4	-0.30	**<0.0001***	**-0.25**	**<0.00***	0.09	0.06	0.12	**0.01***
Band 5	-0.08	0.07	**-0.29**	**<0.00***	-0.04	0.33	0.13	**0.00***
Band 6	-0.36	**<0.0001***						
Band 7	-0.38	**<0.0001***	**-0.29**	**<0.00***	-0.01	0.90	-0.01	0.88
Band 9	0.14	**0.002***						
NDVI	0.17	**0.000***	0.03	0.46	0.14	**0.00 ***	0.21	**<0.00***
SAVI	0.07	0.13	0.05	0.32	0.19	**<0.00***	0.22	**<0.00***
EVI	0.09	**0.04***	**0.13**	**0.00***	0.19	**<0.00***	0.07	0.13
SRI	0.20	**<0.00***	**0.10**	**0.04***	0.13	**<0.00***	0.21	**<0.00***

3.3.3 Simple and multi-linear results in predicting species diversity

A series of simple linear regressions were performed, regressing diversity indices (H’ and D) against each of the Landsat spectral bands and VIs, over period. Simple linear models based on Landsat spectral bands and VIs with H’ did not perform well when compared to multiple linear regression. H’ and band 7 (SWIR-2) for 2019 had slightly better relationship of (r^2 = 0.14) and (RMSE = 0.73) (remove brackets) amongst other remote sensed data over period, but this was slightly better than band 6 (SWIR-1) with r^2 = 0.12 and RMSE = 0.74. With VIs, H’ for 1996 had better relationship with NDVI and SAVI (r^2 = 0.05) and (RMSE = 0.77; 0.77) respectively when compared to other VIs over period. Beside, evaluating the relationship between multiple variables, H' demonstrated higher relationship to combined Landsat spectral bands and VIs for all years used in this study. For example, in 1990 (r^2 of 0.36), 1996 (r^2 of 0.43), 2009 (r^2 of 0.30) and 2019 (r^2 of 0.34) (Table 3.7 a), as compared to Landsat spectral bands (Table 3.7 c) and VIs (Table 3.7 b). Furthermore, both H' and D showed the lowest relationship with VIs (Table 3.7 b). In this regard, the best model for estimating tree species diversity was derived from the H' and combined Landsat spectral bands and VIs for all years (Figure 3.1).

Table 3. 7: Relationship observed between two common measures of tree species diversity (H' and D) and a. combined VIs and Landsat spectral bands, b. VIs and c. Landsat spectral bands

Year	**Index**	**R^2**	**RMSE**	**AIC**
a.				
1990	H'	0.36	0.64	-428.03
	D	0.30	0.10	-2282.14
1996	H'	0.43	0.60	-488.13
	D	0.20	0.10	-2219.76
2009	H'	0.30	0.67	-387.88
	D	0.20	0.10	-2220.10
2019	H'	0.34	0.65	-407.33
	D	0.24	0.10	2236.89
b.				
1990	H'	0.08	0.76	-261.67
	D	0.09	0.11	-2166.30
1996	H'	0.28	0.67	-382.70
	D	0.04	0.11	-2143.04
2009	H'	0.13	0.74	-292.36
	D	0.15	0.10	-2201.47
2019	H'	0.14	0.73	-296.21
	D	0.08	0.11	-2161.93
c.				
1990	H'	0.21	0.71	-318.23
	D	0.17	0.10	-2215.99
1996	H'	0.29	0.67	-386.94
	D	0.16	0.10	-2201.60
2009	H'	0.25	0.69	-359.73
	D	0.17	0.10	-2206.86
2019	H'	0.21	0.71	-327.78
	D	0.17	0.10	-2206.98


a. 1990
y = 1x
r² = 0,3601
H
Pred(H)
0
0.5
1
1.5
2
2.5
3
3.5
b. 1996
y = 1x - 2E-13
r² = 0,4343
H
Pred(H)

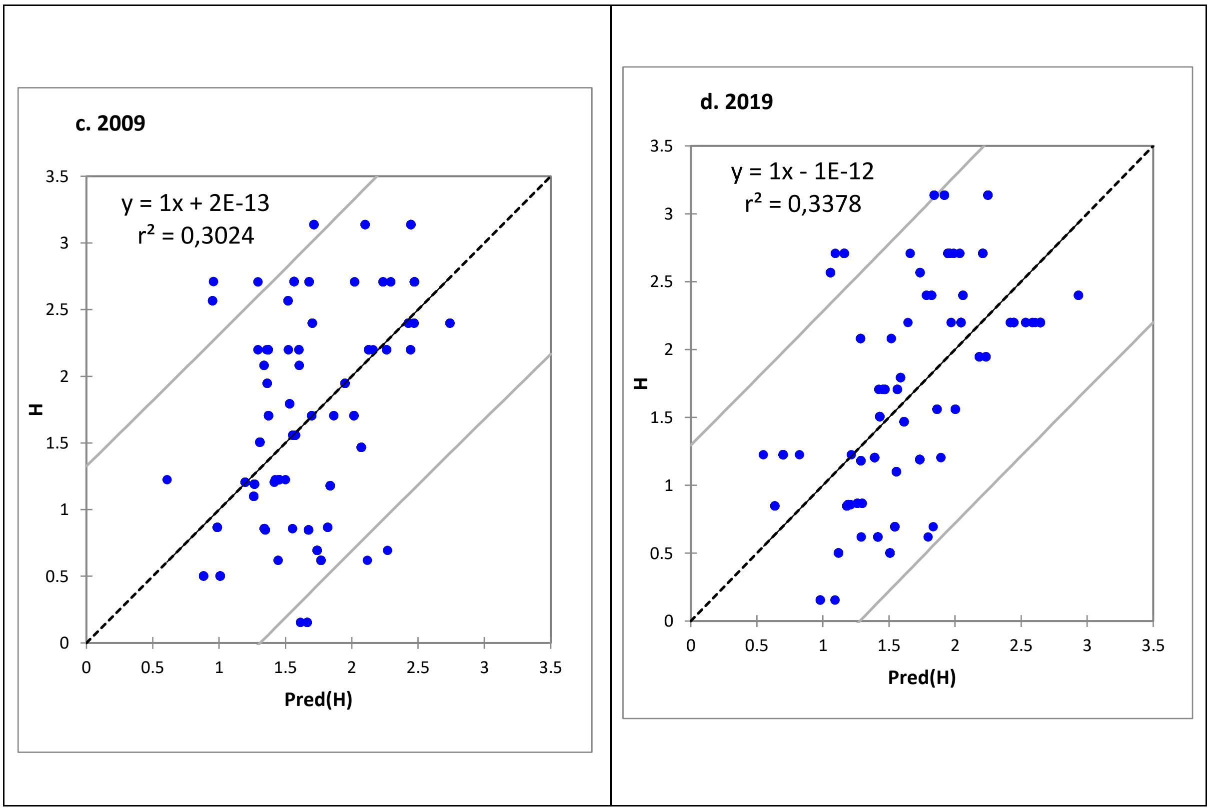
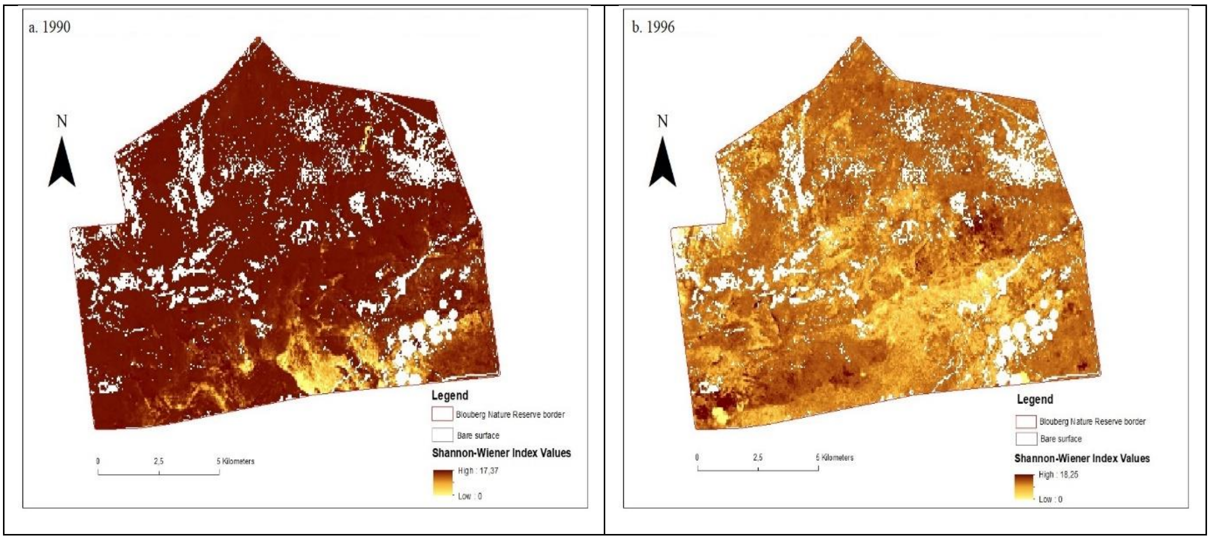


Figure 3. 1**:** Linear regression of the field measured values (y-axis) and predicted values (x-axis) for tree species diversity indices in the BNR.

In general, H’ demonstrated better relationship with combined Landsat spectral bands and VIs than with individual remote sensed data. Consequently, the best model (regression equation) with lowest RMSE and cAIC, and highest r2 was derived from combined spectral bands and VIs and used to map diversity in the study area across different years. Obtained model equation was used to calculated diversity map in GIS environment. Consequently, H’ species diversity maps of the study area were derived (Figure 3.2).



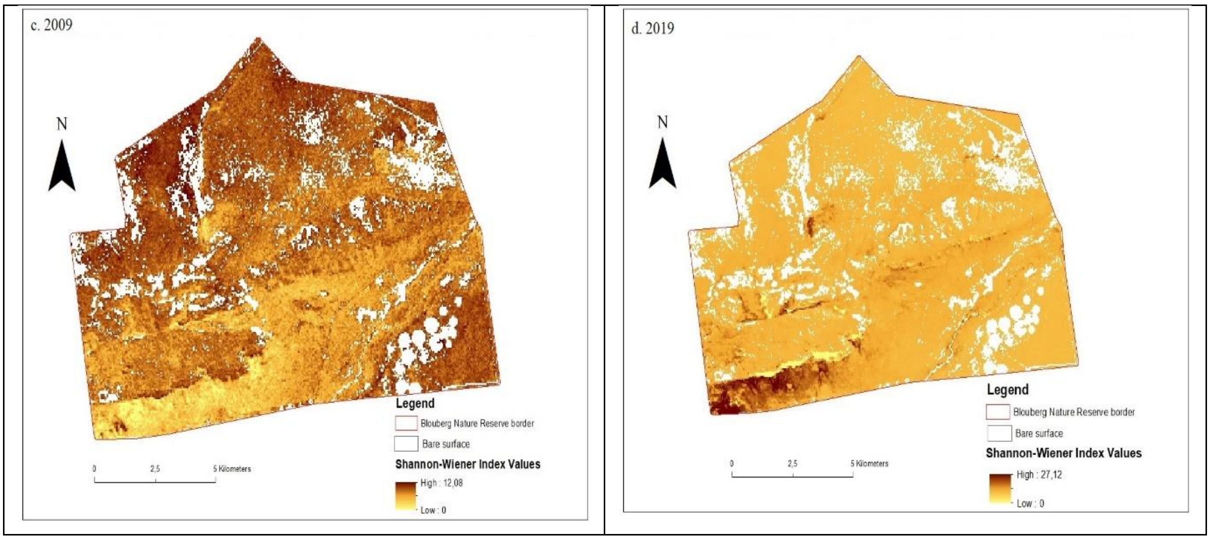


Figure 3. 2: Tree species diversity thematic maps derived from H’, and combined VIs and Landsat spectral data over the period a.1990, b.1996, c.2009 and d.2019.

Figure 3.2 shows the great decrease in species diversity from 1990 to 1996. The species diversity then slightly increased from 1996 to 2009. Furthermore, species diversity decreased from 2009 to 2019. The highest diversity value was obtained in 2019 as compared to other period, however, only small portion of the study area was highly diverse, whereas 1996 obtained lower highest value than other period, but the diversity was distributed all over the area. High diversity was observed along the river as well as at the base of Soutpansberg Mountain; nonetheless, the diversity varies per period. The Soutpansberg Mountain ranges from the east to the south west whereas the river flows from the east to the south of an area.

In addition to remote sensed data and diversity indices, environmental variables were also integrated in this study to explain the variation in species diversity (Figure 3.3). Mean annual temperature, rainfall and evapotranspiration over the BNR varied between a minimum of 1 ºC in 2015, 198 mm/year in 2015, 500 mm/year in 2012 and maximum of 17 ºC in 2017, 380 mm/year in 2016, 666 mm/year in 2015 respectively. The increase in mean annual temperature was observed in 2013, 2016 and 2017, whereas the decrease in temperature was observed from 2010 to 2012; 2013 to 2015 and 2017 to 2019. In terms of rainfall, the decrease was observed from 2010 to 2012, 2013 to 2015 and 2016 to 2018; nevertheless, great increase was observed in 2013 and 2016. Additionally, an increase in evapotranspiration rate was observed from 2009 to 2010 and 2012 to 2015, whereas the decrease was observed in 2012 and 2018. Further, the highest elevation was observed on the top of Soutpansberg mountain ranges, then medium at the most north, east, south of the study area and low at the bottom of Soutpansberg mountain ranges. The results showed strong positive significant correlation ($p < 0.05$) between H' and annual evapotranspiration in all years. Furthermore, it was evapotranspiration in 2018 which had the highest relationship with H' ($r^2 = 0.17$) than other years. In addition, H' had negative insignificant relationship with annual rainfall across all years ($p > 0.05$).

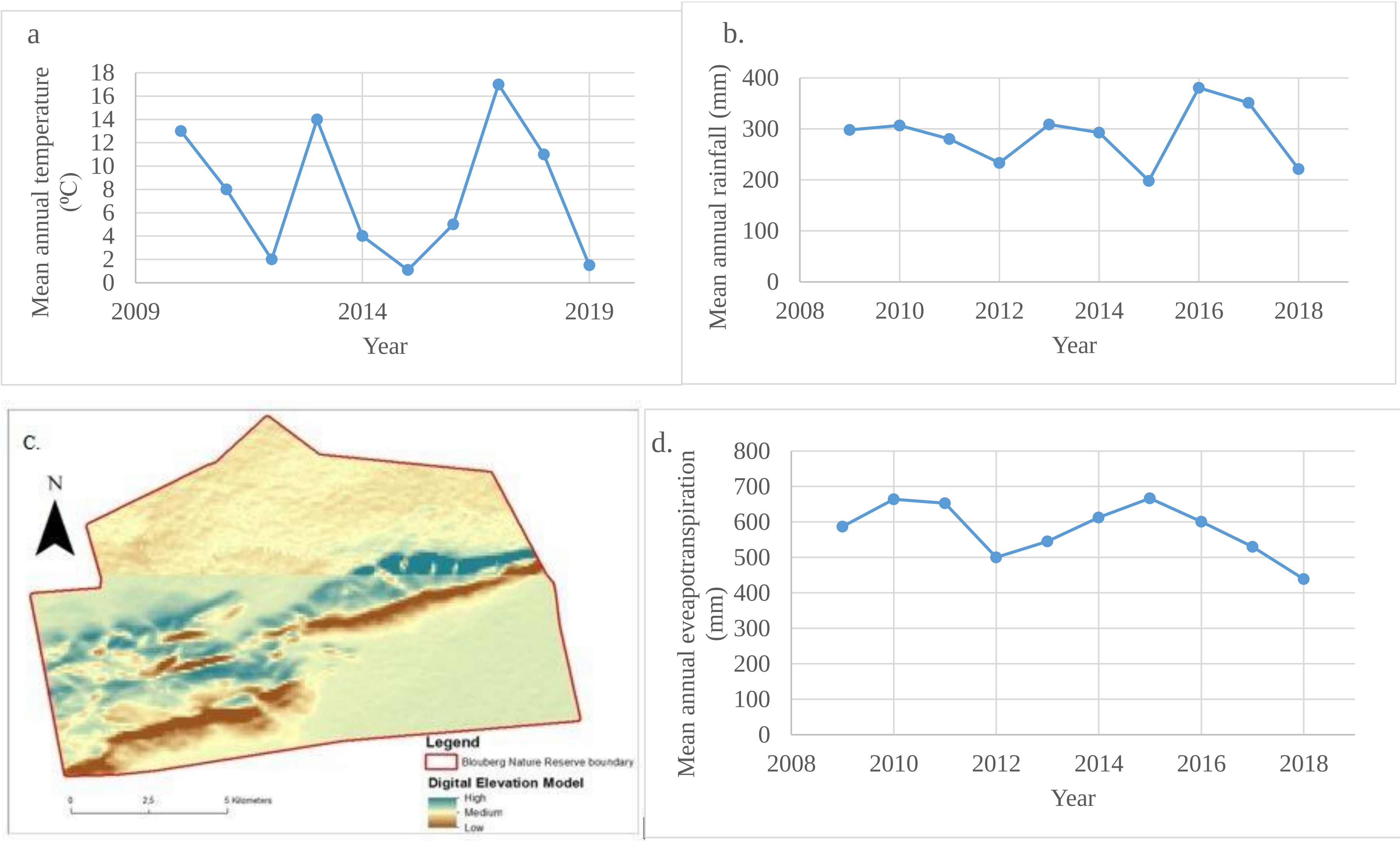


Figure 3. 3: Climatic and topography data

3.4 Discussion

BNR is one of the most important PAs in Limpopo province that incorporates local communities in biodiversity conservation. The reserve is endowed with a wide range of vegetation and wild animals that have the potential to contribute greatly to economic growth through tourism (Blouberg Municipality, 2017). It is, therefore, important to ensure that tree species diversity in the area is regularly examined to enable sustainable conservation. Thus, the understanding of the tree species diversity status before and after involving local communities in biodiversity conservation is crucial as it provides reserve management with the necessary baseline information about tree species distribution within the reserve, which is essential in planning and management of the reserve.

3.4.1 Variation in tree species diversity before and after involving local communities in biodiversity conservation.

The results of this study demonstrated a significant ($p < 0.5$) variation in tree species diversity from 1990 to 2019. The high species diversity observed at the base of the Soutpansberg mountain might be attributed to favorable conditions such as humid and warm temperatures, whereas along the river might be attributed to the high wetness from the water in the river. For instance, Li *et al*., (2019) observed high diversity of Salicaceae plants in warm and wet areas than other regions in China. The increased in rainfall might also be defined by the high species diversity along the river in 2019. For instance, Shoko *et al*., (2019) found that the high production of C3 AGB favors environments with high soil moisture. In addition, the high rate of evapotranspiration at the area might be attributed to the solar radiation of an area. According to Li *et al*., (2019) and Shoko *et al*., (2019), solar radiation is one of the primary sources of energy that regulates physical, chemical and biological processes of terrestrial ecosystems. Thus, the rate of evapotranspiration defines the species diversity (Silva *et al*., 2017; Li *et al*., 2019). In terms of elevation, the results of the study illustrate the decrease in species diversity in increasing elevation.

The results of the study are similar with of Gwali *et al*., (2010) and Imani *et al*., (2016) where they found that species diversity decreases with increasing altitude in semiarid savannah woodland in central Uganda and Kahuzi-Biega National Park and its surrounding forest parks, and the Democratic Republic of Congo respectively. Similarly, Toledo-Garibaldi and Williams-Linera, (2014) and Pandey and Kumar, (2018) reported that species richness decreased unimodally with elevation gradient in Mountains of Eastern Mexico, and Khangchendzonga National Park, Sikkim respectively. Low diversity at the top of the mountain might be attributed to the rough and rocky terrain giving rise to only competitive species. Additionally, their moderately drained surfaces offered by plateau (Phil-Eze, 2012). The results of the study contrast with of Zhang *et al*., (2013) and Kanagaraj *et al*., (2017) who found highest species diversity appeared in the middle elevation in the Baihua Mountain Reserve, Beijing, China and Pachamalai Reserve Forest, Tamil Nadu respectively. Overall, the variation in tree species diversity in areas such as Soutpansberg Mountain and along the river remain almost stable throughout the period. This therefore ascertain assumption that vegetation structure and composition are also influenced strongly by elevation (Imani *et al*. 2016; Sainge *et al*., 2019), evapotranspiration, temperature and rainfall (Li *et al*., 2019).

Our results demonstrated that tree species diversity in BNR can be successfully predicted by H' in conjunction with Landsat variables. These findings imply the potential of using freely available emerging sensors for monitoring species diversity. On the other hand, from the findings of the study, we deduce that the multi-linear regression results in better models that can improve the prediction of tree species diversity. The findings of the study revealed that environmental variables had an influence on tree species diversity over time.

3.4.2 The performance of simple and multi-linear regression.

It was found that H' in conjunction with remotely sensed variables could better determine tree species diversity when compared to D. H' was the better diversity index to define species diversity. This is because it considers both abundance and richness of the community (Dogan and Dogan, 2004; Arekhi *et al*., 2017; Madosela *et al*., 2017). Moreover, Madonsela *et al*., (2017) added that species diversity indices that cogitate both species richness and abundance like H' and D usually have better relationship with Landsat-8 spectral variables. However, in this case H' might be useful since the study does not focus only to determine the dominant species. Nevertheless, in some plots, the diversity was very low and this could be explained by the fact that they were dominated by few types and total number of species besides other abiotic and biotic factors as ascribed by the H'. This finding is approximately consistent with those of Shah, (2013) where they observed lowest value of H' of 0.79 at site I to a highest of 3.95 at site III of Wular Lake, Kashmir Himalaya.

The relationship between H' and combined remote sensed data were explained better when compared to individual remote sensed data over the period. Furthermore, the relationship between H' and individual remote sensed data for 2019 is better than other years used. This could be explained by the fact that Landsat-8 OLI is recently launched with advanced properties than the previous Landsat data. Landsat-8 OLI has shown to be complex and vibrant compared to previous Landsat images like Landsat-5 TM (Poursanidis *et al*., 2015). For instance, Poursanidis *et al*., (2015) found that classification results from Landsat-8 OLI provide more accurate results of over 80% compared to the Landsat-5 TM.

In addition, in simple linear regression, H' showed a better significant positive relationship with VIs when compared to Landsat spectral bands. Our study further shows that H' has a better positive significant relationship with NDVI and SAVI with (r^2 = 0.05) and (RMSE = 0,772; 0,770), respectively when compared to other VIs over period. This might be because the used VIs were calculated using NIR which has been suggested for discriminating species diversity (Arekhi *et al*., 2017; Peng *et al*., 2018). Additionally, according to Fajji, (2017) different VIs are computed from the combinations of two or more spectral bands, assuming that multi band analysis would provide further information than a single one. Furthermore, the results of the study could be attributed to the sensitivity of the VIs to variability in vegetation characteristics i.e. shape and size of the tree, water content, and associated background. Hence, this might be influence the results of this study. The same, the results might be attributed to the environmental factors such as amount of rainfall and temperature received in the study area.

This finding is consistent with those of Arekhi *et al*., (2017) where they found NDVI having the highest significant positive correlation with H' calculated from basal area (3 × 3 Shannon Index Basal Area (SIBA)) with (r = 0.685) in June in the Gönen dam watershed area, in Turkey. Furthermore, Peng *et al*., (2018) confirmed that the combination of NDVI and H' used to estimate species richness. In addition, Gaitán *et al*., (2013) study also showed a strong correlation between NDVI and species richness in steppes and ecosystems respectively. According to Madonsela *et al*., (2017) the differences in sensitivity to vegetation characteristics could be explained by the different measurement scales of VIs. For, instance in this study, the VIs which had better relationship with H' (NDVI and SAVI) have a measurement scale which ranges from -1 to 1.

Regarding the influence of environmental factors, Shoko *et al*., (2019) found that increase with *Themeda triandra* (C4) aboveground biomass (AGB) in March was marked with an increase in temperature with the highest significant positive relationship ($r^2 = 0.82$, $p < 0.005$) within the Drakensberg area in KwaZulu Natal. Similarly, Mapfumo *et al*., (2016) observed the linear relationship between H' and NDVI in wet part of Zambia ($r^2 = 0.68$; $p = 0.017$) and assumed that it could be explained by the fact that wet ecosystems receive high rainfall above 1000 mm leading to high diversity which facilitates high Coefficient of Variation in the NDVI. Overall, our study demonstrated lower relationships when compared to other studies, this might have attributed to the fact that other studies are using derivatives (Madonsela *et al*., 2017), commercial satellite images (Mutowo and Murwira, 2012), they were considering seasons (Mapfumo *et al*., 2016; Arekhi *et al*., 2017) that might have improved their predictions of species diversity.

About the better relationship with SWIR region of Landsat-8 OLI, it could be attributed to the improved moisture content of soil and vegetation of an area. In similar with Jakubauskas and Price (1997) observation, biophysical properties of forest canopy are best explained by a combination of spectral information in the SWIR regions of Landsat-7 Enhanced Thematic Mapper (ETM). Additionally, Madonsela *et al*., (2017) also confirmed that the Landsat program gathers crucial spectral information in the SWIR region which is related to tree properties. The negative significant relationship between H' and spectral bands could be attributed to the amount of vegetation cover. Madonsela *et al*., (2017) made an assumption that positive correlation in the visible region indicates high spectral signal reflectance across all bands and this is typical of dry vegetation due to the background effect as it had dropped its foliage cover and vice versa. This ascertains our results since the area has a diverse tree species.

3.4.3 Implications to biodiversity conservation

Deducing from the results of this study, the use of remote sensing on estimating tree species diversity to understand the state of tree species diversity since the local communities' involvement in biodiversity conservation plays an important role in conservation management. The results also imply that remote sensing explained the variation in species diversity better when integrated with environmental variables since are also known to influence natural resources (Silva *et al*., 2017; Shoko *et al*., 2019) such as species diversity. Moreover, this demonstrates how ecological knowledge and satellite-based information can be effectively combined to address a wide range of current natural resource management.

3.5 Conclusions

The reported results lead to the conclusion that tree species diversity can be predicted using H' and combined Landsat spectral bands and VIs and further established that multi-linear regression techniques assist in maximum utilization of remotely sensed data for the purpose of biodiversity conservation. Moreover, NDVI and SAVI results confirmed its reported ability in estimating vegetation diversity. We can also conclude that the species diversity in the area varies over the period. However, changes in species diversity over time were not the same across the study area since some areas showed rapid changes, whereas others like along the river and at the base of Soutpansberg Mountain appeared to be nearly stable with time. Overall, we conclude that the results of this study indicate that remote sensing can successfully be used to predict tree species diversity to track the changes of species diversity in PAs. Additionally, the findings of the study indicate that the ecological condition of the nature reserve was slightly affected since the involvement of local communities in biodiversity conservation. Thus, the results can be used for planning and management of the PAs, especially if further research on benefits and costs associated with local communities' involvement in biodiversity conservation in PAs are investigated and well understood.

4. Chapter four

An assessment of the benefits and costs associated with local communities' involvement in biodiversity conservation in Blouberg Nature Reserve, Limpopo, South Africa

Abstract

We assess the mutual benefits and costs that local communities surrounding Blouberg Nature Reserve (BNR) and the nature reserve accrue from local communities' involvement in biodiversity conservation. A self-administered questionnaire survey was conducted with 335 household respondents from four villages surrounding the nature reserve. Respondents were selected using a stratified systematic sampling procedure. A structured interview was conducted with a purposefully selected BNR Manager. The main findings were that the community members do not obtain sufficient benefits from the nature reserve, but also do not incur numerous costs from the nature reserve. Despite this, there was a considerable support for biodiversity conservation (84.2%) since household respondents still held positive attitudes towards biodiversity conservation in the reserve and most of them would report illegal activities to the authorities. However, concerns were raised by the household respondents (17.1%) in relation to benefits (job opportunities, natural and cultural resources, and community development) they acquired from the nature reserve. Further, it was noted that poor communication (5.1%) between communities and the nature reserve management resulted in them developing negative attitudes towards the nature reserve. Furthermore, the majority of the household respondents (89.6%) were not participating in biodiversity conservation in the nature reserve, but they had better knowledge about nature conservation regardless of their education level. On the side of the nature reserve, the Nature Reserve Manager reported that the local communities receive benefits when they are available such as fuel-wood for special occasions such as funerals and bush meat sold at Treasury approved tariffs during culling. However, illegal activities like poaching are still experienced in the nature reserve.

Keywords: benefits; costs; community-based natural resource management approach; community involvement, biodiversity conservation

4.1 Introduction

Biodiversity plays an important role in people's lives. Biodiversity includes plants, animals and other organisms and is defined in the Convention on Biological Diversity (CBD) as "the variability among organisms from all sources including *inter alia* terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part: this includes diversity within species, between species and of ecosystems" (United Nations Environmental Programme Finance Initiative, 2008). It reinforces the delivery of ecosystem services important for human well-being (Wang and Gamon, 2019). However, biodiversity destruction worldwide remains one of the most disturbing challenges (Sieber *et al*., 2013; Ntshane and Gambiza, 2016). Amongst the causes accelerating biodiversity loss include land-use changes (Ntshane and Gambiza, 2016), climate change (Khare and Ghosh, 2016; Li *et al*., 2018) introduction of invasive alien species, unsustainable utilization of natural resources and pollution (Thant, 2017). Human activities are the main causes of biodiversity loss compared to natural causes of extinction (Kideghesho, 2008; Slingenberg *et al*., 2009; Thant, 2017). According to Thant, (2017) amongst the main human activities affecting biodiversity conservation include habitat destruction, overharvesting, spread of alien species and pollution. For instance, Zhang *et al*., (2013) found human disturbance mainly from agriculture and tourism as one of the factors affecting biodiversity in Baihua Mountain Reserve in China.

Due to accelerated destruction and extinction of the world's biodiversity, Protected Areas (PAs), has been introduced in 1872 (Poirier and Ostergren, 2002; Andrade and Rhodes, 2012; Burgess, 2012). According to United Nations Environment Programme - World Conservation Monitoring Centre *et al*., (2018), there has been good progress in increasing the global coverage of terrestrial PAs, with coverage slightly increasing from 14.7% in 2016 to 14.9% in 2018. PAs were created to protect biodiversity for the benefits of present and future generations (Poirier and Ostergren, 2002; West *et al*., 2006). Most of the PAs are administered under fortress conservation policies, whereby local communities are denied direct access to natural resources (Andrade and Rhodes, 2012 and Ayivor *et al*, 2013). However, since 1980s, it came to the scientists' attention that communities play an important role in biodiversity conservation (Vodouhê *et al*., 2010; Thant, 2017). To date, many areas have adopted the Community-Based Natural Resource Management (CBNRM) programmes that aim to sustainably conserve the planet's biodiversity, while sustaining the livelihoods of communities (Vodouhê *et al*., 2010; Mahumuza and Balkwill, 2013; Milupi *et al*., 2017).

However, some of the PAs are still exposed to illegal activities that affect biodiversity, on the other hand local communities surrounding PAs are also experiencing challenges from PAs. The challenges and threats that biodiversity is exposed are due to high human demands for natural resources (Thant, 2017). Thus, it is essential to study the benefits and costs that local communities receive and face respectively from being involved in biodiversity conservation in

PAs. This information is helpful in understanding the cause of such challenges and threats to biodiversity conservation. Moreover, the study of local people's views, perceptions and attitudes towards PAs and their associated wildlife is also critical for the assessment and understanding of acceptance of local communities (Vodouhê *et al*., 2010; Andrade and Rhodes, 2012; Chowdhury *et al*., 2014). Consequently, this will provide a better understanding of how to minimize the costs and how to maximize the benefits associated with PAs which will improve the conservation of biodiversity in PAs (Thant, 2017).

4.2 Materials and methods

4.2.1 Data sampling procedure

The study was conducted using a questionnaire survey to elicit information on biodiversity conservation. We used self-administered questionnaires to obtain data from household heads, or in their absence, any adult member who was willing to participate in the study. The participants' age ranged from ≤ 16 to ≥ 60. This age category was chosen because according to le Roux-Kemp, (2013) some of the South African households are led by 16-year old people sometimes called "child-headed households", as for ≥ 60, it was shown that they have vast knowledge and experience on nature conservation, also refers as indigenous people (Davies *et al*., 2008).

In order to obtain a robust data set for analysis, a sample size of 335 was determined using the Raosoft formula portal (http://www.raosoft.com/samplesize.html) at 95% confidence level with a 5% error margin. The sample size was calculated from a total of 2 602 households from four villages surrounding the BNR. The villages selected are within 3 km radius from the nature reserve boundary. Household statistics were obtained from Statistics South Africa (StatsSA) 2019. The number of households per village was selected, using a stratified sampling technique as shown in Table 4.1. The number of households selected from each village was calculated, using the following formula: $ni = (hi/N) * n$; where hi is total number of households in each village, N total households of all selected communities and n is sample size. Furthermore, households visited in each village were selected using systematic sampling procedure. Systematic sampling ensures that each member has an equal probability of being chosen in the sample. Moreover, the sample is spread more evenly over the population, thus, no large part will fail to be represented in the sample.

Table 4. 1: Stratified sample for villages neighbouring Blouberg Nature Reserve

Village	Household number	Sample size per household
Endwinsdale	181	23
Indermark	2257	291
Ga-Moyaga	31	4
Glenfernes	133	17
Total	**2602**	**335**

The questionnaire questions were mostly structured to be close-ended, but a few questions were open-ended. According to Naidoo, (2017), closed-ended questions offer an opportunity to compare responses between participants and conduct quantitative analyses of the responses. On the other hand, open-ended questions allow household members to speak of their experience in their own terms and words that had not been expected by the researcher but giving an input to the matter being investigated. Therefore, open-ended questions gave the community members an opportunity to fully express themselves and provide detailed information. We asked participants about their involvement in nature reserve activities, the benefits and costs they obtain from the nature reserve, as well as their attitudes, views and perceptions on the nature reserve management. Moreover, a questionnaire was structured in a way that would provide information on the personal profiles of the participants. In some cases, the household respondents were asked to score the extent to which they agreed with the statement offered like a five-point Likert scale. For instance, the household respondents were given the statement that the relationship between their communities and the nature reserve is good where the household respondents agree or disagree.

An in-depth structured interview was conducted with the purposefully chosen BNR Manager to acquire information on community involvement in the nature reserve. The interview, guided by a template with questions, obtained information on the benefits and costs of involving local communities in biodiversity conservation within the nature reserve, how do they address the costs they face from local communities. The Nature Reserve Manager was selected because of his position, responsibility, experience, and knowledge in the management and running of the nature reserve.

The approached participants were briefed about the objectives of the research and then asked whether they desired to participate in the survey or not. For ethical concerns, the name of the household respondents was not recorded and they were told that their answers would be recorded as anonymous. In addition, no recording devices were used.

4.2.2 Analysis

Generated information from the community members gathered through a questionnaire survey were coded and analysed in International Business Machines (IBM) Statistical Package for Social Sciences (SPSS) software version 25 (IBM SPSS Statistics 25). Descriptive statistics were used to show the frequencies in the percentage of respondents (per household) for selected variables. In addition, Spearman Correlation Coefficient was used to show the correlation between the selected variables including demographic characteristics and conservation knowledge, and involvement; and involvement and conservation knowledge, benefits and costs. The correlation's significance analysed at 95% confidence interval. Furthermore, findings from questionnaire survey were represented in the form of tables and graphs. On the other hand, information generated from the interview with Nature Reserve Manager was analysed through content analysis method.

4.3 Results

4.3.1 Demographic profile

The results of the gender distribution of the community household respondents indicate that the gender was almost balanced, as one hundred and forty - six (43.6%) of three hundred and thirty-fifty (335) household respondents, were males and one hundred and eighty - nine (56.4%) were females. However, the female population outnumbered the male population in the area by approximately 12%, largely because many of the men were migrant labourers, who work in cities elsewhere in South Africa.

The population is relatively middle to old age. The average age for the household respondents was 4.48 (45) years with the majority of the household respondents being between 21 and 30 (20.9%) and 31 and 40 (23.0%) years followed by elders being greater than 60 (17.6%). Thus, the less or equal to 16 age group represents a very small portion of seven (2.1%), followed by youth being between 17- 20 (8.1%) then middle age between 41 and 50 (10.7%).

In response to the educational background, the majority of the household respondents have formal education level, that is, Grade 12 (27.8%), Secondary (25.7%); College certificate (12.5%), Diploma (9.6%), Primary (9.0%), Undergraduate (1.5%) and Post-graduate (1.2%), whereas minority had no formal education, which accounted for 12.8% of the household respondents. Overall, these findings revealed that people from the selected communities are educated.

According to the questionnaire results, seventy-five (22.4%) of the household respondents are employed, fourteen (4.2%) are self-employed and two hundred and forty-six (73.4%) are unemployed. However, out of 73.4% of unemployed only 55.8% is economically active whereas 17.6% is not economically active.

4.3.2 Biodiversity conservation knowledge

4.3.2.1 Conservation knowledge

Household respondents were asked about their understanding and knowledge of various concepts in biodiversity conservation, including the role of the nature reserve and management as well as the purpose of conserving nature particularly in BNR. Out of three hundred and thirty-five household respondents, two hundred and thirty-four (69.8%) indicated that is to protect wildlife, twelve (3.6%) to give local people jobs and sixty-four (19.1%) said they do not know, whereas twenty-five (7.5%) pointed out another role. Out of 7.5% household respondents further mentioned other nature reserve role amongst them include education (0.6%), for entertainment (0.9%), protect wildlife and give local people jobs (0.6%), hunting (0.9%), tourism (3.6%), to keep their dangerous animals away from community members (0.6%) and to keep their animals (0.3%). Responding to the purpose of the nature reserve others mentioned that is to keep animals away from them, to make money from the visitors, and to save animals and plants that are important.

Responding to the question of nature reserve management role, 20.0% indicated that they are conservation decision makers, 4.8% conservation planners, 3.3% facilitators, 24.2% both conservation decision makers, conservation planners and facilitators, and 47.8% they do not know. In response to nature reserve management role question, no single household respondent indicated any other activity other than those listed on the questionnaire.

When asked about the reasons to conserve nature, majority (64.2%) of the household respondents indicated they were doing it for future generations, followed by 26.9% who did not know, 6.6% who wanted to ensure continuous functioning of the ecosystem and lastly 2.4% mentioned others. Out of 2.4% other mentioned reasons touched on education, to keep animals away from the neighboring communities, save animals and plants, to have more animals and plants, to keep animals safe, to make money from visitors and to save animals that are important. Overall, 68.8% of the household respondents have conservation knowledge, whereas only small portion of 31.27% does not have knowledge of conservation.

4.32.2 Conservation knowledge by gender, age and education

The findings of the study revealed that both females and males have knowledge of the role of the nature reserve in particular which is to protect wildlife. However, females slightly had more knowledge than male respondents. The age of the household respondents also had a role in the conservation knowledge, where the majority of 21-50 and above 60 had more conservation knowledge than age groups below 20 years and 51-60 years. With education, majority of those that have conservation knowledge had formal education level (Secondary and Grade 12), followed by high education (College certificate and Diploma) then no formal education (No schooling) and lastly formal education level (University post-graduate and undergraduate).

The study found that there was a significant difference in the knowledge of the role of nature among the demographic characteristics ($p = 0.00$). However, age does not have a bearing on household's knowledge of the role of the nature reserve (Table 4.2).

Table 4. 2: Significant between demographic characteristics and nature reserve role

	p-value
Gender	**0.00**
Age	0.39
Education	**0.00**

4.3.3 Benefits accrued by local communities from the nature reserve

Perceived natural, cultural and economic benefits associated with the nature reserve were investigated. For natural resources, only forty-five (13.4%) household respondents agreed that they are or they have been receiving benefits, whereas the majority of the household respondents, two hundred and ninety (86.6%) had never received any benefits from the nature reserve. Most of the benefits received by local communities from BNR were non-monetary. Fuelwood (9.9%), foods particularly bush meats (1.2%) and water (0.6%) is the main benefits acquired by the local community than other natural resources. The majority of the household respondents cited that they were getting natural resources, particularly fuel-wood per load occasionally like during funerals (9.9%) and water per liter during time where they do not get water from their taps for a long time (0.6%). For food like bush meat, they mentioned that they were getting it with the cheapest price during culling. The Nature Reserve Manager also confirmed that local communities get benefits such as fuel-wood occasionally like during funerals or during bush encroachment control initiatives, on the other hand, carcasses are sold according to Treasury approved tariffs, which is at low cost when compared to commercial value of such items to the community members.

For cultural resources, almost all the household respondents, three hundred and two (90.1%) showed that they do not receive cultural resources, whereas thirty-three (9.9%) respondents indicated that they have received cultural resources from the nature reserve. The cultural benefits they received include an opportunity to have a view on wildlife within the nature reserve (2.4%), worship or perform any religious activity within the nature reserve (4.5%) and opportunity to walk in the nature reserve (0.3%). The household respondents which account for 2.7% also mentioned other cultural benefits amongst others include that the nature reserve sometimes gives their school children opportunity to visit the nature reserve at the cheapest price (2.4%) and opportunity to come and swim (0.3%).

Sustainable development for the involved communities in biodiversity conservation is one of the objectives of CBNRM initiatives. The community development was measured by asking the household respondents infrastructure facility that was provided by the nature reserve and "other" option was provided to give the household respondents opportunity to mention anything they received for the community. Hence, according to our findings, the majority of the household respondents (94.6%) indicated that the nature reserve does not provide the community with anything, followed by the 3.6% which indicated that they do not know, then (0.9%) saying they are not sure, lastly (0.9%) mentioned other things they obtained from the nature reserve for the community development. Out of 0.9% of the other obtained community development, the household respondents indicated that the nature reserve has donated chairs to the school (0.3%), they bought soccer kit for the community team (0.3%) and lastly (0.3%) aerial network.

In responding to the question of employment, almost all the household respondents (99.4%) said that there is no one working in the nature reserve from their families whereas only (0.3%) indicated that there is one working as a Field ranger and another one working as Environmental cleaner. The results clearly indicate that formal employment is almost non-existent and this emphasizes the importance of considering community-based opportunities. The Nature Reserve Manager also indicated that they give local community members job opportunities when they are available. Overall, among the above-mentioned benefits, fuelwood, food, employment, infrastructural development, water, opportunity to worship or perform any religious activity and view wildlife within the nature reserve are the most important benefits for local communities.

4.3.4 Costs faced by the local communities surrounding the nature reserve as well as the nature in the reserve

The relocation of local people due to the establishment of the nature reserve was investigated. The study findings show that only 1.5% of the household respondents' family members had been relocated for the establishment of the nature reserve, whereas 98.5% indicated no relocation. Damages and injuries from BNR wildlife were also investigated. Thus, crop-raiding was the reported damage from the household respondents with the highest percentage compared to other costs accounting for 3.3%, followed by destruction of their fences which accounts for 0.6%. Meanwhile, the household respondents mentioned that the animals from the nature reserve rarely damaged their crops rarely (once in 24 months) particularly in farming season (2.1%), others mentioned that once in the past years (1.5%), despite the fact that only few household respondents reported that crop damage was either often (every month) accounting for 0.3%. Furthermore, no single household respondents reported injuries from wildlife.

Regarding the household respondents' reaction to crop raiders, some cited that they reported them to the authorities (3.3%), some indicated that they were chasing them away (0.3%), while others mentioned that they quitted farming (0.3%). No single respondents indicated the killing of the animals responsible for the crop damage. However, the Nature Reserve Manager reported illegal activities such as poaching and limited illegal harvesting of trees for fuel-wood. Poaching was reported to be seen by the presence of the snares around the nature reserve. These illegal activities were reported to be managed through counter poaching patrols and operations.

4.3.5 Involvement of local communities in biodiversity conservation in BNR

The findings of the study reveal that out of three hundred and thirty-five, only a small percentage of thirty - five (10.4%) of the household respondents agree that they were involved in biodiversity conservation in BNR and larger percentage of three hundred (89.6%) stated that they were not involved. Out of 10.4% of those who were involved, 1.5% are involved in the form of attending meetings, 0.3% in planning and decision-making process, 2.1% volunteering in any conservation activities and 6.6% and other conservation activities. Out of 6.6% of other conservation activities include reporting escaped animals from the nature reserve like vultures, snakes and illegal activities (4.8%), fence fixing (1.5%) and bush encroachment control (0.3%). Overall, the number of participants in conserving biodiversity in BNR is very small. Furthermore, out of those who are involved, 7.5% indicated that their knowledge was enhanced through their involvement while 3.0% was not enhanced.

4.3.5.1 Community involvement by benefits and costs

The majority of the household respondents, who were not involved, reported that they did not get natural benefits from the nature reserve while few household respondents who were involved reported that they do not receive benefits from the nature reserve. Alternatively, there were few who were involved and they were receiving few benefits. According to the Nature Reserve Manager, community members participated freely in the conservation of nature within the nature reserve. There was a significant positive correlation between household respondents' conservation involvement and access to natural benefits ($r = 0.18$; $p = 0.00$), and insignificant positive correlation with cultural benefits ($r = 0.02$; $p = 0.74$).

4.3.5.2 Community involvement by demographic profile

Moreover, households' involvement in nature conservation did not vary with age ($r = 0.01$; $p = 0.89$) and has significant positive correlation with gender ($r = 0.11$; $p = 0.04$). Meanwhile, there is an insignificant negative relationship between households' involvement and education level ($r = -0.03$; $p = 0.64$).

4.3.6 Relationship between the community and nature reserve management

The questionnaire survey shows that the relationship between the community members and nature reserve management was generally good as indicated by at least 54.2% (Figure 4.1). Household respondents who disagreed with the statement that the relationship between the community and the nature reserve management is good, mentioned they are not given job opportunities (8.7%), communication was poor (5.1%), the nature reserve management did not respond quickly when they report escaped animals from the nature reserve (0.9%). Further, the nature reserve management does not give community members bursaries to further their studies (1.5%), besides not helping the community (3.6%) and restricting communities' access to reserve (1.8%). They also indicated that animals from the reserve destroy community members' crops and fences (0.9%), community members are no longer having enough land for grazing and farming (1.8%), there is nepotism when distributing available job opportunities (1.5%), other community members practice illegal communities within the nature reserve (2.4%), community members live in fear of wild animals (1.2%), the nature reserve management do not distribute information about the nature reserve (2.4%), community members never seen nature reserve manager came to their community (1.2%), and the relationship is only with other communities (1.2%).

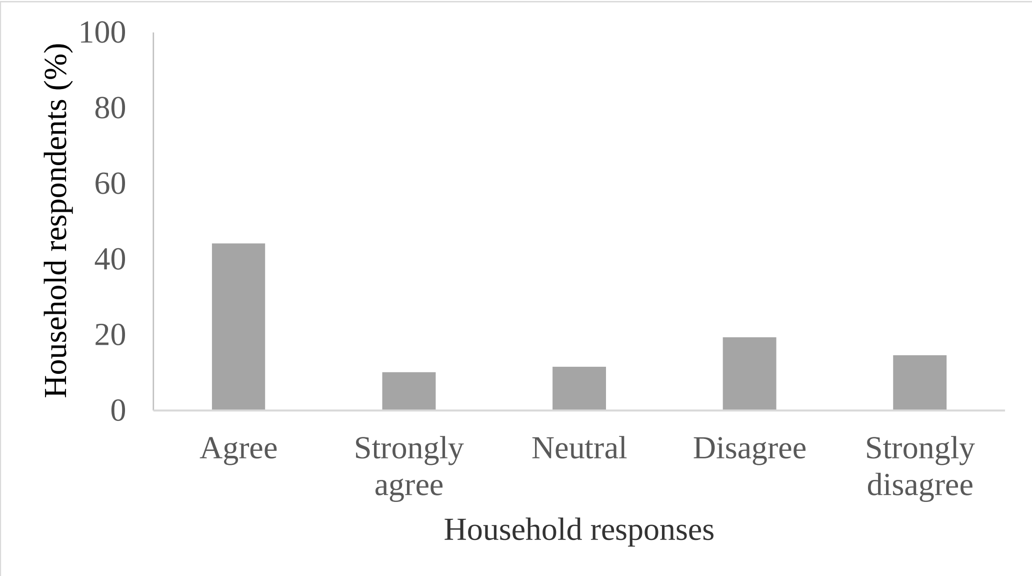


Figure 4. 1: Household responses on the good relationship between the nature reserve management and the community.

Communities suggested the need to strengthen the relationship between the nature reserve management and the communities amongst others include that they would like to see problem animal issues being addressed (1.8%). Others emphasized on the need to employ local people in the nature reserve management (9.6%), as well as more contribution to community development (1.8%). Some wanted to see more access and use of resources in the reserve (5.1%), proper communication (3%). Moreover, some indicate that the reserve management should ensure equal distribution of jobs and natural resources from the nature reserve (2.1%), provide community members with bursaries to further their studies (1.2%) and the community should also discipline their kids not to practice illegal activities in the nature reserve (1.8%). In addition, local communities highlighted that the nature reserve management should involve community in decision making (0.6%), nature reserve management should at least respond quickly when the community members report on escaped animals (0.9%), and ensure visit and distribution of information about the nature reserve (6.3%). Further, in terms of access, the Nature Reserve Manager indicated that the nature reserve is guided by legislation thus, access is regulated.

4.3.7 Views, attitudes and perceptions of the local community members towards nature reserve management

Views, attitudes and perception of local communities towards nature reserve management were also investigated in this study. For instance, in the event of seeing a poacher in the nature reserve, the majority of the household respondents (78.2%) indicated that they would report to the authority, followed by 21.2% who indicated that they would keep quiet, 0.3% indicated that they would help the poacher to kill animals or harvest plants and 0.3% mentioned that they would do nothing.

Further, majority of the household respondents (87.5%) indicated that they would report to the authorities any fence damaged whereas 9.3% indicated that they would keep quiet, 2.7% indicated that they would encourage the community to fix it and lastly, 0.6% mentioned that they will do nothing because they do not know where to report. Furthermore, majority of the household respondents (47.2%) assumed that people poach to sell animal products, followed by 33.7% indicating that they poach for bush meat, and then 19.1% mentioned other reasons. Further, out of 19.1%, household respondents indicated that people poach for both bush meat and to sell animal products (1.2%). Some emphasized that they do not know (5.1%), whereas others highlighted that for making a living from selling and also eating (0.3) and poverty (4.5%). Despite that some indicated that there was no poaching (0.3%). Other said that the poachers do not know the importance of the animals they kill and the plants they harvest green (2.1%), they are reducing damages the animals will cause (0.3%), to perform rituals and for bush meat (0.3%), and unemployment (5.1%).

Some of the household respondents mention that nature reserve management should do both community outreaches, hire more rangers and better fencing (46.3%) for better conservation. Others indicated that better fencing (22.7%); more rangers (19.4%); community outreach (8.1%) would ensure biodiversity conservation in the reserve. Further, 3.6% mentioned amongst others that nature reserve management should hire more security officers (0.3%) and nature reserve management should involve the community in decision-making (0.6%).

Household respondents accounting for (0.6%) emphasized the generation of employment and the recruitment of more rangers and better fencing (0.3%). In addition, others mentioned that nature reserve management should just remove the fence (0.3%), nature reserve management should ensure tight security (0.3%), and the community members should not cut rare indigenous trees (0.3%). Despite that, only 0.9% indicated that they do not know.

4.4 Discussion

4.4.1 Conservation knowledge

This study reveals that the majority of the household respondents had knowledge of conservation, particularly the role of the nature reserve and purpose of conserving nature; however, they do not have more knowledge on the role of nature reserve management. The results reveal that females had more conservation knowledge than males. This might be attributed to the fact that females are dominant in the Blouberg Local Municipality (Blouberg Municipality, 2017). Our results are not similar to other studies like Thant, (2017) who found that males had better knowledge about the PA's operations than females with a mean of 18.3 which was significant ($p < 0.001$) in Chatthin Wildlife Sanctuary in Myanmar. The positive correlation between conservation knowledge and gender and age might be attributed to the willingness of an individual to participate in nature conservation. Furthermore, Kellert and Berry, (1987) also indicated gender as one of the demographic factors in determining attitudes about wildlife. The negative significant correlation between education and conservation knowledge shows that it does not require individual to be educated in order to gain conservation knowledge. This shows that willingness to conserve nature depends on individual's attitude to conserve nature.

According to Makindi, (2016), adequate information and knowledge in the conservation related concepts is one of the factors ensuring long-term effectiveness of the participation in nature conservation. Likewise, Htun *et al*., (2012) and Chowdhury *et al*., (2014) further confirmed that local people's perceptions and attitudes towards PAs is determined amongst others by their knowledge on the management of PAs. Majority of the household respondents in our case are not involved in biodiversity conservation in the BNR, even-though they have adequate conservation knowledge. This might be ascribed by the benefits and the costs they acquire and face from the nature reserve, respectively. Thus, our study contradicts with other studies which observed that the majority of the household respondents who have nature conservation knowledge being involved in nature conservation (Makindi, 2016).

4.4.2 Benefits acquired by local communities as well as by nature in the reserve

Some studies indicated that it is generally believed that local communities are more likely to support conservation initiatives if they receive direct benefits from them (Bajracharya *et al*., 2006). The results of the study show that local communities get limited natural resources, for instance, they do not get easy access to fuel-wood since they indicated that they only get fuel-wood occasionally like during funerals. Contrary to observation by Bajracharya *et al*., (2006) in Annapurna Conservation Area, an overwhelming majority of the respondents indicated that they have easy access to fuel-wood and fodder. Not as good as to our findings, some local communities receive benefits but are restricted on access to natural resources in their nearest PAs (Kideghesho *et al*., 2007; Vodouhê *et al*., 2010). These natural resources are amongst the most crucial resources for subsistence use by local communities.

The household respondents of this study did not mention any building development for the community and this is unlike other studies (Dabo, 2017; Mahumuza and Balkwill, 2013; Secretariat of the Convention on Biological Diversity, 2008). For instance, Dabo, (2017) indicated that Community Forest Management Areas scheme in Pete, Zanzibar helped the community to build schools for their children, supply households in the village with electricity and build a mosque.

A key aspect when looking at communities and biodiversity efforts is employment opportunities in PAs. However, in our case, out of three hundred and thirty-five household respondents only two household respondents accounting for 0.3% each mentioned that some members of their households were working in the nature reserve, as Environmental cleaner and Field ranger respectively. This illustrate that the nature reserve is still lacking on employment creation. Thus, the findings of the study correspond with Mugisha, (2002) study where they found that majority of their respondents (93.9%) indicated that PAs (Kibale National Park, Lake Mburo National Park and the southern part of Mt. Elgon National Park) in Uganda did not employ them and small percentage (1.1%) was employed. However, the result of the study, contradict with other studies (Mbaiwa, 2004; Bajracharya *et al*., 2006; Makindi, 2016; Dabo, 2017). Makindi, (2016) found that half of their respondents indicated that a member of the household was working in Kimana Community Wildlife Sanctuary in Kenya. Dabo, (2017) on the other hand found that majority of the respondents were employed in the Community-Forest Management Areas in Pete, Zanzibar. Moreover, Bajracharya *et al*., (2006) found that Annapurna Conservation Area has provided direct 242 employment opportunities in which almost half of them (49.6%) are local staff from the area.

We deduce that most of the benefits received by local communities were non-monetary. Furthermore, they are not similar to other studies who found that local communities were receiving benefits including monetary benefits (Weladji and Tchamba, 2003; Mbaiwa, 2004; Bajracharya *et al*., 2006; Vodouhê *et al*., 2010). In other cases, local people are given money for infrastructural development, such as in Integrated Conservation and Development Initiative in Korup National Park in Cameroon (Weladji and Tchamba, 2003) and in other National Parks such as Pendjari National Park in Benin, local people are given a percentage of revenue generated from tourism activities in the park (Vodouhê *et al*., 2010). Furthermore, our study indicated that almost all of the respondents who do not get access to resources within the nature reserve indicated that they were restricted, whereas few claimed that they never bothered.

4.4.3 Costs faced by local communities as well as by nature in the reserve

Despite the many important benefits of PAs, local communities also experience a number of costs of being involved in conservation. Relocation as one of the costs, minority of the household respondents in this study experienced relocation from the nature reserve. Majority were not affected because they started living in their communities after the nature reserve was established. Our findings correspond with the study by Méndez-López *et al*., (2013) who established that one of their study communities, La Mancolona, had suffered two forced displacements resulting from the establishment of two Biosphere Reserves, Montes Azules and Calakmul where their livelihoods were disrupted since they were far from their social network. Kideghesho, (2007) and Dabo, (2017) emphasised that the process of relocation had terminated most cultural and traditional practices land in the name of conservation.

Further, no reported injuries from the household respondents, this might be attributed to the fact that there were few dangerous animals in the nature reserve. In general, the incidence of crop damage or losses appeared to be less experienced compared to other studies nevertheless, this might look minor, but those whose crops are their staple food might be greatly affected. Most studies reported crop damage around PAs elsewhere varying in extent and intensity (Mugisha, 2002; Weladji and Tchamba, 2003; Bajracharya *et al*., 2006; Dar *et al*., 2009;

Gandiwa *et al*., 2013; Seifu and Beyene, 2014; Makindi, 2016; Thant, 2017). In addition, crop damage by wild animals is one of the main reasons for park-people conflicts and negative attitude towards conservation even though they receive benefits from conservation.

Strategies used by affected local communities surrounding BNR to respond to damages from animals from BNR are similar to other studies (Thant, 2017). However, Thant (2017) study, respondents specified that they were chasing the animals that caused damages by shouting. Moreover, some of the studies found that not only carnivores are responsible for crop damages (Thant, 2017). For instance, pests such as birds and rabbits were reported amongst the crop raiders in Chatthin Wildlife Sanctuary in Myanmar (Thant, 2017). Seifu and Beyene, (2014) on the other hand reported that elephants were the main animals causing crop damage in Babile Elephant Sanctuary in Ethiopia. No single respondents from our study that indicated the killing of the animals responsible for the crop damage. This shows that local communities did not develop negative attitude towards conservation due to their loss.

4.4.4 Involvement of local communities in biodiversity conservation

Our findings illustrated the lowest number of participants in conservation of biodiversity in BNR. Our results are consistent with other studies like Enetji *et al*., (2012) and Méndez-López *et al*., (2013). Méndez-López *et al*., (2013) study found that overall involvement of local people in formalized conservation initiatives in six communities in Southeast Mexico reaches only about 25%. A growing body of research explains low levels of local participation in PAs amongst other include the restriction approach of this instrument for biodiversity conservation. For example, in this study, majority of the respondents for the reasons acquired from the state of the relationship between the community and the nature reserve as well as why they were not getting natural resources from the nature reserve was that they were restricted.

Meanwhile, out of thirty-five participating respondents only twenty-five participants' knowledge was enhanced. Majority of the household respondents who did not participate in biodiversity conservation did not get benefits, whereas minority who participated in biodiversity conservation were getting benefits. However, the benefits do not depend on the participation of local people since there are some who obtained benefits while they are not participating in nature conservation. According to literature, local communities should benefit simultaneously to ensure the conservation of PAs (Lepetu *et al*., 2008). The correlation between household respondents' involvement and natural and cultural benefits might be attributed to the fact that household respondents get those benefits despite their amount. Thus, local peoples' participation in conservation is influenced by the benefits they acquire from the PAs.

4.4.5 Relationship between the community members and the nature reserve management

Respondents who were benefiting from the nature reserve were likely to say that they strongly agree that the relationship between the community and the nature reserve is good than those who were not benefiting. According to Thant, (2017), the interaction between PA staff and community members plays an important role in shaping the relationship and trust between the PA and local people. In this study, majority of the respondents who indicated that they strongly disagreed that the relationship between the community and nature reserve management was good, indicated that they never saw Nature Reserve Manager coming to their community. This finding is similar to Thant, (2017) study, where they found that nearly 70% of their respondents indicated that they did not see or meet with the staff in Chatthin Wildlife Sanctuary.

Furthermore, amongst the other reasons mentioned by unimpressed household respondents (34%) for the relationship between the community and the nature reserve management are similar to Mugisha, (2002) study, where 49.2% indicated that they were denied access to natural resources. Poor communication and lack of job opportunities were the major indicated reasons for the poor relationship between the nature reserve management and local communities and this could potentially be a major source of resentment and conflict between local communities and BNR management in the future, if it is not properly addressed.

4.4.6 Views, perceptions and attitudes of the local community members towards nature reserve management

Local people's perceptions on the nature reserve management influenced the way they interact with PAs and determine the effectiveness of conservation (Vodouhê *et al.*, 2010; Andre and Rhodes, 2012; Chowdhury *et al.*, 2014). Most of the respondents indicated that they would report to the authorities if they saw a poacher, whereas few opted to remain quiet or they will help the poacher to kill the animals and harvest plants. Meanwhile, those who indicated that they will keep quite feared that the poachers would harm or threaten them, whereas those who claimed to help the poachers would do that because the nature reserve is doing nothing for the community. Roe, (2015) recommended that local people collaboration with law enforcement organizations would be a crucial strategy to successful combat illegal activities like poaching.

Additionally, it was suggested by the local people that there should be a reward system for people who contribute to anti-poaching activities (Thant, 2017). According to recent studies the more local communities receive benefits, the more they likely to develop positive attitudes towards conservation (Lepetu *et al.*, 2008). However, our finding shows that local people in BNR held positive attitudes toward conservation of nature in BNR even though they get few benefits, despite the fact that they are not impressed with the job opportunities and a way of communication from the nature reserve. This confirms Chowdhury *et al*., (2014)'s observation that that local people's needs, perceptions, and attitudes line with their personal attributes.

4.5 Conclusions

Local people reported that they do not receive sufficient support from the nature reserve but still held positive attitudes towards PA. The results of this study contradict with the paradox that people living close to or in the PAs get more benefits from PAs and bear most of the costs from crop damage. However, the household respondents' behaviour remained unchanged in terms of involving in illegal activities, since illegal activities particularly poaching still occurred in the nature reserve and their support to conservation remained low since majority are not participating in conserving nature. Overall, the community-based approach to conservation in BNR has, therefore, had not helped to improve the living standards of local communities within BNR. The results of this study lead to conclusion that there is a need to increase local people's access to benefits from the PAs and more involvement in conservation of natural resource in order to enhance their support for conservation and sustainability of the PAs.

5. Chapter five

An assessment of the implications of involving local communities in biodiversity conservation: A synthesis

5.1 Introduction

CBNRM approach has been adopted and implemented in most Southern African countries (Mbaiwa, 2004). The approach gives local communities control over natural resources management (Schafer and Bell, 2002; Pailler *et al*., 2015; Matsvange *et al*., 2016). The fundamental concept debates that decentralizing control of natural resources to local communities improves households' access to and management of natural resources, thus improving the resource base and their benefits to communities (Pailler *et al*., 2015). CBNRM has done this believing that local communities play a vital role in conservation of biodiversity in PAs (Méndez-López *et al*., 2014; Makindi, 2016), thus they need to be involved in biodiversity conservation. Further, the previous approach, that is centralised approach, is assumed to have initiated widespread poverty (Schafer and Bell, 2002). Schafer and Bell, (2002) further emphasised that involved local communities would not use resources in ways that are illegal and unsustainable. However, according to literature the involvement of local communities in biodiversity conservation in PAs has not resulted in effective, efficient and successful biodiversity conservation. Thus, the focus of this research study was to assess the implications of involving local communities in biodiversity conservation in Blouberg Nature Reserve in Limpopo Province, South Africa. Hence, objectives of the study were to:

I. Assess the state of biodiversity before and after involving local communities in biodiversity conservation in Blouberg Nature Reserve in Limpopo Province, South Africa.

II. Identify and assess benefits and costs of involving local communities in biodiversity conservation in Blouberg Nature Reserve in Limpopo Province, South Africa.

III. Investigate views, perceptions and attitudes of local communities towards Blouberg Nature Reserve management in Limpopo Province, South Africa.

5.2 Estimating tree species diversity as an indicator of biodiversity conservation in Blouberg Nature Reserve

The study aimed at assessing the variation in tree species diversity before and after involving local communities in biodiversity conservation using Landsat data and diversity indices. The study intended to assess the state of tree species diversity since the involvement of local communities in CBNRM initiative in Blouberg Nature Reserve. The results revealed that Landsat spectral bands and VIs in conjunction with H' performed better than individual Landsat spectral bands and VIs with (r^2 = 0.36; r^2 = 0.34) before and after involving local communities in biodiversity conservation respectively. Thus, based on these findings of this study, Landsat spectral bands and VIs in conjunction with H' were used to estimate and map long-term variations in tree diversity in Blouberg Nature Reserve, Limpopo. Thus, species diversity varied over period with highest and lowest species diversity in 1990 and 2009 respectively (Chapter 3). The integration of Landsat spectral bands and VIs in conjunction with H' have the potential to accurately assess the tree species diversity in PAs for a long-term and that is critical for suitable natural resources management, particularly for those that involve local communities in biodiversity conservation.

5.3 Identification and assessment of the benefits and costs of involving local communities in biodiversity conservation as well as investigating views, perceptions and attitudes of local communities towards BNR management

CBNRM has been widely promoted as a strategy that aims to conserve biodiversity, while simultaneously enhancing rural livelihoods (Mbaiwa, 2004; Lepetu *et al*., 2008; Pailler *et al*., 2015). However, based on the results of this study community members do not obtain sufficient benefits from the nature reserve, but also do not incur numerous costs from the nature reserve. Even though, there was a considerable support for biodiversity conservation (84.2%) since household respondents still held positive attitudes towards biodiversity conservation in the reserve and most of them would report illegal activities to the authorities. However, concerns were raised by the household respondents (17.1%) in relation to benefits (job opportunities, natural and cultural resources, and community development) they acquired from the nature reserve. Further, it was noted that poor communication (5.1%) between communities and the nature reserve management resulted in them developing negative attitudes towards the nature reserve. Furthermore, the majority of the household respondents (89.6%) were not participating in biodiversity conservation in the nature reserve, but they had better knowledge about nature conservation regardless of their education level. Thus, CBNRM has not fully realized its intended goals and objectives in the case of Blouberg Nature Reserve.

5.4 Conclusions

The study results have highlighted the importance of integrating information from both physical and human aspects for better monitoring of natural resources in PAs.

Thus, the following conclusions were made based on the findings of the study:

I. The combined Landsat spectral bands in conjunction with VIs and H’ improved the estimation of tree species diversity in BNR.

II. The results of the study demonstrated the decrease in tree species diversity in BNR since local communities were involved (1990 - 2019). However, temperature, rainfall, geology and evapotranspiration also had an influence on the status of the estimated tree species diversity of Blouberg Nature Reserve in the period 2009 - 2019.

III. Majority of the community members are not involved in biodiversity conservation activities in BNR. They do not get sufficient benefits and costs, however, the benefits acquired and costs faced do not depend on their involvement in biodiversity conservation in the nature reserve.

IV. Local community members held the positive views, perceptions and attitudes towards the nature reserve, despite the concerns raised in terms of job opportunities, communication between reserve management and local communities, and access to natural resources within the nature reserve.

V. Further, there is a support for biodiversity conservation despite that there is still poaching occurring within the nature reserve.

5.5 Recommendations

The study would like to make the following recommendations based on the above findings:

For future research:

I. The diversity of plant species would tend to increase animal species diversity. However, estimation of animal species together with tree species is suggested for future research.

II. The study revealed the ability of the Landsat in conjunction with H’ in estimating tree species diversity accurately, however the obtained relationships were low, so it will be of importance for future research to integrate VIs derived from high resolution satellite to species diversity estimation accuracies.

III. Further, the use of spatial explicit methods in assessing conservation endeavors in future research initiatives is recommended.

IV. The findings demonstrated a considerable support for biodiversity conservation (84.2%) since most of the household respondents indicated that they would report illegal activities to the authorities, thus the results from the by-physical aspect revealed a decrease in species diversity since the involvement of the local communities in biodiversity conservation. The study therefore, recommends that future research focus on the identification of specific human disturbance and other factors that might have impacts on tree species diversity in PAs.

V. The results revealed that there was a low participation in conserving biodiversity in BNR, thus, the study recommends that future research focus on the factors influencing the participation in conserving biodiversity in BNR.

VI. It will be clearer for future research to further investigate the influence of the governance and institutions on the CBRNM outcomes.

For the study area:

I. Law enforcement and effective patrolling should be prioritized in BNR to reduce poaching within the reserve and patrol the fence regularly.

II. There is a need for improved outreach and communication activities by the Blouberg Nature Reserve management to improve communication and minimize the complaints.

III. The nature reserve should create job opportunities such as creation of small businesses to alleviate poverty and in a way that would help reduce complains on access to natural resources within the nature reserve.

VII. The government and other conservation stakeholders should provide advice on alternative source of livelihood for the local community rather than expect provision of natural resource from the nature reserve.

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Annexures

Annexure 1: Permission letter for the communities

P.O Box 3069

Mphogodiba

0732

P.O Box 1593

Senwabaranwa

0700

03 March 2019

Dear Sir/Madam

REQUEST FOR PERMISSION TO DISTRIBUTE RESEARCH QUESTIONNAIRES AND CONDUCT INTERVIEWS

I am a registered student doing a Masters in Geography with the University of Limpopo. My research topic is: 'ASSESSMENT OF THE IMPLICATIONS OF INVOLVING LOCAL COMMUNITIES IN BIODIVERISTY CONSERVATION: A CASE STUDY OF BLOUBERG NATURE RESERVE IN LIMPOPO, SOUTH AFRICA'.

I hereby request permission to distribute questionnaires to the community members surrounding Blouberg Nature Reserve.

Yours faithfully

Mangana Rampheri

Annexure 2: Research Tool - Questionnaire

An assessment of the implications of involving local communities in biodiversity conservation: A case study of Blouberg Nature Reserve in Limpopo, South Africa

Questionnaire

I am Ms Rampheri, a masters degree student from the University of Limpopo. I am conducting an academic research on community involvement in biodiversity conservation in Blouberg Nature Reserve. I hereby declare that the research will be conducted in a transparent, honest and ethical manner. I shall respect the confidentiality of your response by not revealing your names when the research is finally written up. I will also explain fully the purpose of the study so that you can make a decision on participation. You have the right to decide whether or not you want to participate and I shall respect your right. Are you willing to participate?

Yes	No

Please make a tick next to the most appropriate response according to your opinion where the answers are provided

SECTION A: DEMOGRAPHIC CHARACTERISTICS

1. Gender

Male	1		Female	2

2. Age

≤16	1	17-20	2	21-30	3	31-40	4	41-50	5	51-60	6	>60	7

3. Highest level of education

No schooling	1	College certificate	5
Primary	2	Diploma	6
Secondary	3	University undergraduate degree	7
Grade 12	4	Postgraduate degree	8

4. Employment status

Employed	1	Self-employed	2	Unemployed	3

SECTION B: KNOWLEDGE ON NATURE CONSERVATION

1. What is the role of the reserve?

Protect wildlife	1	Other- Specify…………………………………………	4
Give local people jobs	2	I don't know	5
Provide local communities with infrastructure	3		

2. What is the role of the reserve management?

Conservation decision maker	1	1, 2 and 3	4
Conservation planner	2	I don't know	5
Facilitator	3	Other- Specify……………………………………….	6

3.Why do we have to conserve nature?

Protect wildlife for future generations	1	I don't know	4
Ensure continuous functioning of an ecosystem	2	Other- Specify……………………………………….	5

SECTION C: BENEFITS

1. Have you ever had access to natural resources within the reserve?

YES	1		NO (**Go to 3**)	2

2. If YES, which of the following?

Natural resources	Tick	Estimated amount	Frequency (months)		
			Often (3)	Several (6)	Sometimes (12)
Water	1				
Fuel woods	2				
Fibre	3				
Building materials	4				
Animal skin	5				
Food	6				

Medicinal plants	7				
Other (specify)	8				

3. If you do not have access to natural resources from the reserve, have you tried to access them?

YES	1		NO (**Go to 5**)	2

4. If YES, what happened?

5. If you did not try to access natural resources in the reserve, why?

We are restricted	1	Never bother	2	Other- Specify……………………..	3

6. Have you ever had access to cultural resources?

YES	1		NO	2

7. If YES, which one of the following?

Opportunity to have a view on wildlife within the reserve?	1	Opportunity to walk in the reserve?	3
Worship or perform any religious activity within the reserve?	2	Other (Specify)……………………	4

8. Does the reserve provide any infrastructure facilities to the community?

School	1	Roads	6
Community hall	2	Dam	7
Clinic	3	Community park	8
Library	4	Other- Specify……………………………………	9

9. Are you involved in biodiversity conservation in the reserve?

YES	1		NO (**Go to 13**)	2

10. If YES, which activities are you involved in?

Attend meetings	1	Volunteering in any conservation activity	4
Planning and decision making processes	2	Other (Specify)…………………………………………………………	5

11. Does your involvement in the reserve enhance your conservation knowledge?

YES	1		NO	2

12. If YES, how?

13. Are you or any member of your family employed within the reserve?

Security guard	1	Environmental educator	5
Run a tourist restaurant / lodge	2	Environmental cleaner	6
Field ranger	3	Sell cultural materials (beads, pots, utensils, clothes etc.)	7
Run a curio shop	4	Other (Specify)………………………………..	8

SECTION C: COSTS

1. Indicate on whether you have experience the following because of the establishment of the reserve:

Activity	**YES**	**NO**
You or member of your family been relocated		
Affected on agriculture		
Affected your livelihood		

2. Have you ever experienced injury or damage from wildlife from the reserve?

YES	1		NO	2

3. What kind of injury or damage from wildlife?

Type	**Tick**	**Frequency (Months)**	**What did you do**

		Often (every month)	Sometimes (12)	Rarely (24)	Other (Specify)	Killed it	Reported PA authorities to come and fetch it	Other (Specify)
1.Destroy my fence								
2.Damage my crops								
3.Destroy my livestock								
4.Transmit diseases to my livestock								
5.Transmit diseases to my people								
6.Attach and kill my people								
7. Compete for our resources (e.g. grass, land and water)								

SECTION E: PERCEPTIONS, VIEWS AND ATTITUDES

1. **The relationship between the management of this reserve and your community is good**

Agree	1	Strongly Agree	2	Neutral	3	Disagree	4	Strongly disagree	5

2. **If disagree in 1, what are your reasons?**

3. **From question 1, if disagree, what do you think can strengthen the relationship between the reserve and the nearest communities?**

4. If you see a poacher enters to the reserve or kills animals within the reserve, what would you do?

Keep quite	1	Help him/her to kill it	3
Report to the authority	2	Other- Specify……………………………...	4

5. What would you do if you find the reserve's fence in bad condition?

Report to the authority	1	Enter the reserve and set snares and set fire	4
Encourage community to fix it	2	Keep quite	5
Enter the reserve and harvest anything I want	3	Other- Specify……………………………………….	6

6. Why do people involve in poaching and illegal hunting of wildlife?

For bush meat	1	To sell animal products	2	Others- specify…………………………..	3

7.If we have to conserve wildlife in this reserve what is to be done?

Community outreach	1	More rangers	2	Better fencing	3	(1, 2 and 3)	4	Other- specify………….	5

Thank you for taking your precious time to complete the questionnaire survey.

Your assistance in this honor is greatly appreciated.

Annexure 3: Research Tool - Interview Guide

Interview guide: Reserve Manager

- In which year did you involve local communities?
- Are there any benefits (every benefit from social to economic) the involved communities get from the reserve? If Yes, name them. If No, why?
- How do you make sure that all the involved communities acquire benefits from the reserve? How do you distribute the benefits to the communities?
- How do you involve local communities in biodiversity conservation? The ways in which they are involved.
- How do you ensure effective community participation?
- Do you experience any costs (challenges) from the involved communities? If Yes, name them.
- How do you address those costs arise from the communities?
- If you may range the relationship between the reserve management and involved communities, how will you range it? Very strong? Strong? Moderate? Weak? Or very weak?
- Do involved community members get the access to the reserve anytime they want or is there a routine they use to access the reserve?