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Regeneration and Restoration Status of Miombo Woodland as A Result of Land Use Changes at the Buffer Zone of Gile National Park, Zambezia Central Mozambique

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A Thesis Submitted in Fulfillment of the Requirements for the Degree of Doctor of Philosophy in Forest Resource to the Faculty of Agronomy and Forestry Engineering, Eduardo Mondlane University.

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DECLARATION

I declare that this thesis is my unaided work. It has not been submitted before for any degree or examination in any other University. It is submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy in Forest Resources in the Forestry Engineering Department, Faculty of Agronomy and Forestry Engineering, Eduardo Mondlane University.

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Maputo, July 22, 2024

DEDICATION

This Thesis is dedicated to:

- To my father, whose dreams and aspirations for my educational success continue to inspire me every day. Although he passed away too soon to witness the realization of his desires, his spirit and guidance remain a guiding light in my journey.

- To all those who lost their lives to COVID-19 and their grieving families, may we honor their memories by striving for a better and more compassionate world.

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ABSTRACT

Study about impacts of deforestation and forest degradation (D&D), land use land cover change (LULCC), status of regeneration and restoration of Miombo woodland were conducted at the buffer zone of Gile National park (GNAP), central Mozambique. Household (HH) interviews, key informant interviews (KIIs), and focus group discussion (FGD) were used to collect data from the community. In total, 12 transects, 48 plots, and 240 subplots were sampled in dense Miombo woodland (DMWL), open Miombo woodland (OMWL), and abandoned agricultural land (AAL) to assess regeneration structure. Landsat imagery of 1999, 2009, and 2019 were used to analyze LULCC. Supervised classification was used for image classification. 200 HH were selected based on a simple random sampling technique. Chi-square test, Logistic regression analysis, Descriptive statistics, and Kruskal-Wallis were used to analyze data. Analysis and quantification of Spatio-temporal dynamics of the LULCC were done using QGIS 2.8.1 and ArcMap 10.1. Data collected through FGD and KIIs were analyzed qualitatively. Of all respondents taken for an interview, 47% were male-headed, and 53% were female-headed and mainly engaged in slash-and-burn agriculture. The most collected forest products were firewood, thatch grass, medicinal plants, and wild fruits. The mean forest dependency index (FDI) was 0.51 (SD = 0.40. About 80.5% of the respondents strongly agreed that D&D is the primary cause of the loss of economic woody species and the scarcity of fertile land in the study area. The overall accuracy for 1999, 2009, and 2019 were 90%, 90%, and 91%, respectively. DMWL and OMWL are the most dominant land cover class in 1999. Of the total land cover, about 34.57 and 40.86 % of land covers remained unchanged from 1999 to 2009 and 2009 to 2019 correspondingly. Within 20 years, about 14.85 % of DMWL has been changed to other land uses. Matured woody species density was significantly different between AAL&DMWL and DMWL & OMWL. However, there was no significant difference between OMWL and AAL. Regeneration density was significantly different between land-use types. The most regenerated family was Fabaceae. All respondents reported that no assisted restoration activity was/is taking place in the area. Slash and burn agriculture and animal grazing were ranked first and last most important factors affecting the regeneration of Miombo woodland, respectively. The adverse impacts of LULCC were associated with the underlying factors related to human activities. To solve the issue of regeneration, there must be broad-scale restoration projects around the area supported by awareness creation and incentive mechanisms to conserve forests. Our findings suggest the importance of diversifying sources of income, creating a market value chain for their product, and strengthening collaboration between the park and the community surrounding the park could reduce the dependence of the community on slash and burn agriculture as well as safeguard the park from degradation and at the same time maintain the livelihood of the community.

Keywords: Deforestation, Miombo Woodland, Land Use Land Cover Change (LULCC)
Gile National Park (GNAP)

RESUMO

Um estudo sobre os impactos da desflorestação e da degradação florestal (D&D), da mudança de cobertura do solo no uso da terra (LULCC), do estado de regeneração e restauração da floresta de Miombo foi realizado na zona tampão do Parque Nacional do Gile (GNAP), centro de Moçambique. Foram utilizadas entrevistas aos agregados familiares (HH), entrevistas a informadores-chave (EIC) e discussões em grupos focais (FGD) para recolher dados da comunidade. No total, foram amostrados 12 transectos, 48 parcelas e 240 subparcelas em florestas densas de Miombo (DMWL), florestas abertas de Miombo (OMWL) e terras agrícolas abandonadas (AAL) para avaliar a estrutura de regeneração. Foram utilizadas imagens Landsat de 1999, 2009 e 2019 para analisar o LULCC. A classificação supervisionada foi utilizada para a classificação das imagens. Foram seleccionados 200 AF com base numa técnica de amostragem aleatória simples. O teste do qui-quadrado, a análise de regressão logística, a estatística descritiva e o Kruskal-Wallis foram utilizados para a análise dos dados. A análise e quantificação da dinâmica espaço-temporal do LULCC foram feitas através do QGIS 2.8.1 e do ArcMap 10.1. Os dados recolhidos através de FGD e KIIs foram analisados qualitativamente. De todos os entrevistados, entrevistados, 47% eram chefiados por homens e 53% eram chefiados por mulheres e estavam principalmente envolvidos na agricultura de queimada. Os produtos florestais mais recolhidos foram a lenha, a palha, as plantas medicinais e os frutos silvestres. O índice médio de dependência florestal (IDE) foi de 0,51 (DP = 0,40. Cerca de 80,5% dos inquiridos concordaram fortemente que o D&D é a principal causa da perda de espécies lenhosas económicas e da escassez de terras férteis na área de estudo. A precisão global para 1999, 2009 e 2019 foram de 90%, 90% e 91%, respetivamente, DMWL e OMWL são a classe de cobertura do solo mais dominante em 1999. Da cobertura total do solo, cerca de 34 ,57 e 40,86% da cobertura do solo permaneceram inalteradas desde então. de espécies lenhosas maduras foi significativamente diferente entre AAL&DMWL e DMWL & OMWL. está a ser realizada na área. Os impactes adversos do LULCC estiveram associados aos factores subjacentes relacionados com as actividades humanas. Para resolver a questão da regeneração, devem existir projectos de restauro em grande escala em toda a área, apoiados pela sensibilização e mecanismos de incentivo para a conservação das florestas. As nossas descobertas sugerem que a importância de diversificar as fontes de rendimento, criar uma cadeia de valor de mercado para os seus produtos e reforçar a colaboração entre o parque e a comunidade em redor do parque poderia reduzir a dependência da comunidade da agricultura de queimada, bem como salvaguardar o parque da degradação e ao mesmo tempo manter a subsistência da comunidade.

Palavras-chave: Desflorestação, Florestas de Miombo, Alteração do Uso do Solo e Cobertura do Solo, Parque Nacional de Gile

LIST OF ABBREVIATION AND ACRONYMS

AAL=Abandoned Agricultural Land

AL=Agricultural Land

ANAC = National Administration of Conservation Area

ArcGIS = Aeronautical Reconnaissance Coverage Geographic Information System.

CM=Community

D&D= Deforestation and Forest Degradation

DBH=Diameter at Breast Height

DINAF= Direcção Nacional de Florestas

DINAGECA=National Directorate of Geography and Cadastre

DMWL =Dense Miombo Woodland

DMWL=Dense Miombo Woodland

ERDAS= Earth Resources Data Analysis System

FAO= Food and Agriculture Organization

FDI = Forest Dependency Index

FGD = Focus Group Discussion

FLR =Forest Landscape Restoration

FSC= Forest Stewardship Council

GNR=Gile National Reserve

HH=Household,

IPCC= Intergovernmental Panel on Climate Change

IUCN = International Union for Conservation of Nature

IVI = Importance Value Index

K=Kappa Statistics.

KIIs =Key Informant Interviews

Km=Kilometer

KML= Keyhole Markup Language

LANDSAT TM =Thematic Mapper

LULC=Land Use Land Cover

LULCC= Land Use/Land Cover Change

MLC =Maximum Likelihood Algorithm

NP =National Park

NTFP= Non-Timber Forest Products

OLI = Operational Land Imager

OMWL= Open Miombo Woodland

OR=Odd Ratio

OT=Others,

PA=Producer's Accuracy,

PhD= Doctor of Philosophy

QGIS= Quantum Geographic Information System

RD = Relative Density

RDo =Relative Dominance

REDD+= Reducing Emissions from Deforestation and Forest Degradation

RF = Relative Frequency

RL = Regeneration Limitation

SD=Standard Deviation

SJ = Similarity Index

SL=Shrub Land

SPSS= Statistical Package for Social Sciences

TIRs= Thermal Infrared Sensor

TM =Thematic Mapper

UA=User's Accuracy,

UNEP= United Nations Environment Program

USGS = United States Geological Survey

UTM= Universal Transverse Mercator

VIF = Variance Inflation Factor

WB=Water Body,

WBG=World Bank Group

WGS = World Geodetic System

WRI= World Resources Institute

ZILMP= Zambézia Landscape Program

CHAPTER 1. GENERAL INTRODUCTION

1.1. Background of the Study

Forests are important not only as a source of wood, but also as protectors of hills, thus regulating the flow of water, protection of watersheds, reduction of soil erosion rate, tourism, provision of non-timber forest products (NTFP), wildlife habitat, carbon storage for change mitigation climate, among others (DINAF, 2018). Miombo woodlands represent one of the largest areas of global tropical dry forests (FAO,2012) and a vast African dryland forest ecosystem (Dewees et al., 2011; Dewees et al., 2010; Gumbo et al., 2018). It represent the most extensive savanna woodland type, in southern Africa covering up to 1.9 million sq.km (Frost, 2020). It covers substantial portions of southern Africa: Angola, Zimbabwe, Zambia, Malawi, Mozambique, and Tanzania, and most of the southern part of the Democratic Republic of Congo (Dewees et al., 2010). Miombo woodland regions are characterized by significant climatic and environmental gradients, ranging from dry to wet Miombo (Ribeiro et al., 2008; Gonçalves *et al*., 2017; Frost, 2020).

Characteristically, Miombo is found in areas that receive more than 700 mm mean annual rainfall on nutrient-poor soils, and is dominated by a few species, mostly from the genera *Brachystegia*, *Julbernardia* and *Isoberlinia* (Campbell, 1996; Dewees, et al., 2011; Lupala et al., 2015 ; Bhattarai et al., 2020) in which these genera are seldom found outside Miombo (Chidumayo, 1996). The composition and structure of Miombo woodland appears superficially to be relatively uniform over large regions, suggesting a broad similarity in key environmental conditions (Musamba, et al., 2011).

Miombo woodland supports a high diversity of plant species, including a considerable level of endemism, and is an important habitat for many charismatic animal species including herbivores (e.g. *Loxodonta africana* and *antelopes*), carnivores (e.g. *Panthera leo* and *Lycaon pictus*, amongst others), various species of birds and a diversity of insects (Ribeiro et al., 2020). Miombo woodland is a resilient ecosystem (Ribeiro et al., 2020) and its floristic species richness is estimated at 8,500 species, of which 54% are endemic (Assédé et al., 2020; Dewees et al., 2010) . The high regeneration capacity of Miombo woodlands is mainly due to disturbance resistance as well as its capacity of vegetative reproduction from roots, and coppicing from cut stumps (Shirima et al., 2015).

Miombo woodland is important for livelihoods in which about seventy-five million people inhabited in the Miombo regions, and additionally 25 million urban dwellers rely on as a source of energy (Dewees et al., 2011). Most Miombo has been heavily disturbed precisely because it has great local value. It provides dry-season fodder for large livestock populations and fuelwood for domestic use and rural industry. It offers construction material for farm structures and homes for millions. It is a rich source of wild foods and fruits, reducing the vulnerability of poor rural households from the risks of crop failures. With few alternative economic opportunities, up to a third of household consumption among poor rural households can come from dry woodlands (Dewees et al., 2010). Due to its capacity of sequestering an enormous amount of carbon, from a global perspective, Miombo is quite important (Bhattarai et al., 2020; Dewees et al., 2010; Hamza Mgumia, 2017; Malunga et al., 2021).

Land use land cover change following tree cutting (farming and energy fuel), forest fire, grazing, high poverty and unsustainable resource use deteriorate Miombo woodland ecosystem (Campbell et al., 2008). Land use/land cover change (LULCC) is a major issue in global environment change (Anchan et al., 2018; Andualem et al., 2018). Rapid worldwide population growth accompanied by human activities has led to rapid LULCC (Anchan et al., 2018; Shah et al., 2017; Yirsaw et al., 2017). LULCC has become a central and important component in current strategies for managing natural resources and monitoring environmental changes (Rawat et al., 2013). LULCC is an important factor affecting carbon cycling process and bringing changes to carbon sources and sinks in terrestrial ecosystems through changes in biophysical properties of the land-cover (Ge et al., 2008; Lai et al., 2016; Quesada et al., 2018). A quarter of the total carbon emission by human activities is caused by land use changes as a result of deforestation and forest degradation (Daniel et al., 2016; IPCC, 2001) .

Restoration is the long-term process of regaining ecological functionality and enhancing human well-being across deforested or degraded forest landscapes (IUCN and WRI, 2014). Forest restoration activities have become increasingly common around the world in which regeneration of trees is often a key component (Löf et al., 2019). Regeneration is the process by which mature individuals of a plant population are replaced by new individuals of the next generation (Larson &

Funk, 2016). To meet the increasing demands of provisioning services of forests which many people heavily rely on (Aerts and Honnay, 2011), passive and /or active forest restoration is probably the only solution in the face of today's forest loss (Holl & Aide, 2011; Lamb et al., 2005).

Transformative policies require a systemic understanding of the context of deforestation in order to identify strategic interventions (Minang et al., 2015).There are numerous global, national regional and even subnational targets for increasing forest area and forest restoration. Accordingly, it is imperative to develop low-cost strategies and techniques for landscape restoration. The most widely used restoration strategies involving planting of tree seedlings are often costly and their application for restoring vast expanses of degraded forest lands may be limited (IUCN and WRI 2014;Chokkalingam et al., 2018).

Fluctuations in forest cover following deforestation and forest degradation have a significant impact on rural residents' livelihoods, as it is challenging to have access to harvest forest products. The quality of life in the rural communities has worsened in recent years as the essential means of livelihood, such as fertile land and forest resources, are increasingly being threatened (Innocent, 2019). It is an indisputable fact that the dependence of millions of people on forests leads to degradation and deforestation; several benefits are accruing from such loss (in the aspect of livelihoods, income, and employment) for sustenance of indigenous people (Wajim, 2020).

Loss of functionality of protected areas from surrounding land-use modification is a particularly daunting problem in developing nations. These areas are where land-use change has been occurring rapidly over the last 25 years and it is projected to continue (Bailey et al., 2015). In opposite, the resources in and around protected areas are more critical to people living adjacent to it (Dibaba et al.,2020; Hartter & Southworth, 2009). As such, to ensure the effectiveness of protected areas, it is necessary to understand changes driven by the surrounding landscapes (Chiteculo et al., 2018a; Kintz et al., 2006). Knowledge of LULCC over a time horizon can be of great importance in the context of preparing concrete local, regional and national land management measures and can be used to reverse land use issues, illegal occupations, habitats destruction, ecological and natural resource deterioration, loss of biodiversity (Bamford et al., 2014; Mucova et al., 2018a).

1.2. Statement of the Problem

The loss of tropical forests due to land use land cover change (LULCC) is a major concern as it causes global CO_2 fluctuation (Bonan, 2008; Pongratz et al., 2014). Miombo woodlands has global importance as it is a reservoir of carbon in large coverage and supports high floral and faunal diversity which is a source of living for millions of people and believed as natural insurance (Dewees et al., 2010). The dynamics of Miombo are essentially driven by the social, cultural, economic and ecological factors (Zolho, 2005). Given the fast land use and land cover changes in the last 10-20 years in Mozambique, Miombo has been substantially intervened by human activities (Ribeiro et al., 2020) and are considered to be vulnerable to climate change impacts (Ribeiro et al., 2015).

Deforestation rates and poverty estimates in the Miombo eco- region are disturbing mostly due to land clearing for agriculture and wood extraction for energy (Dewees et al., 2011). Recent and up-to-date information on forest condition and the extent of forest degradation enable the prioritization of human and financial resources to prevent further degradation and to restore and rehabilitate degraded forests (FAO, 2011& 2015). Planning and managing to slow or reverse forest loss requires detailed information on forest status and change over time (Uddin *et al*., 2015). In the past, forest ecosystems were subjected to infrequent natural disturbances and natural succession was enough to return it to its former condition within years or decades depending on the severity of the disturbance (Chokkalingam *et al*., 2018). These days, however, human-induced disturbances are often too severe for natural succession to restore the damage and it require human interventions to overcome the problem (APFN and FAO, 2017).

More recently, there have been dynamic changes in Miombo cover due to over exploitation as well as land cover conversion (Gumbo *et al*., 2018). Despite their importance, the Miombo woodlands are facing a countless threat to its biodiversity, derived from a complex combination of direct and indirect drivers posed by human activities including conversion into agricultural land, charcoal production, and fire (Assédé et al., 2020). Human growth have increased the competing demands on land and woodland resources with consequences for the ecosystems' capacity to provide goods and services (Ribeiro et al., 2020). However, despite of its importance for biodiversity and for the livelihoods of millions of inhabitants, Miombo woodland has received little attention from the scientific community (Gumbo et al., 2018; Siyum, 2020).

The main forest restoration practices advocated in Miombo woodlands is mostly through coppice natural regeneration because of the associated benefits of better rates of growth due to the already established root system (Chirwa et al.,2014). Miombo woodland actually regenerates fairly easily and prolifically, provided that regeneration is not inhibited by late dry season fires or by cultivation (Dewees et al.,2011). Many woody species found in Miombo reproduce vegetative, so Miombo recovers well from harvesting because of its ability to easily regenerate (Chidumayo, 2004) and this capacity is quite important throughout the Miombo region (Dewees et al., 2011).

To ensure the successive existence of woody species within different generations, regeneration is very important and a fundamental process which drives forest dynamics (Feldmann et al., 2020; Larson & Funk, 2016; Parveen et al., 2010). Miombo is a resilient ecosystem and can return to its original state in 15-20 years after disturbances are removed (Ribeiro et al.,2020) as it have ability of regenerating naturally after disturbance (Afrifa *et al*., 2016), and its regeneration is stimulated by presence of open patches created by disturbances and death or felling of mature trees (Mwansa, 2018). Regenerating capacity of Miombo ecosystem is a key to its productivity and ability to survive disturbances (Sangeda & Maleko, 2018 ; Chidumayo & Gumbo, 2013). The survival of regeneration of individuals of Miombo has ability to influence plant population and community dynamic (Johnstone et al., 2016; Larson & Funk, 2016; Syampungani et al., 2017).

Mozambique have still extensive forest cover of which Miombo is the predominant forest ecosystem and covers two thirds of the total forest area (World Bank, 2018). In spite of tremendous value and unrealized potential, Mozambican forest is being rapidly depleted with deforestation rate of 0.79% per year (WBG, 2018). D&D drivers in Mozambique are multiple, complex, and act simultaneously or in a time sequence. The process of conversion of intact forests to other land uses through time most often begins with forest disturbance, typically selective logging (Sitoe *et al*., 2016). Several studies have been done in Mozambique in the past to identify and understand the main agents and causes of D&D at the national level having identified the complexity of their interaction and concluding, the need for more detailed analysis and collection of more information and quantitative data (Sitoe et al., 2012, 2013).

Even though Zambézia Province is home to luxurious forests, population growth and rural poverty are driving extensive loss of natural forest in this Province (WBG, 2018). Zambezia province has the second highest rural population density and deforestation rates in the country

(Montfort et al., 2021). Between 2001 and 2016, Zambezia province lost about 5% of its forest cover (approximately 5440 km^2) to small-scale slash and burn agriculture and charcoal production. With limited access to alternative sources of income, Zambézia's largely rural population is caught in a cycle of unsustainable forest use and land practices (World Bank, 2018). Since 2009 there has been a growing threat around Gile National Park (Mercier et al., 2016) , and now it has suffered extensively from poaching and, more recently, illegal logging of valuable species (WBG, 2018) . Gilé National Park, which is the most protected area in the country and may soon be affected by land clearing activities, which are increasing on its periphery and account for a deforestation rate of 0.28% between 2005 and 2013, D&D in the buffer zone are increasing year after year (Mercier *et al.*,2016).

Mozambique is engaged in a pilot project for REDD+ in two provinces, including Zambézia, establishing a series of new management and monitoring programs such as restoration of degraded lands, strengthening protected areas management and the implementation of the Zambézia Integrated Landscape Management Program (ZILMP). In Mozambique, little is known about land use, and land-cover changes at the national level are still very incipient (Mucova et al., 2018; Sitoe et al., 2012). Drivers of deforestation and forest degradation vary per province, based on forest type, economic, social and natural characteristics (Sitoe et al., 2016).

Although Gile National Park (GNAP) is the only protected area in Mozambique with no permanent settlements in its core area and represents one of the largest intact area of Miombo woodland in Mozambique (Montfort et al., 2021a), it has been one of the flash points for illegal logging. In 2016 alone, the park apprehended five tractors and 23 trucks involved in illegal logging inside the park (Mercier et al.,2016). To that end, the buffer zone of the park is suffering from the degradation of Miombo woodland (Montfort et al., 2021), for instance, from 2003 to 2013, Mozambique lost about 267,000 ha annually due to deforestation, of which 613.97ha loss was registered at the buffer zone of GNAP (World Bank, 2018).

The status of regeneration and restoration, drivers of D&D of Miombo woodland in the buffer zone of GNAP, is little known and not well documented; as it has been studied only in the regrowth /abandoned agricultural land (AAL) (Montfort et al., 2021). Therefore, this study intends to fill this gap by having the following objectives.

1.3. Study Objectives

1.3.1. General Objective

The General objective of the study was to assess cause of deforestation and forest degradation, Regeneration and Restoration Status of Miombo Woodland as a result of land use land cover changes at the buffer zone of GNAP in Zambezia, Central Mozambique.

1.3.2. Specific Objectives

- To evaluate Land Use and Land Cover Changes of Gile National Park Buffer Zone Central Mozambique.
- To identify Socio-economic and ecological impacts of deforestation and forest degradation on Residents community livelihood at GNAP buffer zone.
- To explore regeneration and restoration status of Miombo woodland in buffer zone of GNAP central Mozambique.
- To identify and measure the diversity of regenerated woody species in buffer zone of GNAP

1.4. Hypothesis

- There is a significant difference in diversity and distribution of regenerating woody species across different land use types at the buffer zone of GNAP.
- Socio-economically and ecologically, D&D significantly impacts human livelihoods following LULCC in the study area.
- The pattern of spatial regeneration distribution of woody species is regularly distributed and varies across different anthropogenic disturbances (land use type) in the study area.

1.5. Background

The background of this study is presented in three perspectives: The Historical perspective, which explains the role of Miombo woodland and the impact of deforestation and forest degradation; the Theoretical background, which explains forest cover change and the Conceptual perspective containing definitions of the significant concepts in the study topic.

1.5.1. Historical Background

Dry woodlands including Miombo make up over 40% of forest cover in the tropics and widely thought to be undergoing rapid degradation as a result of human activity (Abbot & Homewood, 1999). Miombo is a colloquial term of savanna-woodland dominated by the *genera Brachystegia*, *Julbernardia* and/or *Isoberlinia* (Frost, 1996). Miombo woodlands form a continuous coverage in eastern, central and southern Africa, often dominated by trees of *Brachystegia*, *Julbernadia* and *Isoberlinia* genera of the family *Leguminosae* and subfamily *Caesalpinioideae* (Bhattarai et al., 2020; Campbell, 1996).

Miombo woodlands are one of the world's most important ecosystems, which play an essential role at the social, economic and environmental levels (Malunga et al., 2021; Ribeiro et al., 2015).Miombo woodlands provide vital resources to the livelihoods of millions of rural and urban people living in and around these woodlands generally and in central, eastern and southern Africa particularly (Gumbo et al., 2018, Matowo et al 2019). Miombo is also essential for livelihoods and is considered natural insurance (Dewees et al., 2011; Dewees et al., 2010). People inhabit Miombo regions, and urban dwellers rely on Miombo wood as a source of energy (Dewees et al., 2011; Ryan et al., 2016a). Most of its ecosystem and woody species growth has been influenced by anthropogenic processes, including selective logging, shifting agriculture, fires, genetics, climate and soils and wood collection (Chirwa et al., 2008; Ribeiro et al., 2020).

The most common type of Miombo in Mozambique has a structure of an "open forest" with two strata: the upper story is composed of woody vegetation of *Brachystegia*, *Julbernardia* and *Isoberlinia* with others, and the lower story is composed of herbaceous with *Themeda triandra*, *Panicum*, *Hyparrhenia* and *Andropogon* (Gumbo et al., 2018). Miombo woodlands are the most extensive tropical seasonal woodland and dry forest formation in Africa, and most Miombo in southern Africa have been heavily disturbed because it has great local value (Dewees et al., 2010). Statistics on forest cover in the Miombo countries continue to show a decline in cover (Dewees et al., 2011). Miombo woodland cover represents a significant shrinkage of one third (estimated 1.9 million km^2) as compared with the previous estimate of 2.7 million km^2 (Ribeiro et al., 2020). Regeneration of Miombo occurs through coppicing, root suckers and seedlings, which fall under sexual (seedling) and asexual, which is through vegetative propagation (root suckers and coppices from stumps) (Chirwa et al., 2014). However, natural vegetative propagation is the most feasible in the sustainable management of Miombo because it have robust regeneration in harvested areas for charcoal, firewood, poles and timber production. Root suckers and coppices proliferate compared with seedlings offering remarkable and rapid recovery of disturbed Miombo ecosystems (Sangeda & Maleko, 2018).

Forest landscape restoration (FLR) is the long-term process of regaining ecological functionality and enhancing human well-being across deforested or degraded forest landscapes (Chirwa, 2014; Chokkalingam et al., 2018; IUCN and WRI, 2006). It is an emerging concept that refers to an approach involving stakeholders in all affected land-use sectors and applying participatory decision-making processes (Chokkalingam et al., 2018). FLR is an approach to forest restoration that seeks to balance human needs with those of biodiversity, thus aiming to restore a range of forest functions and accepting and negotiating the trade-offs between them (Mansourian et al., 2005).

The implementation of restoration can vary considerably in temporal scale, size and purpose. It can serve one single landscape function or objective (e.g. adapting/ mitigating climate change or biodiversity conservation), or it may be carried out for multiple combined objectives (Lapstun, 2015). For many conservationists, restoration is either about restoring original forest cover in degraded areas or planting forest corridors to link protected areas and requires the ability to work across disciplines, including agriculture, forest-compatible income-generation activities, forestry, and addressing water issues as well as specific social issues (Mansourian et al., 2005).

Protection of young re-growths against fires would enhance their survival and, consequently, their establishment and development into adult trees (Chirwa et al.,2015). Most of the woodlands across southern Africa are capable of recovering following disturbance cessation (Chirwa et al., 2008). Regeneration of Miombo involves the replacement of the old matured and disturbed individuals by new individuals of the next generation through vegetative reproduction and seedling emergence, whereby the survival of each individual can influence plant population and community dynamic (Afrifa et al., 2016; Feldmann et al., 2020; Larson & Funk, 2016).

Forest degradation is a process leading to a ‘temporary or permanent deterioration in the density or structure of vegetation cover and/or its species composition (IUCN, 2021). It is a change in forest attributes that leads to a lower productive capacity caused by an increase in disturbances.

The time-scale of forest degradation processes is in the order of a few years to a few decades (Sitoe et al., 2016; Okia, 2012). Findings on global patterns of forest degradation indicate that commercial timber extraction and logging activities account for more than 70 percent of forest deforestation and degradation (Lapstun, 2015; Packiam, 2015). Deforestation has been attributed to socio-demographic factors, such as population growth and the political economy of class structure, and specific exploitation activities like commercial logging, forest farming, fuel wood gathering, and pasture clearance for cattle production (FAO, 2007; Jarot and Mutaqin, 2016).

1.5.2. Theoretical Framework

Human societies constantly coevolve with their environment through change, instability, and mutual adaptation. As a result, land use change is non-linear and is associated with other societal and biophysical changes through a series of transitions. It is essential to understand under what conditions land use changes take place. The causal mechanisms behind land use changes can invoke two forces of a different nature. One, though socio-ecological factors, which means changes in land use decisions that result from a severe degradation in ecosystem services caused by past land use practices, the critical point is that this process is endogenous to the coupled socio-ecological system. On the other hand, land use changes could be caused by socio-economic change and innovation that take place independently of the ecological system and follow their own dynamics. These changes are exogenous: they can be driven by urbanization, economic development or globalization and yet have an impact on land management and thus lead to a land use change. These two lines of explanation of land use changes raise the following questions: Are the sources of land use changes primarily ecological or socio-economic; endogenous or exogenous; local or global? (Defries et al., 2004; Grimm et al., 2008; Lambin & Meyfroidt, 2009). The relative importance of endogenous versus exogenous forces significantly impacts how land use changes can be understood, modelled and accelerated by policy intervention (Perz, 2007).

Forest transitions represent a subset of land use transitions (Foley et al., 2005). Forest transition theory: how does forest cover change over time? The forest cover dynamics are also captured in a time dimension, theorized as the forest transition theory (Indarto & Mutaqin, 2016). This theory was introduced by Mather (1992). Initially, he developed this idea based on a basic sequence of natural resource destruction and conservation. This model argues that forest destruction is inevitable at an early stage to meet human needs. Rising demand and prices for the forest will incentivize people to conserve and restore their forest. Forest transition theory focuses more on the temporal changing of forest cover or a change in forest cover trends over time (Lambin & Meyfroidt, 2009). The concept of forest transition refers to a change at a national or regional scale from decreasing to expanding national forest areas, from net deforestation to net reforestation (Lambin & Meyfroidt, 2009; Mather, 1992).

Brockhaus et al. (2009) further describe the forest transition in the sequence as shown in Figure 1.1. After the stage when forest cover is still high and the deforestation rate is low, as the development takes place, then forest cover and deforestation rate are low due to scarcity of forest. Two forces eventually stabilize forest cover, economic development, better paid, off-farm jobs reduce the agricultural rent and the profitability of deforestation, and forest scarcity, where scarce forest cover increases forest rent (the value of forest products and environmental services) and puts the brakes on forest conversion (Rudel et al., 2005). In the end, an increasing forest rent could stimulate the transition by incentivizing forest plantation or reforestation/afforestation.

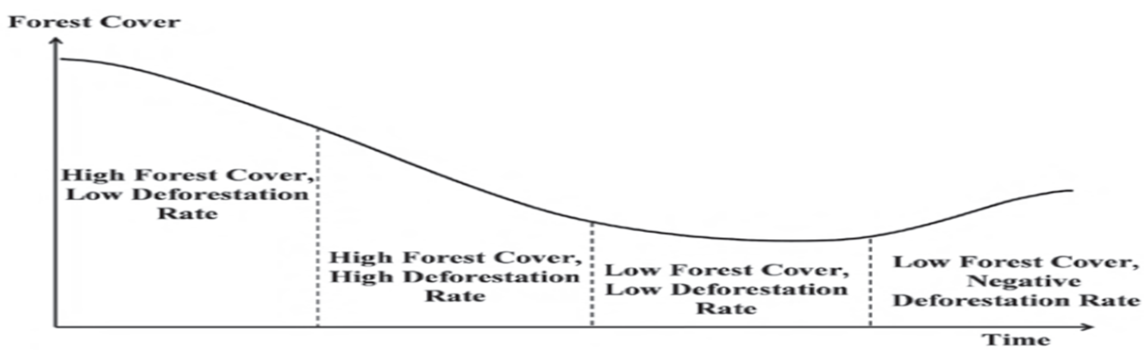

Figure 1.1 Stages of forest transition

Source; Brockhaus et al (2009)

This Forest transition theory provides a way to describe the relationship between forest cover and its degradation. The central point of using this theory for this study is to show that Mozambique as a country and Zambezia as a province where rich in forest cover and that forest is gradually exposed to D&D due to several factors and at the sometime before this forest resource lost totally, action can be taken to restore this vital forest as used by (Sitoe et al., 2016). So, as long as the change in forest coverage nationally as general and the study area specifically passing through this serious of steps directly or indirectly, it fulfils and falls under forest transition theory.

1.5.3. Conceptual Framework of the Study

The management of Miombo woodland should enhance its biomass regeneration (Chidumayo et al., 1996). The loss of Miombo woodland is driven mainly by two major processes; land clearing for agriculture and wood extraction for different uses (Campbell et al., 2007). Productivity in Miombo woodland is a function of disturbance factors; the way it responds to harvesting (regeneration) and human activities affect its regeneration rate (Chidumayo et al., 1996). In the context of its intensified disturbances and meeting human demands, the sustainability of Miombo woodlands requires a clear understanding of dynamics, magnitude and the impact of these disturbances, together with the knowledge of factors affecting its resilience (Matowo et al.,2019). This research proposes a conceptual framework for understanding Miombo regeneration status with disturbance factors (Figure 1.2). In so doing, it answers the following analytical questions: are Miombo woodlands regenerating in the study area or not, and what are the factors affecting the regeneration of Miombo woodlands? How does disturbance maintain the diversity and richness of regenerated species? Which woody species have more regenerated sapling in the study area, and why?

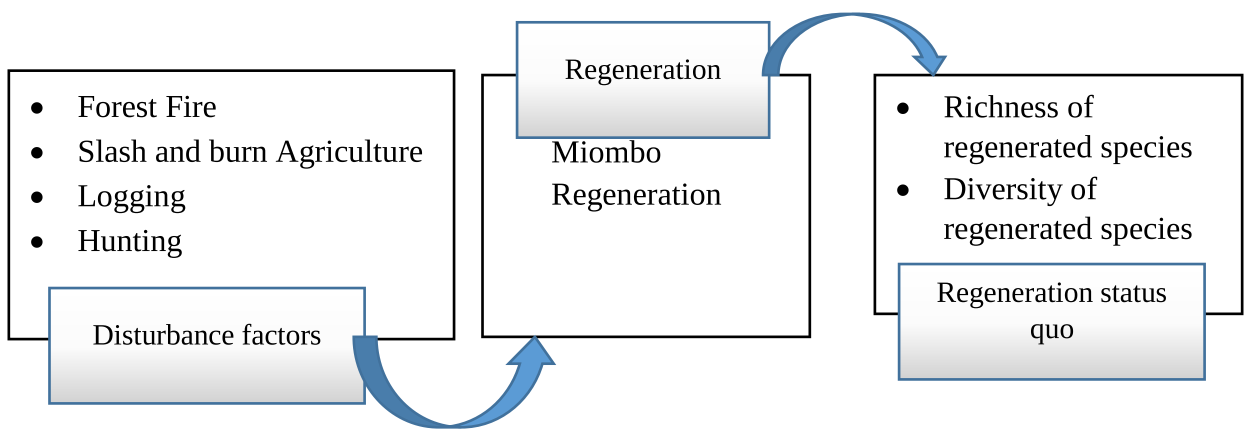

Figure 1.2 Conceptual framework of the relationship between regeneration, factors affecting regeneration and regeneration status quo in Miombo ecosystem.

Source ; Adopted from Matowo et al (2019).

This study used the attribution theory to contextualize users-driven deforestation and forest degradation. This theory is initially designed in social psychology to explain how and why people form an opinion or perception about a particular event, resource or observation (Weiner, 1985).

The theory helps in judging human understanding, decision-making, and actions. A particular action can be judged on whether a behavior is caused by internal or external reasons, i.e., by the actor or something outside the actor. In explaining deforestation and degradation, the attribution theory can form the basis for explaining the events, processes, or decisions to which the users-related deforestation and degradation problems could be attributed (Duguma et al., 2019). Accordingly, for instance, user-driven deforestation and degradation could be caused by livelihood needs but could also result from external pressures such as land deprivation or markets for forest products. Both external and internal pressures affect the welfare of the actors concerned (Winkler, 2010).

Steg & Vlek (2009) state that environmental behavior is driven by any or combination of three key factors: motivational factors (i.e. perceived costs and benefits, moral and normative concerns and acts), contextual factors such as physical infrastructure, technical facilities, the availability of products and its characteristics and customary behavior. Stern (2000) gives a more detailed view of this by identifying four causal variables for a given environmental behavior: attitudinal factors (including norms, beliefs, and values); External or contextual factors, which include (interpersonal influences (e.g., persuasion, modelling); community expectations; advertising; government regulations; other legal and institutional factors); personal capabilities; and habit or routine behaviors (Figure 1.3). Personal capacity should not have considered as seriously important since every household depends on forest products irrespective of their capacity. Livelihood is a crucial part of the contextual factors driving. To achieve pro-environmental behavior, Steg & Vlek (2009) proposed two key strategies that target the factors that influence environmental behaviors: (1) Informational strategies that focus on changing the perceptions, norms, motivations and knowledge and (2) structural strategies that target changing the context in which decisions, about a given environmental behavior, are made. This study looks through these two lenses to identify what factors aggravate LULCC following deforestation and degradation and could help to minimize it.

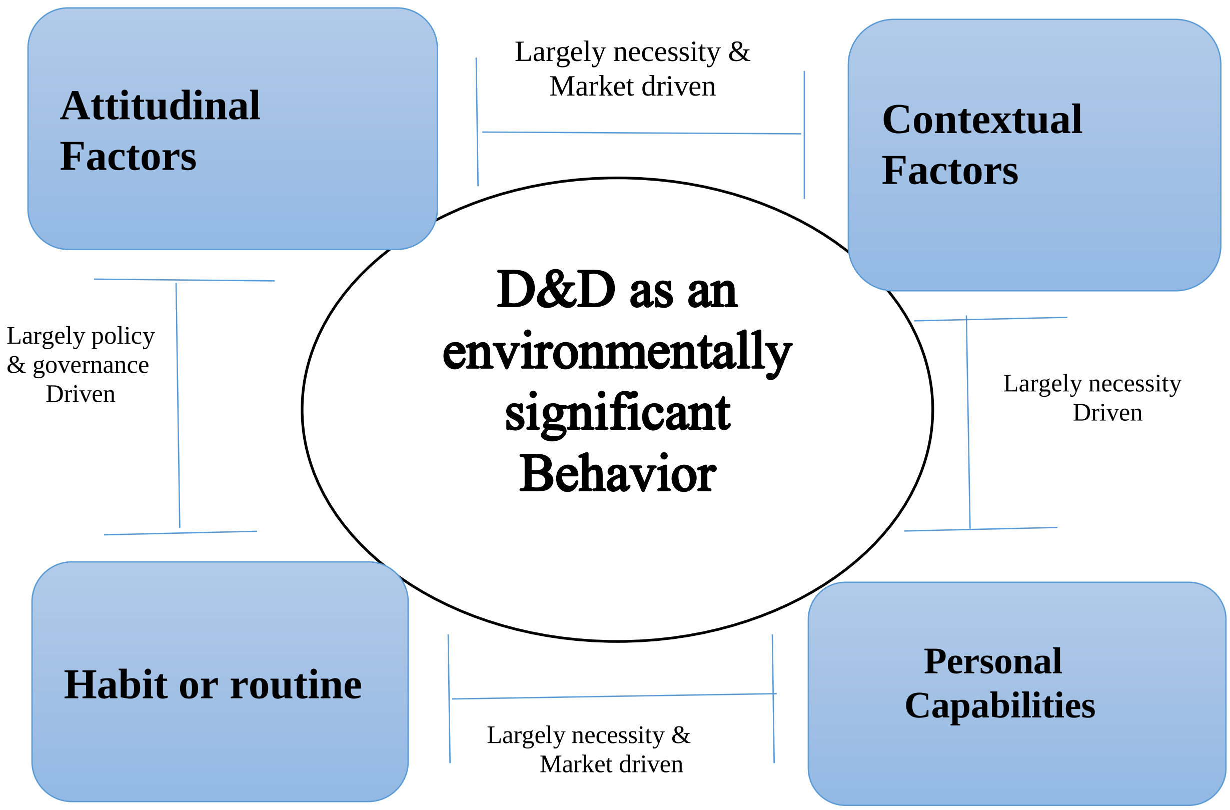

Figure 1.3 Conceptual framing of the aspects of D&D as an Environmental behavior.

Source; Duguma et al (2019)

Briefly, the proximate cause of D&D is defined as human activities that directly change the physical environment reflected in land cover, which is formed by the underlying driving force, the indirect factor. The proximate factor is the near-final or the last human activities altering tree cover or the direct sources of D&D. LULCC is a multifaceted process (Robinson et al., 2013) covering various socioeconomic, demographic and environmental variables. Particularly for the underlying causes, causative relationships and links among them are neither one-way nor single nor linear (Angelsen & Kaimowitz,1999). In this context, the association between explanatory variables and LULCC can be in the form of dual effects, positive or negative signs. A brief dual effect hypothesis of LULCC is summarized in (Figure 1.4).

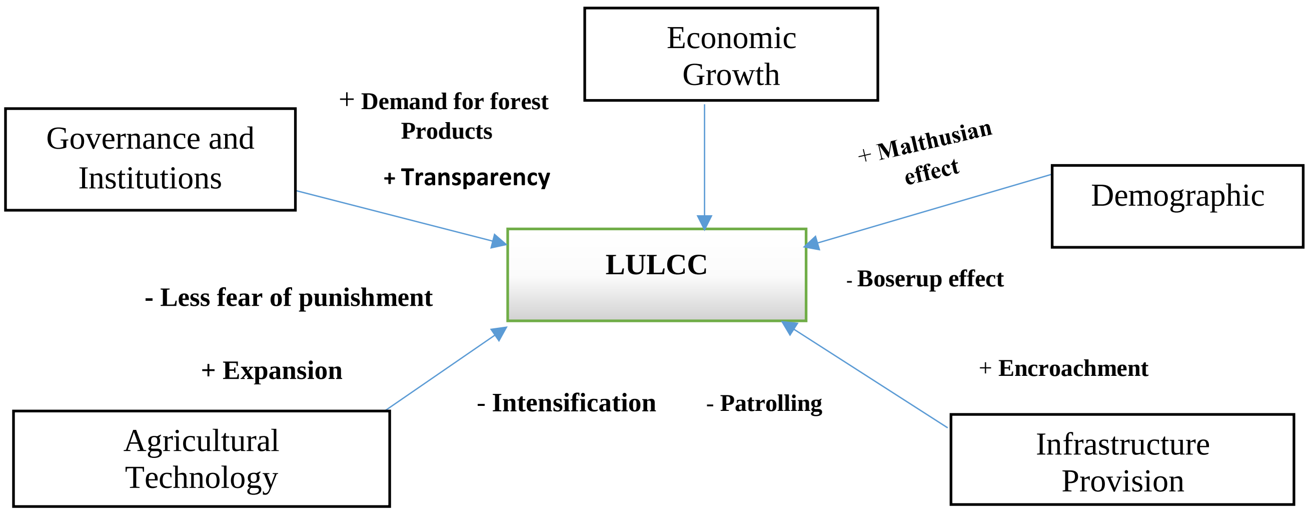

Figure 1.4 Dual effect hypothesis of proximate and underlying causes of LULCC

Source: Adopted from Mahapatr & Kant (2005)

Economic growth, for instance, affects LULCC in both positive and negative ways. The positive impact of LULCC can be exemplified by increasing economic growth, which may be hypothesized under the frontier theory. In contrast, increasing capital invested in forest frontier areas brings more forest pressure. Companies, loggers, and small farmers work together - a growth coalition - to expand their encroachment into forest areas. Rural peasants and poor farmers are also organized under more extensive networks in exploiting their forest resources (Rudel & Roper, 1997; Walker & Smith, 1993).

Since global warming is believed as an anthropogenic problem, more attention is paid to demographic factors, and regarding these factors, a well-known hypothesis is a *Malthusian perspective* seeing that increasing population can cause more pressure on forests. From an economic point of view, more population means higher demand for agricultural products. Those effects could incentivize people to expand agricultural activities into forest areas resulting in LULCC. However, an adverse impact of population growth is expected under *the Boserup effect*, arguing that more population mean more creativity, ideas, and technology leading to less pressure on forests (Bilsborrow & Geores, 1994 cited in Jarot and Mutaqin, 2016). It is also possible that the increasing population in rural areas may be followed by rural-to-urban migration leaving more land to be forested. The *Boserup hypothesis* can also explain the negative effect of agricultural technology on deforestation (LULCC). A new technology that encourages labor-intensive agricultural activities results in less LULCC and makes it possible for agriculture to utilize marginal land rather than forest (Mahapatra and Kant, 2005). However, developing agricultural technology may also incentivize farmers to expand their agricultural land into forest areas.

Moreover, another helpful theory concerning income is the immiserization theory which postulates that the poor tend to extract natural resources more to meet their needs, resulting in expanding deforestation and forest degradation leading to high LULCC (Walker, 1993). Furthermore Angelsen, (2007) divide this explanation into two drivers, local villagers and outsiders. The role and responsibility of local villagers and outsiders in using or degrading forest resources is quite different, depending on their understanding and use right.

In the face of population growth and increment of over-dependence of a rural community on forest resources, the existing natural forest is depleting, and rural poverty is driving extensive loss of this resource in Zambezia. Forests are managed in different interventions like a concession, community forestry and reserve, which have the same goal but different management principles and governance guidelines. The nature of falling forest under this different management intervention exposes this resource to competition among different users and, simultaneously, to degradation in quality and quantity. To solve this problem, different sectors of government took remedies like identifying causes of D&D and implementing different natural resource management (Terra, 2017).

Gilé National Park is one of the most protected parks in Mozambique, and it is also a park that has feared degradation in recent times due to activities experienced by the community living in the buffer zone. To keep this park with its biodiversity intact, undertaking a study on the buffer zone to stabilize the availability of the resource for community living there is paramount. With all efforts and gabs as the initial idea, this current study was undertaken in the buffer zone of Gile National Park to study the socio-economic and ecological impact of D&D, to measure the status of Miombo woodland regeneration, and to identify factors affecting its regeneration, and to evaluate LULCC.

1.6. Justification of the Study

This study provides contribution for the literature on a site-specific study about the regeneration and restoration status of Miombo woodland, the cause of D&D, the socio-economic and ecological impact of D&D, and the level of land use land cover changes. This study is an academic study that gives helpful information to national and international organizations to promote forest conservation for the ecosystem function of the Gile National Park. Identifying the significant cause affecting forest coverage of the study area, the socio-economic and ecological impact of D&D, and the status of restoration and more preferred woody species by communities for different uses help the Mozambique Government to design an effective management policy. Moreover, communities and development organizations can clearly understand the critical cause and points regarded to restoration and preferred woody species and decide to participate in managing the resource.

1.7. Significance of the Study

The study of regeneration and restoration status of Miombo woodland as a result of D&D and land-use land cover changes at the Buffer zone of GNAP in Zambezia Province central Mozambique resulted in significant output that could impact the forest users, policy, and decision-makers. This study dug out factors that expose forests to degradation in understanding the livelihood strategies of rural residents and their level of relying on the existing natural forest and investment related to forest resources in the study area. Understanding people's livelihood strategies can help identify the relationship between forest and their living standards, which directly or indirectly tell us about the cause of forest degradation and also evaluate the restoration activities in the study area. Specifically, studying with rural residents provides insight and understanding of aspects such as: how natural resources are currently used, their indigenous knowledge on management of the forest, their coping mechanisms to shocks and stresses, and their views on natural forest putting local people in the center of forest resources management with the understanding that local communities are significant players in forest management and are believed to have a significant understanding of their local environmental problems. Thus, their perceptions in deforestation and restoration discussions cannot be ignored.

The data collected in this study allow for management of the impacts of forest D&D and to enhance restoration to be monitored throughout the development of deep awareness creation, sharing responsibility, creating a sense of ownership, and showing the direction to the policy developer as well as decision-makers. The outcomes of this study provide the necessary information and tools such as status of regeneration and restoration of Miombo woodland, cause of LULCC and D&D to put in place a monitoring plan to evaluate poverty alleviation and socio-economic impacts of local economic development initiatives such as forestry, agriculture, and tourism. The study further provided recommendations for climate change mitigation programs that need to be put in place by forestry companies to offset any potential negative impacts. Recommended mitigation measures are also cross-referenced with relevant Forest Stewardship Council (FSC) criterion indicators to show how recommended programs meet FSC requirements and expose possible gaps in the certification standard. The FSC standard is chosen since it is internationally recognized and is a requirement by the Mozambique government in the concession area.

1.8. Scope of the Study

The study focuses on the socio economic impact of D&D, the status of regeneration and restoration of Miombo woodland and LULCC at the buffer zone of GNAP Zambezia, central Mozambique. In addition, limiting the study to the selected site was to focus on generating adequate information that would contribute to the management of GNAP; as it is one of the National Park where no one living inside of it in the country (Terra, 2016). The study did not include the assessment of soil seed banks, forest growth, timber volumes, and soils, even though they could be related to this study. The study excluded the topics mentioned above due to the limited time and budget available.

1.9. Research Approach

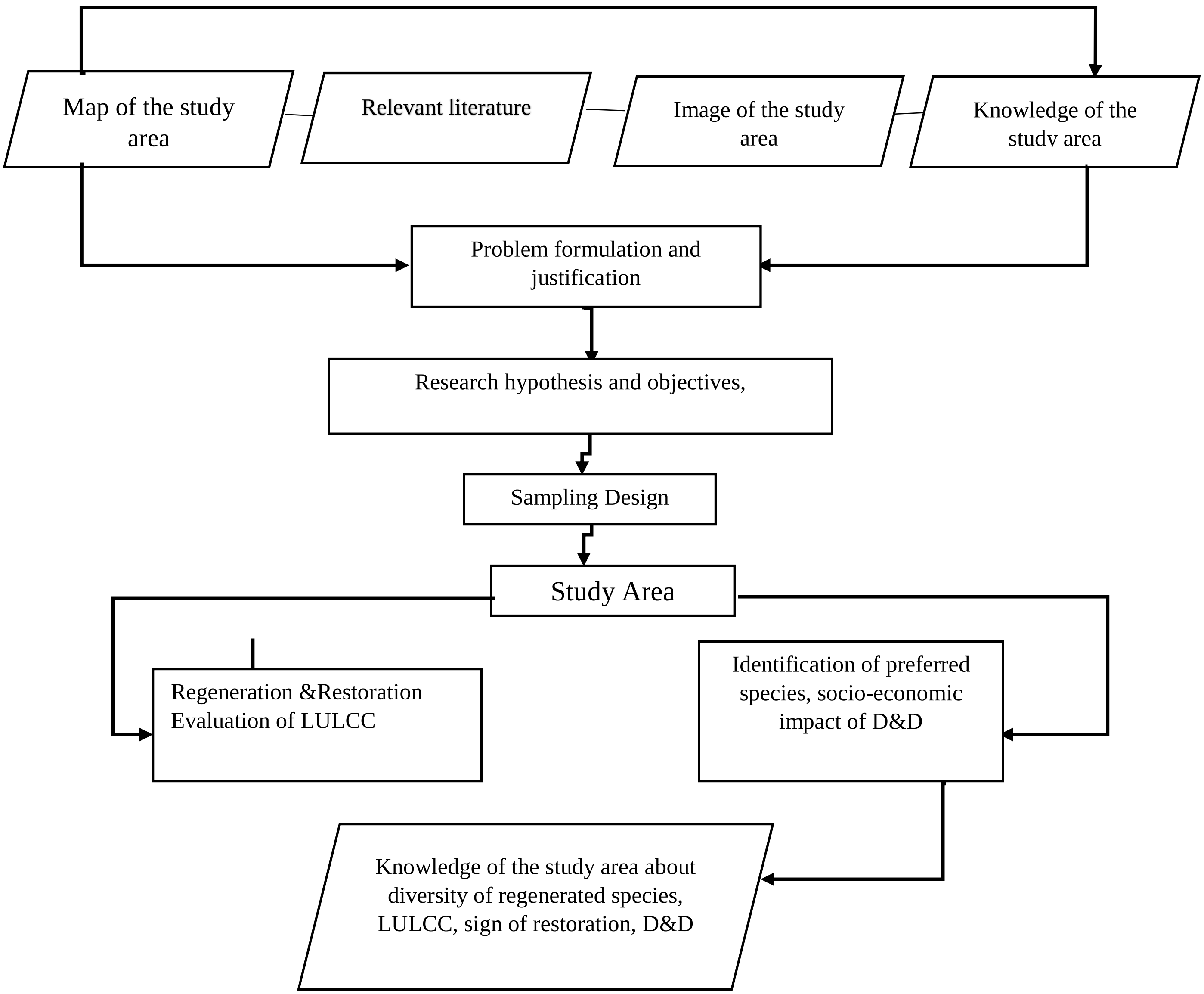

Figure 1.5 Research Approach

1.10. Thesis Outline

This PhD dissertation has six Chapters. Chapter 1 focuses on the general introduction of the study, statement of the problem, general and specific research objectives, hypothesis, background, conceptual framework, Significance, Scope and Research approach, and justification of the study. Chapter 2 presents literature review related to each objective. Chapter 3 presents the description of the study area, and the methods employed in this research. Chapter 4, devoted to the first study objective, presents the Socio-economic and ecological impacts of deforestation and forest degradation on the Resident's community livelihood at the GNAP buffer zone. Chapter 5 is devoted to the second objective, Land Use and Land Cover Changes of GNAP Buffer Zone from 1999 to 2019, Central Mozambique. Chapter 6 is devoted to the third objective, Miombo woodland's regeneration and restoration status following Land Use Land Cover Changes at the buffer zone of GNAP central Mozambique. Each chapter have details of the introductions, methods used, results achieved, discussion, and conclusions. Chapter 7 presents the general discussion, conclusion, and recommendations highlighting the overall contribution of the study as well as recommendations for the application of research findings and further research.

CHAPTER 2 LITERATURE REVIEW

2.1 Socio-Economic and Ecological Impacts of Deforestation and Forest Degradation on Community Livelihood

Forests are known for their natural and numerous resource banks. They have helped in numerous ways to sustain development and human needs the world over for centuries and most people have utilized and harvested fuelwood and timber, wild animals (for meat) and grazed their livestock in forests (Rahmat et al., 2019). Forests across the world are considered to be a huge socio-economic and environmental benefit to host and adjacent communities (Duguma et al., 2019). Over 90% of the 1.2 billion people living in poverty worldwide now rely on forest products extraction (Duguma et al., 2019; Ullah, Noor, Abid, Kashinda, et al., 2021). Deforestation and woodland degradation reduced woodland based provisioning ES supply (Silva et al., 2019).

2.1.1 Socio-Economic impacts of D&D on community livelihood

Forest products (timber and non-timber resources) have very significant economic impacts on improving individual and family income (Ullah et al., 2021). It is an undisputable truism that the dependence of millions of people on forests leads to degradation and deforestation, there are several benefits accruing from such loss (in the aspect of livelihoods, income and employment) for the sustenance of indigenous people (Wajim, 2020). In most developing countries, forests are significant in the livelihoods of local people. Local people rely on the forests for various consumables and commercial goods such as fuelwood, construction materials, medicinal products and food (Ullah et al., 2021). About 350 million people live adjacent to dense forests and rely on them for their livelihood and income (Thondhlana et al., 2012), 25–30% of rural dwellers' source of income depends on environmental resources which include the forests in developing countries and consequently, forests also serve as a safety net during times of crisis or seasonal food shortages (C. Shackleton & Shackleton, 2004).

In spite of its importance, the natural tropical high forest has continued to diminish rapidly in the African continent, thus dwindling sustainable forest management. Majority of the people residing in Africa use fuel wood as their main source of energy for cooking (Zorrilla-Miras et al., 2018). In many areas, due to increasing population the existing wood resources are over exploited (Wajim, 2020). Despite of this Deforestation and degradation of the ecosystem is rapidly on the increase; without any corresponding precautionary measures to rectify the situation, the forests have continued to suffer overexploitation (Ullah et al., 2021).

With reduced forests people are less able to benefit from the natural resources these ecosystems provide. This can lead to increased poverty and in cases people may need to move in order to find forests which can sustain them (Wajim, 2020). The forests of Africa are the most depleted of all the tropical regions with only 30 per cent of the historical stands still remaining (Giliba, Boon, Kayombo, Leonard, et al., 2011). Deforestation and forest degradation is primarily a concern for the developing countries because of its negative contribution (Wajim, 2020).

The major negative socio- economic impacts of deforestation and forest degradation include tourism decline, increased risk of flooding, declined aesthetic quality, loss of landscape quality, unemployment, lower income of residents, lower value of real estates, and reducing (Ullah et al., 2021). Large number of the people living in the communities suffers unemployment, poverty, hunger, forced migration, and civil unrest, it also contributed to loss of lives, and properties(Aliyu et al., 2014; Innocent, 2019). Deforestation destroys essential ecosystem services like the provision fertile soils, leading to the loss of farming and other livelihood opportunities, such as fishing and hunting for food (Ullah et al., 2021).

Decline of other natural resources like firewood and NTFPS caused by deforestation and transformation of natural forests with forest plantations is an indication of socio economic impact of D&D (Heilmayr, 2014). Deforestation can decrease the welfare of forest users by destroying critical stocks of fuel, fodder, food and building materials (Ajake et al., 2011).

Deforestation is a major environmental concern in sub-Saharan Africa and, it is a complex and dynamic process influenced by many different social, economic and biophysical factors (Woollen et al., 2016). In sub-Saharan Africa, a reduction in forest cover can also directly affect the livelihoods of millions of people. Rural households often depend on many different goods and services from forests, including fuelwood, food, and medicine for their domestic use or as a source of income (Tokura, Matimele, Smit, Timm Hoffman, et al., 2020). Deforestation leads to the depletion of the resources, local people not only lose the source of income, but access to other forest products such as firewood and medicinal plants will also be affected. An analysis of the socio economic aspects of coastal forests of Mozambique for example confirms that the livelihoods of coastal populations are supported by resources such as timber, construction materials, fruits, tubers, meat, honey, and medicinal plants. The authors estimate that the value of the use of medicinal plants alone from coastal forests may reach USD 80 million per year (Norfolk & Cosijn, 2013).

Over 80% of Mozambicans rely on subsistence farming for nourishment, even in urban areas. Forest fruits and plants are critical in terms of the provision of food during the year, especially during stress periods (Norfolk & Cosijn, 2013). Forest cover has been continuously reduced in Mozambique in the past 25 years as human pressure on the land and on its natural resource has been growing. The rate of deforestation has been accelerating especially over the past ten years (Tokura et al., 2020).

2.1.2 Ecological Impacts of D&D on Community Livelihood

Deforestation and forest degradation are responsible for around 15% of all greenhouse gas emissions. These greenhouse gas emissions contribute to rising temperatures, changes in patterns of weather and water, and an increased frequency of extreme weather events. It causes habitat destruction, increased risk of predation, as a result, some animals lose their homes, others lose food sources and finally, many lose their lives in fact, deforestation is one of the main causes of extinction (Pacheco et al.,2021). Deforestation and forest degradation (D&D) in the tropics have continued unabated and are posing serious threats to forests and the livelihoods of those who depend on forests and forest resources (Duguma et al., 2019). Recently, evidence is mounting from multiple studies that humans at an aggregate level are exploiting forests at unsustainable rates especially in the tropics. Deforestation, especially in the tropical rainforest, has accelerated significantly (Ajake et al., 2011). Deforestation can decrease the welfare of forest users by eliminating habitat for game species, altering local climates and water sheds. Although Forests provide multiple ecosystem services deforestation and forest degradation (D&D) are causing a significant reduction in the provisioning of valuable ecosystem goods and services from forests in developing countries, especially in the tropics currently poses the greatest threat to the forest ecosystem and the goods and services (Duguma et al., 2019).

The concern about forest loss has been reinforced by the recognition that deforestation and forest degradation account for roughly one-sixth of total anthropogenic emissions of greenhouse gases. Degradation of a standing forest, like deforestation, reduces carbon storage, the quality of species habitat, and the provision of local ecosystem services, such as water quality (Pfaff et al., 2013).

Besides the negative effect of deforestation, it is important to highlight the impact of forest degradation on ecosystem integrity by reducing the availability of goods and services; such as carbon or water regulation (Edwards et al., 2014) and biodiversity (Ricketts et al., 2016), due to species extinction, loss of natural habitats and changes in species distribution (Pereira et al., 2012).

Forests are more than just a collection of trees and other plants—they are integrated ecosystems and home to some of the most diverse life on Earth. They are also major players in the carbon and water cycles that make life possible. When forests are lost or degraded, their destruction sets off a series of changes that affect life both locally and around the world (Pacheco et al.,2021) in developing countries, the regulating and buffering services of ecosystems are critical in terms of maintaining and enhancing livelihoods (including biodiversity, soil fertility, flood control, drought mitigation and water regulation) (Norfolk & Cosijn, 2013).

The most obvious direct impact of deforestation is biodiversity loss –species-rich forested areas are converted to species-poor agricultural lands. However, there are more cryptic impacts resulting from deforestation and forest degradation, such as changes in local temperatures and regional precipitation regimes or increased global greenhouse gas emissions (Longo et al., 2020). These impacts can interact with others, amplifying their individual effects. For instance, changes in precipitation patterns can increase plant mortality, leading to more greenhouse gas emissions, which in turn contribute to further changes in climate (Esquivel-muelbert, 2020). The impacts of deforestation and forest degradation can be direct or indirect and have local, regional, or global consequences (Neto et al., 2019; Ngwira & Watanabe, 2019). Deforestation can lead to a wide range of direct ecological impacts, which are locally, regionally, and globally relevant. Of the local impacts, biodiversity loss is extremely concerning, with several species of trees, mammals, birds, reptiles, amphibians, and terrestrial invertebrates classified as globally threatened (IUCN 2021) cited in (Berenguer et al., 2021).

In Mozambique forest ecosystems, especially the Miombo woodlands, are also critical for water quality, groundwater recharge, and flow retention, as they surround many of the lakes, major rivers, such as the Limpopo, Zambezi, Messalo, and Rovuma Rivers, and the ephemeral small rivers critical for water supplies in the dry season. The ability of forest ecosystems to improve water quality and quantity through the filtration and slow-release functions is not well understood in Mozambique. All provinces except Niassa are exposed to water stresses. These stresses will only increase as the effects of climate change are felt (Norfolk & Cosijn, 2013; Silva et al., 2019).

People are living within the boundaries of most of the protected areas in Mozambique have limited forms of income and derive little financial benefit from tourism and other activities, they therefore exploit the forest resources within these areas. While government officials are encouraging these populations to resettle, either within the protected areas or outside but in concentrated communities, ostensibly to facilitate the provision of basic services such as water, there is large resistance to such efforts, as the resettlement areas are often far from the ecosystem services on which these communities rely, so that accepting such a move would result in increasing impoverishment and resulted in over exploitation of natural resource in the area. As a consequence of the conversion of forest land to agriculture and deforestation Erosion is a major problem in Mozambique (Norfolk & Cosijn, 2013).

2.1.3 Household Forest Dependence

Forest dependency is variously defined by different authors and mainly refers to household reliance on forest products and services for a large portion of their basic household needs (Karupu et al.,2022). Forest resources continue to play an important role to rural communities in developing countries in terms of services, products, and incomes (Garekae & Thakadu, 2017; E. Wale et al., 2022). They have demonstrated to economically dis-advantaged households that they can satisfy everyday necessities such as energy, shelter, medicine, cash incomes, and employment (Dalu et al., 2021). Natural forests are an integral part of livelihoods in rural communities of developing countries (Johansson et al., 2021; Mukete et al., 2018). Households in the global depend on forests for numerous ecosystem services. Small-holder farmers living adjacent to forests collect multiple forest products for consumption and in some cases for sale, particularly fuelwood, building materials, wild foods and medicinal plants (A. Angelsen et al., 2014). When deforestation and forest degradation occur, it is often the forest-dependent poor who have the most to lose (Nerfa et al., 2020). On the other hand, forests act as safety nets for the rural poor in times of unexpected scarcity, or as gap fillers in times of regular seasonal shortfalls (Mukete et al., 2018; Paumgarten, 2005). Forest use includes: the practices involved in harvesting forest products, the use of other provisioning services from forests such as water, the use of forests as land for agriculture, and use for other cultural practices (Anthwal et al., 2010). Forest reliance has been described as a form of economic insurance, support for consumption, and a means of poverty reduction (Fisher, 2004). In Zambia Rural households are highly dependent on forest resources for subsistence foods and materials as well as for cash income. Over 90% of rural households depend on forests to meet their household energy requirements. (Bwalya, 2011). In Mozambique Forests being a major source of household food security associated with the dependence of household on NTFPs (Lubega et al., 2022).

Factors Affecting Household Forest Dependence

Rural livelihoods are highly dependent on environmental sources in developing countries (Ali et al., 2020). Forest resources continue to play an important role to rural communities in developing countries in terms of services, products, and incomes (E. Wale et al., 2022). Since communities are not homogenous in nature, variation on household reliance on forests is inevitable. Based on the literature of forest, people's dependency on forest resources depends on various elements, among them socioeconomic and demographic factors are the most crucial (Ali et al., 2020). Reliance on forest is a function of various factors and key among them includes a household's socio-economic factors (Garekae & Thakadu, 2017). The most common socio-economic factors affecting households' dependence on forest were relative low cost of using forest resources, easy accessibility of forest resources and its forests in a community (Ofoegbu et al., 2017).

2.2 Land Use and Land Cover Changes

2.2.1 Definitions

Land cover is defined by the attributes of the earth's land surface captured in the distribution of vegetation, water, desert and ice and the immediate subsurface, including biota, soil, topography, surface and groundwater, and it also includes those structures created solely by human activities such as mine exposures and settlement (Lambin et al., 2003). Land use change is defined to be any physical, biological or chemical change attributable to management, which may include conversion of grazing to cropping, change in fertilizer use, drainage improvements, installation and use of irrigation, plantations, building farm dams, pollution and land degradation, vegetation removal, changed fire regime, spread of weeds and exotic species, and conversion to nonagricultural uses (BELLO et al., 2018; Fasika et al., 2019). Land use and land cover changes may be grouped into two broad categories as conversion and modification. Conversion refers to changes from one cover or use type to another, while modification involves maintenance of the broad cover or use type in the face of changes in its attributes (Oumer, 2009).

Land-use and land-cover changes refer to (quantitative) changes in the aerial extent (increases or decreases) of a given type of land use or land cover, respectively. Land-use change is a matter of historical process as relating to how people use the land. The land use and land cover change of an area is an outcome of natural and socio-economic aspects and their operation by the human in time and space (Brown et al., 2014; Tewabe & Fentahun, 2020). Land use land cover change is an important issue considering global dynamics and their responses to environmental and socio-economic drivers (Akpoti et al., 2016). Understanding the scope of land use land cover change, driving forces, and consequences is very crucial for proper management of land resources (Bufebo & Elias, 2021). Land use and land cover changes are affirmed to represent the most widely increasing and significant sources of contemporary changes in the earth's land surface (Ogato et al., 2021).

Information on land use/cover and potentials for their best use is essential for the selection, planning, sustainable natural resource management to meet the increasing demands for basic human needs and welfare (Tewabe & Fentahun, 2020). The central theme in land use land cover change (LULC) issues is the interaction between humans and the environment they live in (Belay et al., 2014a; Tewabe & Fentahun, 2020). Land use/cover (LULC) is the most prominent form of the global environmental change phenomenon occurring at spatial and temporal scales (Wubie et al., 2016). Determining the effects of LULC changes on the ecosystem requires knowledge of past land use practices, current LULC patterns, and future projections. Understanding the causes of land cover changes involve looking at proximate or direct causes at the local level and the decisions formed as a result of complex social, economic, political, demographic, technological, cultural, and biophysical factors at a regional/global level (Fasika et al., 2019).

2.2.2 Drivers of Land Use/Land Cover Change

Land use-land cover change (LULCC) scientists advise that before any policy intervention, a thorough understanding of the complex set of immediate causes and indirect driving forces of

LULCC is quite important in a given location (Harden, 2014) . Land use-land cover change (LULCC) is driven by several interacting factors that act at global, regional, and local levels (Bekele et al., 2019; Demissie et al., 2017). LULC changes are influenced by a variety of driving factors (Liyew et al., 2019). These drivers are mainly originated from anthropogenic-induced activities, even though natural factors, also may contribute to substantial changes (Harden, 2014). Land use/land cover change (LULCC) is among the major factors that affect biophysical systems at all scales (Dibabaet al., 2020).

2.2.2.1 Agricultural Expansion as Drivers of LULCC

The expansion of diversified agricultural activities is proximate (direct) causes of LULC changes. Extensive conversion of vegetation covers and expansion of farmlands along with the dissected terrain and ecological vulnerability lands have implications for large-scale geo-ecological fragmentation and land degradation and leads to deterioration of soil quality and productivity (Demissie et al., 2017; Dibaba et al., 2020; Gessesse & Bewket, 2014). According to Gessesse & Bewket (2014), smallholder agricultural land expansion at the expense of other land covers is by far the most widespread driver of land use dynamics and related land cover and ecosystem changes. The conversion of Miombo woodlands into agricultural lands leads to fragmentation and isolation (Lupala et al., 2015).

2.2.2.2 Illegal Logging and Fire

Wood extraction to fulfill the demand of fuel and pole woods is one of the major drivers for clearing extensive area of vegetation cover and trees (Gessesse & Bewket, 2014). Illegal logging and extensive extraction of fuel wood and bush fires have been a continuing challenge in Miombo woodlands as cause of LULCC (Demissie et al., 2017; Lupala et al., 2015).

2.2.2.3 Settlement Expansion

Increased human population pressure and its negative impact on habitat loss in African countries is a common phenomenon (Kideghesho et al., 2006) . Human population growth bordering protected areas is high and has become a serious threat to the management of protected area all over Africa (Demeke & Lemma, 2017). Expansion of settlement (built-up areas) was a cause of LULCC (Demissie et al., 2017; Fasika et al., 2019). In Mozambique specifically in Quirimbas National Park, Northern Mozambique**,** for example according to Mucova et al., (2018),in 2009, human settlements grew by 12.40%, and non-vegetated land increased to 24.61%. On that year, the vegetation had an area equal to 455,870.3 (ha), representing a vegetation decrease of 37%.

2.3 Regeneration and Restoration Status of Miombo Woodland

2.3.1 Definitions

Forest regeneration is the act of renewing tree cover by establishing young trees naturally or artificially-generally, promptly after the previous stand or forest has been removed. It is the process that allows a forest to sustain itself through the growth and survival of seedlings and saplings that replace large forest trees as they die and the very foundation of sustainable forestry. Tree regeneration (Martínez-Ramos et al., 2016). Restoration of species richness and community structure over time implies increasing ecosystem complexity and functionality (Aerts and Honnay, 2011; Lamb & Gilmour, 2005; Martínez-Ramos et al., 2016). Regeneration is an important and fundamental process that drives forest dynamics, as it ensures the continued existence of woody species across generations (Feldmann et al., 2020). Miombo is a resilient ecosystem that can regenerate naturally after disturbances and return to its original state in 15-20 years if disturbances are removed (Ribeiro et al., 2020).

2.3.2 Why undertake forest landscape restoration?

There are several reasons to undertake forest landscape restoration. One is to provide the goods and help re-establish those ecological services or functions no longer being provided by the new forms of land-use (Lamb & Gilmour, 2005; Martínez-Ramos et al., 2016) and to restore some degree of biodiversity to degraded landscapes. Forest landscape restoration incorporates both biophysical and socioeconomic values; that is, ecosystem restoration as well as the changes in human well-being associated with it. It is important to consider the social and economic impacts of forest restoration initiatives, particularly the effects on people living in or near the restored forest area (Lamb & Gilmour, 2005).

2.4 Regeneration Dynamics of Miombo Woodland in Response to Different Disturbances

The sustainability of the seriously threatened African miombo woodlands depends on their capability to maintain sufficient natural regeneration (Elifuraha E Njoghomi et al., 2020).

Regeneration of Miombo involves the replacement of the old matured and disturbed individuals by new individuals of the next generation through vegetative reproduction and seedling emergence, whereby the survival of each individual has ability to influence plant population and community dynamic (Larson & Funk, 2016). Miombo woodland, the most extensive vegetation formation in Africa, recovers well after cessation of disturbances from different land use practices on a site (Syampungani et al., 2016). The mode of regeneration in Miombo dominating area is mostly associated disturbance category, in which, the prevailing environmental conditions such as, fires, competition for nutrients and light influence the number of surviving individuals to enter the next size class (Elifuraha E Njoghomi et al., 2020). The Miombo woodlands are known to have high resilient to disturbances due to their ability to regenerate, Miombo has been recorded to regenerate from disturbances caused by harvesting fuelwood production, wildfires, shifting cultivation, animal disturbance during grazing, and other natural disturbances (Clemens et al., 2018; Daskin et al., 2016; Elifuraha E Njoghomi et al., 2020; Zolho, 2005).

Disturbance Factors in Regeneration of Miombo

The establishment and successive dynamics and productivity of many Miombo species is altered by diverse disturbances (Johnstone et al., 2016) . Some important disturbances in ecosystems include forest fire, livestock grazing, crop cultivation tree harvesting and wild animals (Daskin et al., 2016; Dayamba, 2010; Hollingsworth et al., 2015; Mtimbanjayo & Sangeda, 2018; N. S. Ribeiro et al., 2017; Zolho, 2005). All these different disturbances play significant ecological roles in regeneration of Miombo. The following are various types of disturbances that lead to regeneration of Miombo woodlands.

Role of Forest Fires in Regeneration of Miombo

Humans have a large impact on the dynamics of many ecosystems by altering fire regime (Hantson et al., 2015). The history of forest fires dates back more than 1.5 million years ago when human being first discovered and managed fire (Gowlett, 2016). Despite the advantages gained by human from fire discovery, forest fire has become the major global forest disturbance. The forest fire ignition can be human-induced or a result of environmental causes (Ganteaume & Jappiot, 2013). Miombo woodland experiences human-induced fire in the preparation of land for cultivation, clear bush and undergrowth to improve visibility around settlements and footpaths, keeping away dangerous animals, clear roadside areas before or after grass slashing in road maintenance operations, management of grazing land for both livestock and wildlife, charcoal burning, honey collection and hunting (Emmanuel N. Chidumayo & Gumbo, 2013; N. S. Ribeiro et al., 2017).

Regeneration in Miombo is much affected by fire. For example, Ribeiro et al. (2017) mentioned that late dry season fires are of sufficiently high intensity to kill the natural regeneration of main tree species such as Brachystegia and *Julbernadia* species. Unlike the late fire, early burning allows regeneration due to the low intensity fires resulted from high moisture (grass). These findings suggest that Miombo regeneration is negatively affected by high-intensity fire especially if it happens in the late dry season.

Role of Shifting Cultivation in Regeneration of Miombo

Shifting cultivation influences deforestation of woodlands through the land clearance for farming and crop induced tree cutting (Campbell et al., 2007;Chidumayo, 2018).This practice involves complete removal of the surface vegetation using a mixture of cutting and fire, followed by a period of manual cultivation before eventually shifting to a new patch of land once soil fertility is depleted and allow the abandoned field to regenerate (McNicol et al., 2015). However, during cultivation, weeding and other farm management activities are always administered to reduce competition to the target crop. Regeneration of Miombo tends to differ depending on the fallow period as more time is elapsed with cultivation in the area, more trees are removed (Wallenfang et al., 2015).

Role of Tree Harvesting in Regeneration of Miombo Woodland

Miombo tree species comprised of vast uses in sustaining livelihood of the communities. They are cut for timber, poles, firewood, charcoal production (Malimbwi et al., 2005) as well as specific crop also influences trees harvesting (Lecours et al., 2012; Mandondo et al., 2014; Mataruse et al., 2018) Harvesting in Miombo is usually done as selective or total felling. However, the majority of trees are selectively harvested (Kiruki et al., 2017).

CHAPTER 3. OVERVIEW OF STUDY AREA AND METHODS

3.1. Introductions

This chapter describes the study area, followed by an outline of the general methodology and inquiry, including the sampling design, data collection procedures, and data analysis. Additional and detailed materials and methods for respective objectives are discussed in their particular Chapters.

3.1.1. Description of the Study Area

The study was conducted at the buffer zone of GNAP in Zambezia Province, central Mozambique, at about 1561.46 km north of Maputo, the country's capital city. GNAP extends over the districts of Pebane and Gilé, located in the northeastern part of Zambezia Province (Fusari & Carpaneto, 2006) (Figure 3.1).

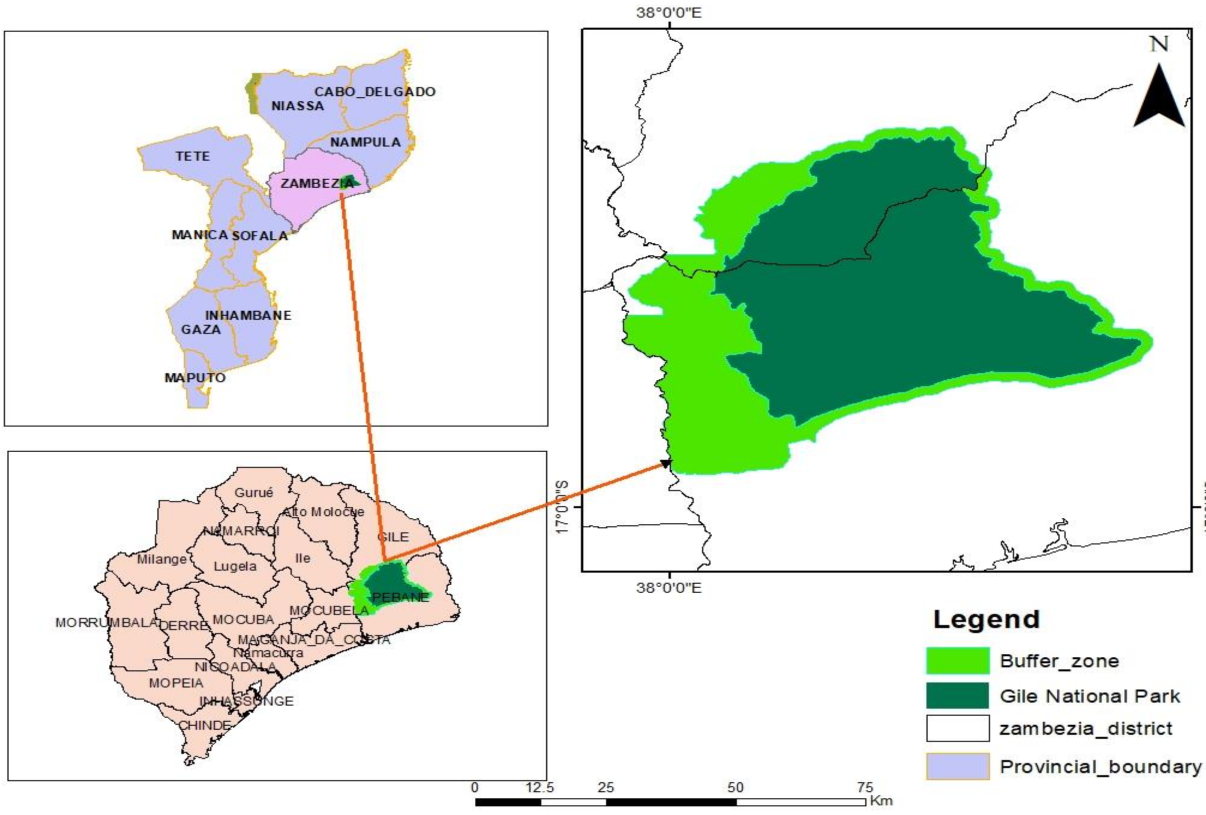

Figure 3.1. Map of the Study Area

3.1.2. Climate

Mozambique has a wide range of sub-climates, ranging from tropical/subtropical in the central and northern regions of the country to arid steppes in the southern interior of the country, which includes a small region of near-desert climates (Penvenne and Sheldon,2021). The hottest temperatures and highest humidity are found in the Zambezi valley, where the average daily temperatures of the 30°Cs are typical, as well as on the coastline in Zambezia (FAO, 2016a). The study area lies within Walter's tropical summer-rainfall climatic zone with a distinct wet period between November and April and a dry period through the other six months (May–October). Annual rainfall is around 800–1000 mm. The maximum average temperature is 35.7 C at the onset of the rainy season, and a minimum is 13.5 C during the dry season (EtcTerra, 2017a; Fusari & Carpaneto, 2006).

3.1.3. Topography and Soils

Topography is relatively flat with elevations lower than 500 m (129 m of altitude on average, standard deviation 55 m) and low slopes. Rocky high elevation areas correspond to inselberg and are covered by small vegetation, representing dry areas. The landscape is characterized by a gently sloping plain and several granite outcrops (inselbergs) that emerge from the woodland. Two types of soil are present in the area, with different fertility: (i) white sandy soil is distributed in the South of the area and has low fertility and water retention capacity; (ii) brown loamy and sandy soils are located in the North with higher fertility and water retention capacity (Etc Terra, 2017a; Fusari & Carpaneto, 2006; Penvenne and Sheldon,2021).

3.1.4. Vegetation and Fauna

The forest in the park and its surroundings is a typical dry Miombo woodland, with the occurrence of open wetland and grassland areas called dambo. Miombo is characterized by species from the genus *Brachystegia*, *Julbernardia*, and *Isoberlinia* (Campbell, 1996). This area is one of the last areas in Mozambique with a relatively large abundance of the tree species *Swartzia madagascariensis* (pau ferro) that faces over-exploitation in the whole country. Riverine Forests also found along the banks of the park's rivers and streams, riverine forests are characterized by a mix of evergreen and semi-evergreen species. These forests thrive in the moist conditions provided by their proximity to water bodies. Riverine forests are crucial for maintaining the hydrological balance of the park, preventing soil erosion, and supporting species that depend on aquatic and semi-aquatic environments. They also act as natural corridors for wildlife, facilitating movement and migration within the park. The open grasslands scattered throughout Gile National Park are essential for the park's herbivore populations. These areas are primarily composed of grasses and other herbaceous plants, which provide grazing opportunities for species such as zebras, buffaloes, and various antelopes. Grasslands also support a range of other wildlife, including predators that rely on herbivores for food. The dynamic nature of grasslands, influenced by seasonal variations in rainfall and grazing pressure, contributes to the park's ecological diversity (ADVZ, 2020). Gile National Park contains several wetland areas that are critical habitats for aquatic plants and animals. These wetlands, including marshes and swamps, are especially important during the dry season when water becomes scarce. They provide essential resources such as water, food, and breeding grounds for many species, including birds, amphibians, and insects. Wetlands also play a significant role in maintaining the overall health of the ecosystem by filtering water, storing floodwaters, and supporting a high level of biodiversity (etc Terra, 2017a).

Gile National Park, located in the Zambezia Province of Mozambique, is a significant conservation area that hosts a rich diversity of fauna. The park's varied habitats, including Miombo woodlands, riverine forests, grasslands, and wetlands, provide suitable environments for numerous wildlife species.

Mammals

The mammalian fauna of Gile National Park includes several large herbivores and carnivores. Key species include elephants (Loxodonta africana), which are crucial for their ecological role in shaping the landscape and maintaining the health of the ecosystem (Junk et al., 2013). The park also supports populations of buffaloes (Syncerus caffer), zebras (Equus quagga), and various antelope species such as the greater kudu (Tragelaphus strepsiceros) and impala (Aepyceros melampus). These herbivores are essential for maintaining the park’s grasslands and woodlands by influencing vegetation dynamics through grazing and browsing.

Predators such as lions (Panthera leo), leopards (Panthera pardus), and spotted hyenas (Crocuta crocuta) are also present in the park. These apex predators play a vital role in controlling herbivore populations, thereby maintaining a balanced ecosystem (Bond & Parr, 2010). Smaller carnivores, including servals (Leptailurus serval) and African wild dogs (Lycaon pictus), contribute to the park's biodiversity.

Birds

Gile National Park is an important bird area, supporting a diverse avian community. The park's wetlands and riverine forests are particularly significant for birdlife, providing essential habitats for both resident and migratory species. Notable bird species include the African fish eagle (*Haliaeetus vocifer*), saddle-billed stork (*Ephippiorhynchus senegalensis*), and various species of kingfishers and herons (ADVZ, 2020). The presence of these birds indicates the health of aquatic ecosystems within the park.

Grasslands and woodlands also host a variety of bird species, such as the lilac-breasted roller (*Coracias caudatus*) and various hornbills (*Bucerotidae*). These birds contribute to the ecological functions of the park, including seed dispersal and insect population control (Etc Terra, 2017).

Reptiles and Amphibians

The reptilian and amphibian fauna of Gile National Park is diverse, reflecting the variety of habitats available. Common reptiles include the Nile crocodile (Crocodylus niloticus), which inhabits the park's rivers and wetlands, and various species of lizards and snakes. Amphibians, such as frogs and toads, are abundant in the park’s wetland areas, playing a crucial role in the food web as both predators and prey (Etc Terra, 2017).

Invertebrates

Invertebrates are a fundamental component of Gile National Park’s biodiversity. Insect species, including butterflies, beetles, and ants, are essential for processes such as pollination, decomposition, and soil aeration. Wetlands support diverse aquatic invertebrate communities, which are critical for nutrient cycling and as food sources for higher trophic levels (Sala & Paruelo, 1997).(etc Terra, 2017a).

3.1.5. Demography and Livelihood Activities

Nobody lives inside the Park (which is exceptional in Mozambique), but about 12,500 inhabitants live in the buffer zone of the Park. The majority of the inhabitants, as in the entire northern part of the Zambezia Province, belong to the Elomwé ethnic group, one of the twenty recognized ethnic groups in Mozambique. The main languages are Lomwé, Macua, Muniga, and official language is Portuguese. Communities residing around the buffer zone of Gile National Park in Mozambique are heavily dependent on the park's resources for their livelihoods. The primary livelihood activities include agriculture, livestock rearing, and the collection of forest products. Subsistence farming is the most common livelihood activity. Local farmers cultivate crops such as maize, cassava, and beans, which are essential for food security (ADVZ, 2020). Livestock, including cattle, goats, and chickens, play a significant role in the local economy. Communities also rely on forest resources such as firewood, medicinal plants, and wild fruits. These resources are vital for daily sustenance and traditional practices. In areas with rivers and wetlands, fishing is another important livelihood activity. Local fishers depend on the aquatic ecosystems for their protein intake and income(Etc Terra, 2017).

3.2. Strategy of Inquiry

Firstly, the Faculty of Agronomy and Forestry Engineering, University of Eduardo Mondlane Research Committee, granted clearance to carry out the research and wrote a credential letter to the National Administration of Conservation Area (ANAC). Since the park's buffer zone falls under the jurisdiction of the ANAC management, credential letters (permission) were sought and granted from ANAC to conduct research in the buffer zone of GNAP. Consequently, a research permit was provided from 2020-2022 at different times. Permission was also sought and granted at the National Park level from the Park Administrators' office.

Regarding the consent of household heads, the traditional leadership (from the chief to the village heads), community leadership, translators, and local guides were also consulted prior to data collection with the help of an experts from the Gile National Park. The research was therefore granted authority, access to, and cooperation from the stakeholders in the buffer zone of GNAP. Once all respective bodies approved, the research team started data collection.

The study used a qualitative and quantitative-methods approach (Quintas-Soriano et al., 2018). One of the advantages of using the integrated methods approach is using various data sets to get a consolidated phenomenon output (Angeler et al., 2018). Qualitative research methods have their roots in social sciences such as social ecology, and this approach seeks to understand people's subjective reality and social exchange, which determine behavior in terms of their knowledge, attitudes, perceptions, beliefs, and fears (Garrido et al., 2017).

The qualitative methodology is rooted within the interpretive paradigm, which emphasizes analyzing and describing phenomena without necessarily relying on quantitative measurements and statistics (Squires & Wiber, 2018). The interpretive paradigm views values as an integral part of social ecology such that it is based on subjective social-ecological knowledge, which is context-dependent. Quantitative research approaches partially contribute to social problems and are unbalanced in that results from the study inform us about inputs and outputs concerning variables or parameters but do not describe how such phenomenon or that unit of measure is locally constituted (Silverman, 2006).

The quantitative research methodology is rooted within the positivist paradigm, which focuses on the need to discover generalizable laws that govern the universe. It values natural science based on objective knowledge from precise observations and verifiable measurements. The mixed and integrated method strategy allowed triangulation of results from different research methods (White et al., 2005) used in this study. Triangulation is whereby one performs concurrent but separate collection and analysis of quantitative and qualitative data to understand the research problem (Creswell, 2007).

The study also employed the convergent model, a variant of the triangulation model whereby the results from the study were then converged by comparing and contrasting the different results during interpretation. The model allows for comparison, confirmation, or validation of the qualitative results with the quantitative results. Between-method triangulation allowed us to confirm the findings generated through one particular method by another (Dey, 1993). For example, the data from a household questionnaire about the cause of land use and land cover changes in the Park's buffer zone was triangulated with related data on land use and land cover changes derived from remote sensing for the same research site to confirm the validity of the result.

3.3. General Methods

The research method is divided into three components based on the three study objectives in which there were a room that all objectives share similar methods. The first objective target is Chapter 4, which is intended to identify the Socio-economic and ecological impacts of deforestation and forest degradation on Residents' community livelihood at the GNAP buffer zone. The second objective, made up of Chapter 5, Evaluates Land Use and Land Cover Changes in the GNAP buffer zone in Central Mozambique by emphasizing the evaluation of land use /cover change in the buffer zone within two decades (1999 -2009 and 2009-2018). The third objective, made up of chapter 6, is based on the assessment of the Regeneration and Restoration status of Miombo woodland at the buffer zone of GNAP central Mozambique.

3.4. Research Design

The research design refers to the overall strategy that one chooses to integrate the different components of a study, such as an outline for the collection, measurement, and analysis of data coherently and logically to address the research problem. Data collection instruments or research instruments are the tools used to collect data to accomplish the study's goals (Harrison et al., 2013). The main methods of collecting data in qualitative research include the following: household surveys, measurement of woody vegetation, focus group discussion (FGD), and key informant interviews (KIIs) (White et al., 2005).

This study in Chapter 4 used household survey, FGD, and KIIs to identify the Socio-economic and ecological impacts of deforestation and forest degradation on the Resident's community livelihood at the GNAP buffer zone. The same methods were also used to collect data for objectives 5 and 6, like the cause of LULCC, factors affecting regeneration, and identifying restoration status in the study area. A field survey was conducted in October 2020 and July 2021 to collect all data needed for this research. For Chapter 5, remote sensing technique was employed to assess land use and land cover changes from 1999-2019 using Landsat TM (Thematic Mapper) and Landsat 8 OLI (Operational Land Imager) imagery with a 30-m spatial resolution for the years of 1999, 2009, and 2019. For chapter 6, the status of Miombo woody species regeneration under defined land-use types Abandoned agricultural land (AAL), Dense Miombo Woodland (DMWL), and Open Miombo Woodland (OMWL) data were collected by establishing transects and plots in each land-use type.

3.5. Sampling Procedure and Data Collection

For Chapter 4, a Socio-economic survey was used to collect data from the local community about resource use and the Socio-economic and ecological impacts of deforestation and forest degradation using household (HH) interviews, key informant interviews (KIIs), and focus group discussion (FGD) as used by Dibaba et al. (2020). In Chapter 4, overall, the goal of the study was to identify the Socio-economic and ecological impacts of D&D on community's livelihood. This study aimed to identify the impacts and give recommendations for decision makers with possible alternatives to safeguard the remaining Miombo woodland and to continue the community's subsistence sustainably. For instance, natural resource management sectors such as wildlife, forests, water, agriculture, health, infrastructure, and economic development can facilitate and collaborate with the park administration to solve the problem of D&D and communities' requirements. However, this depends on whether the available resources and political will are in place to support implementation. Thus, this study intends to identify the socio-economic impact of D&D to address threats to woodland resources and human livelihood.

For Chapter 5, the study focused on land use and land cover classification, which entailed using LANDSAT TM (Thematic Mapper) images from 1999 to 2019. The reference data for validating the different land use and land cover maps were collected from high-resolution images downloaded from the United States Geological Survey (USGS), archive at https://ers.cr.usgs.gov/. All the classifications were performed with the random forest algorithm, a machine learning classifier. This classifier gives the importance of each variable in the classification using the mean decrease accuracy based on assessing the importance of satellite image bands and ancillary data. The land use and land cover map statistics were based on an adjusted error matrix (Olofsson et al., 2013) that enables the computation of classification, area estimates, and area uncertainty. This method adjusts the ordinary pixel count error matrix with the area of each land use and land cover categories on the classified maps. House hold interview, FGD, and KIIs were used for this objective to identify the cause of LULCC in the study area. A detailed description of method applied for land use, land cover classification, and land use and land cover simulation is presented in Chapter 5.

For Chapter 5, data collection was done based on the study strata, which was categorized according to the defined contrasting land use type (AAL, DMWL, and OMWL). Sampling study sites, such as transects and plots, were purposely selected using a knowledgeable guide from the National Park and community following methods of (Feldmann et al., 2020; Gonçalves et al., 2018; Elifuraha et al., 2020). HH interview, FGD, and KIIs were also used to identify the restoration status and factors affecting the regeneration of Miombo woodland. More details are presented in Chapter 6.

3.6. Data Analysis

In Chapter 4, Descriptive statistics of simple frequency analysis were used using SPSS (version 25). Chi-square tests were used to tests different socio-economic impact of D&D. Data collected via FGD, and KIIs were analyzed qualitatively. The details are presented in chapter 4.

In Chapter 5, The analysis and quantification of the Spatio-temporal dynamics of the LULCC from 1999 to 2019 were achieved through Landsat image pre-processing, classification, and post-processing. The general procedure in the pre-processing stage includes compositing, mosaicking (masking), the detection and restoration of bad lines, geometric rectification, radiometric calibration, atmospheric correction, and topographic correction using ArcGIS 10.1 and QGIS 2.8.1. A supervised classification method using a maximum likelihood classifier was used to classify each pixel based on the known ground objects using ArcGIS 10.1; the details for the procedures used for image classification were presented in chapter 5. Concerning land use/land cover change analysis, once the land cover classifications were derived, ArcGIS 10.1 was used to prepare the land use land cover maps of 1999, 2009, and 2019. Then, the areas of the land use land cover (LULC) classes were calculated from the maps, an analysis of LULCC and rates of changes were computed, area of gains, losses, and persistence between the land use/ cover types were calculated using matrix. For accuracy valuation, overall classification accuracy and Kappa coefficient were calculated from the error matrix see chapter 5.

For Chapter 6, Species richness was measured from the total number of species recorded in each plot for stand and regeneration. Shannon–Wiener diversity index, Pielou's Evenness Index, Importance value index (IVI), and Jaccard similarity index were used to analyze species data as used by (Ayanaw et al., 2018; Ifo et al., 2016; Kalaba et al., 2013; Magurran AE, 2004). A nonparametric test (Kruskal- Wallis test) was used to assess stand and regeneration density differences between each land use type (Gonçalves et al., 2018; Kalaba et al., 2013; Munishi &

Temu, 2011). Descriptive statistics of simple frequency analyses were used using SPSS (version 25) to describe the ranking response of respondents about restoration and factors affecting regeneration. Chi-square tests were used to analyze the factors affecting regeneration and to compare respondents' responses to factors affecting regeneration, and the details are presented in chapter 6.

CHAPTER 4. SOCIO-ECONOMIC AND ECOLOGICAL IMPACT OF DEFORESTATION AND FOREST DEGRADATION ON THE RESIDENTS OF GILE NATIONAL PARK BUFFER ZONE CENTRAL MOZAMBIQUE.

4.0. Abstract

The study was conducted at the buffer zone of GNAP, central Mozambique, to analyze the Socio-economic and ecological impacts of D&D on local livelihoods and to measure household's forest dependency in the area. HH and KIIs and FGD were used to collect the required data. A total of 200 households selected based on a random sampling procedure were interviewed using a structured questionnaire. Descriptive statistics were used to summarize data on preferred woody species and socio-economic variables. Chi-square test was used to analyze the impact of D&D. Data collected through FGD and KIIs were analyzed qualitatively. Logistic regression analysis was used to test socio-economic factors' predictive ability of forest dependency. Of the 200 households taken for the interview, 94 (47%) were male-headed, and 106 (53%) were female-headed. Respondents were mainly engaged in slash-and-burn agriculture, and their source of income came from the sale of agriculture and forest product. Almost all of the households attributed their visitation to the forest solely for harvesting forest products. The study examined that forest-based products used by the locals were for home utilization and selling to get cash. Although various forest products were collected from the buffer zone, firewood, thatch grass, medicinal plants, and wild fruits were the most collected products. The study found that income from forest products contributes 23.26 % of the total annual household income. The mean forest dependency index (FDI) was 0.50 (SD = 0.41), suggesting that households were moderately dependent on forest resources. Residents from the southern, northern, and eastern parts of the Park were relatively more dependent on forests for their income and had an index of 0.5,0.6, and 0.6, indicating high forest dependency. In comparison, FDI for the community from western part of the park was about 0.30. Three predictors: age, number of years residing in the area, and education significantly contributed to predicting forest dependency. About 80.5% of the respondents strongly agreed that D&D is the primary cause of the loss of economic woody species and the scarcity of fertile land in the study area. The three most highly ranked causes of D&D were indiscriminate farmland expansion, looking for new farmland by young farmers, and illegal logging. KIIs and FGDs participants noted that long years ago, the area had good forest cover, which is not the case currently. They mentioned that this unpredictability had affected vegetation cover, crop, and animal production, which according to them, had become more severe than in the past.

Key words: Deforestation, Degradation, Forest dependency

4.1. Introduction

Forests across the world are considered to be a substantial socio-economic and ecological benefit to host and adjacent communities (FAO, 2016; Ullah et al., 2021; Wajim, 2020) through the provision of timber, energy, and fodder, particularly in developing countries (Kaimowitz and Angelsen, 1998; FAO, 2016; Wajim, 2020). It provides many direct and indirect ecosystem services (Kyere-Boateng & Marek, 2021). In most developing countries, forest provisioning services are essential, especially in terms of providing direct benefits to the local communities and, thus, represent a significant part of the total economic value of their livelihoods (FAO, 2016; Mullan, 2014).

In sub-Saharan Africa, forest income ranges from 30 to 45% of the total household income (Kalaba et al., 2013; Mamo et al., 2007). Some people depend solely on forests as their only source of subsistence, with its contribution sometimes being found to offset other household livelihood portfolios such as agriculture (McElwee, 2010). The level of use and degree of reliance on forests and their importance as a source of subsistence varies geographically, over time, and across communities (Bwalya, 2013).

Since communities are not homogenous, a variation in household reliance on forests is common (Prado Córdova et al., 2013). Reliance on the forest is a function of various factors; among them, a household's socio-economic factors are critical (Panta et al., 2009). For example, higher education attainment is associated with less reliance on forest resources (Fonta & Ayuk, 2013). This is so because education offers other alternative livelihood opportunities which may generate significant returns compared to forest extraction activities (Masozera & Alavalapati, 2004). Household size is positively associated with forest dependency; larger families have higher subsistence needs which necessitate them to depend more on forest resources (Mamo et al., 2007). On the other hand, the age of the household head is positively related to forest dependency, although with diminishing effect after reaching a peak of physical strength (Godoy et al., 1997). However, older people might possess strong ecological knowledge about their proximate environment, a phenomenon that might increase their likelihood of being more dependent on forest resources.

Despite their importance, the forest has been rapidly diminishing (Aliyu et al., 2014; Wajim, 2020) . Deforestation and forest degradation critically affect millions of people who directly/indirectly depend on its goods and services at the local, regional, and global levels (Kaimowitz and Angelsen,1998; FAO, 2006; Sedano et al., 2020; Soe & Yeo-Chang, 2019). High deforestation rates have been experienced globally, particularly in tropical areas (Makunga & Misana, 2017). Generally, forests declined by 129 million hectares globally between 1990 and 2010 (FAO, 2016b) . Africa is facing a considerable deforestation problem, with the rate of deforestation being higher than in any other continent (UNEP, 2004). Accordingly, of the ten countries in the world with the most significant annual net loss of forested area, six were in Africa (Makunga & Misana, 2017).

The poorest populations in several countries live in and around remote forested areas, and most of them depend upon forests and non-wood forest products for food, medicine, and fibers. The destruction of forests in several areas put tremendous pressure on indigenous populations forcing them to migrate to more densely populated areas (Reboredo, 2013). Forest and forest resources are essential ingredients for the socio-economic survival of any social system (Innocent, 2019; Wajim, 2020). Ecologically, Forest removal causes flooding, siltation of rivers and streams, the eutrophication of fish, and losses in agricultural production systems which, in turn, affect the socio-economic activities of the people, leading to or aggravating unemployment, scarcity of forest resources, emigration, civil unrest, crime, poverty, and food shortage amongst others (Aliyu et al., 2014; Appiah et al., 2009; Innocent, 2019).

Mozambique is richly endowed with natural forests, of which Miombo woodlands comprise most of the country's forested land (World Bank,2018;Ribeiro et al., 2020). It represents the most extensive forest ecosystem, and about 40% population lives within this ecosystem. Although Mozambique's forests have tremendous value and unrealized potential, they are rapidly depleted (Mercier, 2016; World Bank, 2018). Deforestation occurs in many ways, but most of the clearing is done for agricultural purposes and the provision of fuelwood for domestic use (Shackleton et al., 2011). Although forest loss and degradation occurred inside protected areas, it was remarkably rapid and widespread outside protected areas (Mercier et al., 2016; World Bank, 2018).The dynamics of Miombo woodlands are driven by social, cultural, economic, and ecological factors (Zolho, 2005). D&D impacts populations' livelihoods and income generation through the reduction and loss of direct economic services (FAO, 2016b; Jouanjean et al., 2014).

Mozambique's forests contribute multiple social, economic, and ecological benefits (Mercier, 2016). In addition to the ecological subsistence and economic importance of timber and non-timber forest products, it provides food security to most rural residents (Haddaway et al., 2016). Harvesting woody and non-woody resources from forests increase the rural economy and contribute significantly to increasing self-economic reliance and family income (Hall et al., 2015; Richardson, 2006). Local people rely on the forests for various consumables and commercial goods such as fuelwood, construction materials, medicinal products, and food (Ullah, Noor, Abid, Kashinda, et al., 2021). Harvesting forest products can be an essential support operation for individuals and families in forest regions, as non-agricultural livelihoods are especially vulnerable to seasonal demand fluctuations (Ullah, Noor, Abid, Kashinda, et al., 2021). About 89% of the population living in the buffer zone of GNAP is devoted to subsistence agriculture (Etc Terra, 2017b).

Changes in forest cover following D&D have a critical impact on the livelihood of rural inhabitants, as it is challenging to have access to harvest forest products. The quality of life in the rural communities has worsened in recent years as the essential means of livelihood, such as fertile land and forest resources, are increasingly being threatened (Innocent, 2019). It is an indisputable truism that the dependence of millions of people on forests leads to degradation and deforestation; several benefits are accruing from such loss (in the aspect of livelihoods, income and employment) for the sustenance of indigenous people (Wajim, 2020).

Deforestation and forest degradation at Gilé National Park's buffer has been increasing since 1990 (from 0.09% to 0.27%) (Mercier, 2016). Therefore, this study aims to analyze the socio-economic and ecological impacts of D&D on local livelihoods and household forest dependency in the area. Understanding the level of utilization and pattern of forest dependency could enable researchers, policymakers and practitioners to design empirically informed interventions to diversify households' livelihood portfolios and promote sustainable resource utilization in order to foster a balance between forest dependency and biodiversity conservation (Baiyegunhi et al., 2016; Fikir et al., 2016). In order to achieve this, the following research questions were posed to guide the study: (1) what is the level of household forest dependency? (2) How do socio-economic factors influence household forest dependency? (3) Which woody species is more preferred by the community? (4) What are the socio-economic factors that influence D&D? (5) Is there an ecological impact of D&D in the study area?

4.2. Methods

4.2.1. Description of the Study Area

The study was conducted at the buffer zone of GNAP in central Mozambique. GNAP is found between Pebane and Gile districts in the northeastern Zambezia Province (Figure 4.1). People living in the buffer zone of the park depends on subsistence agriculture (Terra, 2017b).

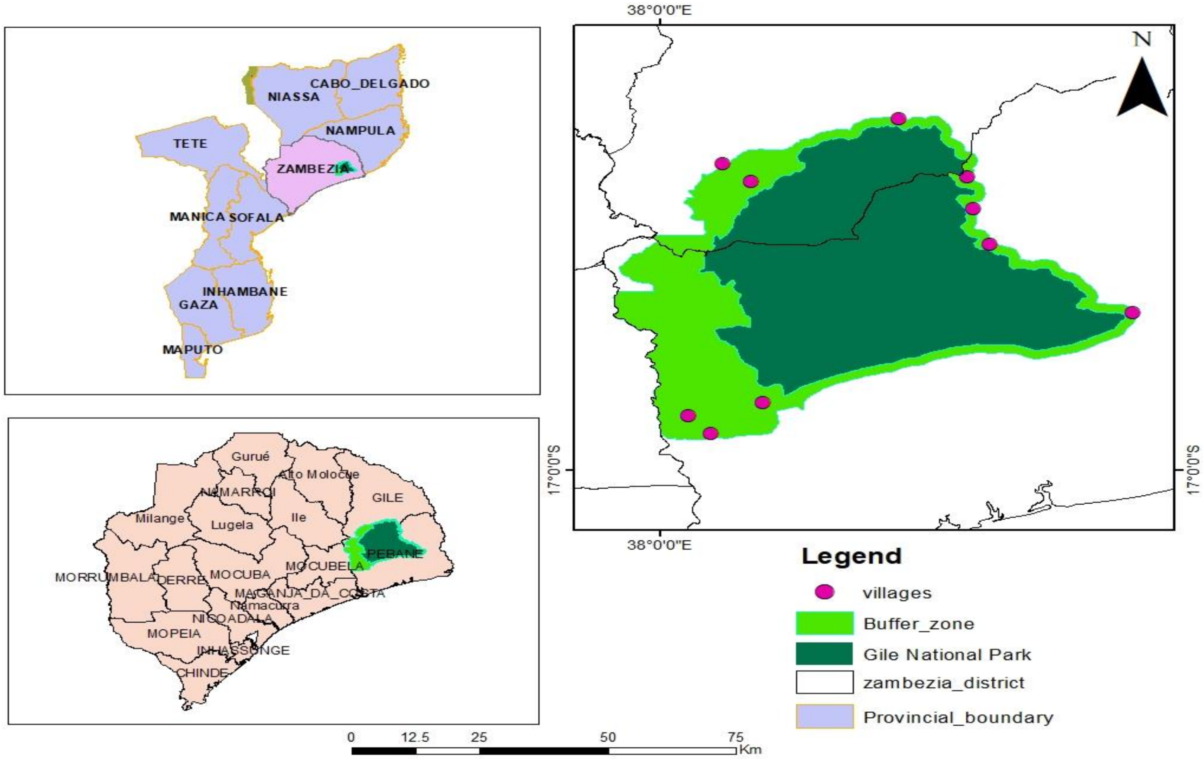

Figure 4.1 Map of the study area

4.2.2. Sampling Method and Data Collection

A socio-economic survey was used to collect data from the local community about resources use and socio-economic and ecological impacts of D&D. Household interview, key informant interview and focus group discussion were used.

Of about 40 communities living in the buffer zone of GNAP, ten communities were randomly selected for formal interviews as there were no significant differences among the community regarding forest cover and their activities in the area. The selected communities were grouped as Community 1, Community 2, Community 3, and Community 4 (CM1, CM2, CM3 and CM4), representing the South, North, East and West parts of the National Park to compare HH forest dependence between them as the facilities in all directions of the park were not similar.

Next, the households' sample frame was established by collecting the list of HH head records from their respective administrative with the help of an expert from GNAP. The sample frame was all HH living in the identified community, and finally, the selections of sample HH were proportional to each community. Accordingly, the total number of households living in the selected community for the target area was about 700. After getting the total number of HH living in each selected community, a total of 200 respondents, about (28%) of the selected household, were taken using simple random sampling techniques (Cochran, 1977). Allocations of the number of sample households to each community were proportional to the number of HH living in each community.

Based on the community's settlement, the proximity of their locations to the GNAP and the number of HH in the selected community, eight FGD were selected for this study. The members of FGD cover the district of Pebane and Gile (Figure 1). Each FGD comprises eight to ten participants drawn from the community members. Members of FGD were selected with the help of community leaders, knowledgeable people and an expert from the GNAP. Twelve KIIs were held with district-level and GNAP experts. During KIIs and FGDs, closed and open-ended questions having information about the community's forest dependency, socio-economic factors affecting their forest dependency and the socio economic and ecological impact of D&D were used. The main focus was to get enough information about local resource use, preferred woody species by the community and the socio-economic & ecological impact of D&D. Open-ended questions were used to collect more details which helped to qualify and clarify respondent's responses, yielding more accurate information and actionable insight. It frees respondents to convey their feedback and ideas in their voices and is the only way to collect in a situation requiring contextualization, complex description and explanation (Hyman & Sierra, 2016).

Data Collection Methods

The questionnaire was composed of two main sections. Section 1 contained questions covering the respondent's socioeconomic background. Respondents were further asked about the agricultural products and the quantity of products they sold. They were also asked about their total agricultural land area, the crops they grew, their crop output, and their total expenditures and income from their agricultural activities. Data on respondents who participated in off-farm activities were similarly noted. The second section of the questionnaire contained the resources extracted from the forests for use within the household. Data on the various types of forest items and products and the frequency of their collection were also collected.

Forest Dependency Model Specifications

Forest dependency of households was calculated as the ratio of annual income earned from forests to the total annual household income. Total annual household income was computed as the sum of all forest income, agricultural income, livestock income, wage income, and returns on accumulated wealth.

Data on items collected from the forest were recorded for each household. Income was computed annually for marketable forest products by multiplying each item's quantity by its market price. Income from nonmarketable forest products, such as a medicinal plant that substitute the purchase of medicine for their home, was computed by calculating the market price of the substituted product. Some households depended on GNAP and surrounding forest concession and earned their livelihood by working part-time. These households' forest incomes were derived by summing up income from forest products. Data on the types of crops and their yield were collected; the prices of crops were obtained from the local market where communities would sell their product. Estimations of wage income were made by including income from daily wages. Income from daily wages was computed by multiplying the number of days worked by the specified wage rate per day; income from salaried jobs was also added to income from daily wages. The annual rate of return on capital investments was calculated at a 10% interest rate as used by Jain & Sajjad (2016). motorcycles, solar panels, home utensils, farm implements, Etc., were included in capital assets as an annual investment to cover capital depreciation.

4.3. Data Analysis

Data obtained through household surveys were coded and analyzed descriptively using the Statistical Package for Social Sciences (SPSS) version 25 (Mngube et al., 2019). Descriptive statistics, namely: cross-tabulations, frequencies and percentages, were used to summarize data on preferred woody species and socio-economic variables. Chi-square tests were used to analyze the socio-economic and ecological impact of D&D. Data collected through FGD and KIIs were analyzed qualitatively. Qualitative data analysis involved thematic and content analysis based on how the results related to the research questions. Content analysis was used to edit qualitative data and reorganize it into meaningful shorter sentences (Vaismoradi et al., 2013). Thematic analysis was used to organize data into themes and identify codes (Kiger & Varpio, 2020).

Binary Logistic regression analysis was used to test socio-economic factors' predictive ability of forest dependency. In this study, the outcome variable (forest dependency) was regressed against selected explanatory variables: Sex, Age, Household family size, Educational level, Length of residency, Employment, Market access and awareness about forest management. These variables were used as a proxy for socio-economic. The variables were chosen because they cut across the social and economic domains; hence, they provide a comprehensive insight into the pattern of household forest dependency. The outcome variable forest dependency was measured as a dichotomous response occupying the value of 1 or 0, where 1 denotes high forest dependency and 0 means low forest dependency (Garekae & Thakadu, 2017). Since there is no set conventional cut-off point for classifying forest dependency, the average value across the study area was considered as the threshold for categorizing forest dependency into low and high levels. This approach has been widely used in forest dependency literature. Hence, the cut-off point value of 0.5 was used in this study. A binary logistic regression model was used to determine the socio-economic factors influencing households' forest dependency (Jain & Sajjad, 2016). Therefore, the forest dependency value of ≤ 0.5 denotes low dependency, while a value of ≥ 0.5 indicates high dependency. The description of the model used to determine the socio-economic factors influencing forest dependency were shown in Equ.4.1.

$$\log\left[\frac{Pi}{1-Pi}\right] = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + \beta_n x_{ni} \qquad \text{4.1}$$

where,

p = The probability of the outcome

i = i^{th} observation in the sample

β = intercept term

$\beta_1, \beta_2 \ldots\ldots \beta_n$ = coefficients associated with each explanatory variable $x_1; x_2 \ldots\ldots\ldots\ldots x_n$

In this study, the variables age, length of residency, Family size of household, sex, education, market access, awareness of forest management and employment opportunity were used to explain households' forest dependency. Table 4.1 presents the description and measurement of the explanatory variables used in the model.

Table 4. 1 Explanatory variables and their expected signs within the forest dependence model.

Variables	Explanation	Expected sign
Dependency	It is a dependent variable (DV), which measures forest dependency.	Not assigned
Sex	1 if male, 0 if female	Positive
Age	The respondents' age in years.	Positive
HHS	Family size of the household.	Positive
Education	Household head level of education (0 = none, 1 =primary, 2 = secondary)	Positive/ Negative
Length of residency	Number of years residing in the area	Positive
Employment	Household head employment status (0 = unemployed, 1 = others, 2 = employed)	Negative
Market access	On a scale of 1 to 5, where a high score is assigned to communities with easy access to a market and a low score to the communities with difficult access to a market.	Negative/ Positive
Awareness about forest management	Awareness of the respondent: We have assigned 0 to aware, 1 to not aware.	Negative/ Positive

4.4. Results

4.4.1. Household Characteristics

Of the 200 households interviewed, 94 (47%) were male-headed, and 106 (53%) were female-headed. Most respondents' family size was in the range of 3 to 5 members, representing about 42% of the sampled respondents. About 28.5% and 29.5% of the respondent's family sizes were below three and between 6-10, respectively. In terms of household age composition, 31.5% of them were in the 46–65-year age range, 29.5% in the age range of 31–45 years (working age) group, 28.5% in the age range of 21–30 years' group and 10.5% of them were above 65 year's age. The result indicates that most respondents were still in the active age groups contributing to the family labor force. Of all respondents, about 56.5% of them have no formal education. About 40.5% of the household heads had a primary school, and only 3% had secondary school.

4.4.2. Occupational Levels and Household Income Sources

Respondents were mainly engaged in agriculture, in which slash-and-burn characterized their farming systems. The main crops grown by farmers are Cassava, Sweet potatoes, Mango, Maize, Rice, Groundnut, Pepper, Tomato, Beans, Banana, Cashew nuts, Sunflower, Sesame and Sugar cane. Keeping livestock (chickens, goats and ducks), pork and fishing were the additional occupations of the farmers in the area. Household consumption and minor selling of charcoal, timber and other non-timber forest products (building materials, herbal medicines, wild fruits, mushrooms, honey, bush meat, artefacts and other household items) were integral to the way of life of the respondents.

Most of the respondents (191; 103 females and 88 male) did not have any off-farm jobs. Those (9; 3 females and 6 males) had off-farm jobs like part-time work from nearby National Park and forestry-related companies in the study area. They also often shared labor among neighbors during the farming seasons to earn additional income. Our study identified HH income from sales of products and domestic animals, forest products and off-farm jobs.

Household Forests Dependency

Generally, forest products provide both subsistence and cash income for households. Our study found that forest and non-forest products were extracted by respondents from the buffer zone of GNAP and include firewood, timber for construction, wild meat, fruits/vegetables, medicinal plants, and fishing. All (n = 200) of the respondents reported that they had visited the forest every time in which almost all of the households (99.4%, n = 199) attributed their visitation to solely harvesting forest products. The study examined that forest-based products used by the locals were for home utilization and selling to get cash. Although various forest products were collected from the park's buffer zone, firewood, thatch grass, medicinal plants, and wild fruits (100%, n = 200) were the most collected products by the respondents, while pols were the least (2.5%, n = 5). The study revealed that all respondents (200) used forest products like firewood, thatch grass, and medicinal plant for their home utilization, while about 5%,15%, and 25% of them used those products correspondingly for selling to get cash in addition to home utilization. Of all, about 39.5% and 26% of the respondents used honey they collected from the forest for home utilization and selling purposes, respectively (Table 4.2); which is a clear indication that the forest in the area helps to regulate the economy of the area, as many people were involved in extracting forest products for sales while others were involved in the extraction of forest products for household consumption.

Table 4. 2 Types of forest products used by local people

S/no	Forest product	Used for home	Used for selling
1.	Firewood	200(100)	10(5)
2.	Medicine	200(100)	50(25)
3.	Thatch grass	200(100)	30(15)
4.	Bush Meat	150(75)	64(32)
5.	Fibers	105(52.5)	50(25)
6.	Honey	79(39.5)	52(26)
7.	Wood (timber)	42(21)	61(30.5)
8.	Mushroom	18(9)	15(7.5)
9.	Charcoal	15(7.5)	35(17.5)
10.	Fish	160(80)	45(25.5)
11.	Wild fruits	200(100)	50(25)
12.	Pols	5(2.5)	37(18.5)

Source: Field survey ,2020; parenthesis () = percentages.

The perceived level of households' reliance on forests was assessed. The respondents were presented with statements in which they were asked to agree or disagree and indicate their agreement or disagreement level, ranging from very low dependency (coded 1) to very high dependency (coded 5). The itemized statements indicate that almost all households (95%, n = 190) were highly dependent on the forest for their livelihoods, whereas only 5% (n = 10) were moderately dependent.

The household's perceived level of reliance on forest resources was further determined using the forest dependency index (FDI). The mean FDI was 0.50 (SD = 0.41), suggesting that households depended moderately on forest resources and varied with their settlement area. Residents from the south, north and eastern part of the park were relatively more dependent on forests compared to the western part as their source of income had an index of 0.6,0.5 and 0.6, respectively, indicating high forest dependency. In comparison, FDI for communities from the western part of the park was about 0.30 and comparatively lower than other communities. Figure 4.2 shows the average forest dependency of all households within the sampled communities.

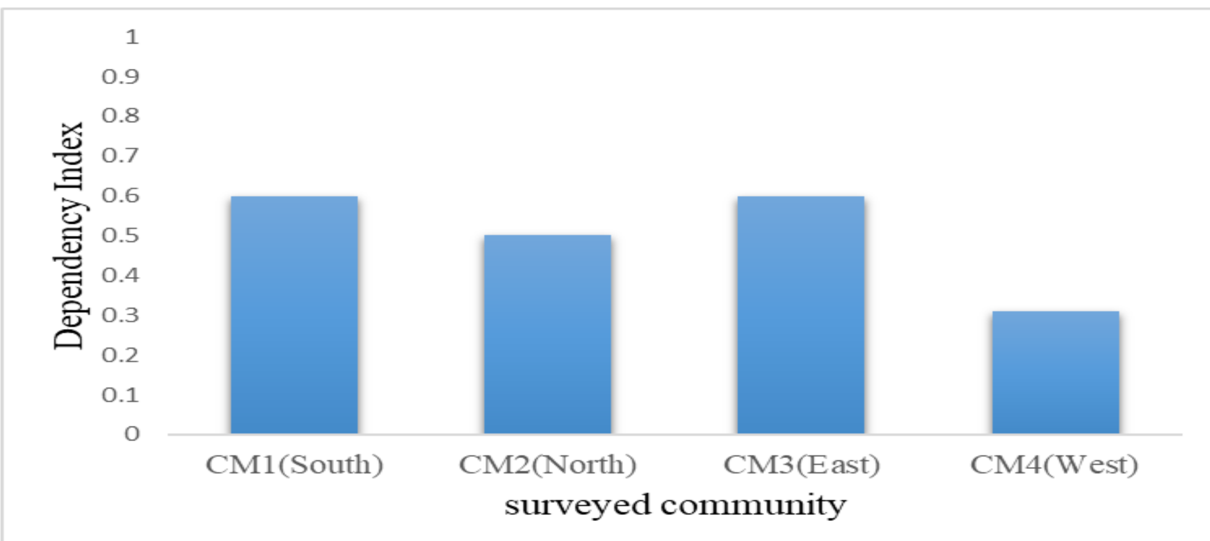

Figure 4.2 Forest dependency in the sampled community. (CM1=South, CM2=North, CM3=East and CM4=West)

In CM4, households are more heavily dependent on agriculture for their source of income, which indirectly makes their dependence on forests low compared to the other communities. Table 4. 2 reveals that most households' primary income comes from agriculture. A small percentage of the households participated in off-farm activities. Income derived from the forests contributes about 33 % to the total income of all households. The average annual income derived from forest resources per household is US$108. The income contributions from forest and non-forest reported from each community are shown in appendix-1. In all sampled communities, households are more heavily dependent on agriculture for their livelihood, indirectly making them highly dependent on forests to access land. In all communities, income earned from agriculture is significantly higher than other sources of income.

Socio-Economic Factors Influencing Household Forests Dependence

A binary logistic regression model was run to assess the predictive ability of the selected socio-economic factors on household forest dependency. Preliminary analyses were conducted to test for multicollinearity, and no violations were observed. All the explanatory variables were above the conventional cut-off point for tolerance and variance inflation factor (VIF): none had tolerance less than 0.10 and greater than 10 for VIF. The likelihood ratio test shows that the regression model was significant ($\chi 2 = 23.00$, $p = 0.01$).

As presented in Table 4.3, three predictors: age, number of residing years in the area and educational level made a statistically significant contribution toward predicting forest dependency. Since the coefficient of those two predictors (age and education) were negative, the odds of reporting high forest dependency decreased with increased age (OR = 0.76). With regards to education, forest dependency decreased with transition from none (illiterate) (OR = 0. 58) to primary (OR = 0.15) and to secondary (OR = 0.11) educational levels correspondingly. However, the odds of reporting high forest dependency increased with an increasing number of residing years in the area (OR=0.75). The result suggests that household heads with higher educational levels and an increase in the age of household heads resulted in a decrease in forest dependency. Nevertheless, the increasing number of residing years in the area increases forest dependency by 0.75, as all other factors are equal. The finding implies that the youthful households were likely to gather more forest products compared to the elderly aged. On the other hand, access to market, household size, sex and employment opportunity were not statistically significant but showed positive and negative associations with forest dependency.

Table 4. 3 Logistic regression model for factors influencing household forest dependency

Predictors	*β*	*SE*	Wald	Exp (β)	95% CI for Exp(β)	
					Lower	Upper
age	-.770	.405	3.617	0.85*	0.02	1.024
sex	.115	1.389	.007	1.12	.074	17.077
Level of Education (none)	-.535	.590	7.825	0.58*	0.01	1.859
Level of Education (primary)	− 1.89	0.72	6.79	0.15*	0.04	0.63
Level of Education (secondary)	− 0.83	0.60	3.89	0.11*	0.01	1.42
Family size	.912	.704	1.676	2.48	.626	9.90
length of residency	1.149	.837	4.885	0.75*	0.03	5.83
Awareness on forest management	-0.284	.813	.122	0.75	.612	16.25
Employment opportunity	-0.802	1.181	.461	0.81	0.32	2.01
Access to market	.726	.429	2.861	2.06	.220	22.54
Constant	1.93	5.063	.146	.145		

β beta coefficients, SE stand error, Exp (β) odd ratio (OR) *p < .05

4.4.3. Preferred Woody Species by Community

According to respondents, most of the woody species are used by the community for more than one purpose. Even though communities use all woody species for more than one purpose, the most preferred species for fruit (food), fuel wood and charcoal production, construction materials for home and medicinal values, they identified five woody species for each preferred use. *Annona senegalensis, Erythrophleum africanum, Pericopsis angolensis,* and *Parinari curatellifolia* were the top-ranked woody species among the listed species for fruit (food), fuel wood and charcoal production, construction materials for home and medicinal values (Table 4.4). *Gardenia volkensii*, *Lannea schimperi*, *Gardenia thunbergia* and *Sclerocarya birrea* were culturally untouched woody species in the study area.

Table 4.4 Most preferred woody species by communities

Top five preferred woody species versus identified uses				Rank
Fruit (Food)	Fuel wood and charcoal	Construction materials	Medicinal values	
Annona senegalensis	*Erythrophleum africanum*	*Pericopsis angolensis*	*Parinari curatellifolia*	1
Pseudolachnostylis maprouneifolia	*Julbernardia globiflora*	*Pseudolachnostylis maprouneifolia*	*Brachystegia spiciformis*	2
Combretum zeyheri	*Brachystegia spiciformis*	*Swartizia madagascariensis*	*Pterocarpus angolensis*	3
Diospyros mespiliformis	*Brachystegia bussei*	*Annona senegalensis*	*Julbernardia globiflora*	4
Tamarindus indica	*Brachystegia boehmii*	*Combretum zeyheri*	*Erythrophleum africanum*	5

4.4.4. Socio-Economic Impact of Deforestation and Forest Degradation

The result of the impact of D&D on the socio-economic livelihood of the resident's community is shown in Table 4.5. Of all, 80.5% of the respondents strongly agreed that D&D are a significant cause of loss of economic woody species in the study area. Also, when the total percentage of respondents was summed together, it indicated that 100% (80.5% + 19.5%) of the respondents confirmed that D&D is a significant cause of the loss of economic woody species in the area. Of all, 96 % and 90.5 % of the respondents strongly agree that D&D contributed to the scarcity of fertile land and the primary cause of loss of medicinal plants in the study area, respectively. Furthermore, 97.5% (76.5% + 21%) of respondents stated that the loss of wild edible food sources in the study area is caused following D&D.

Table 4.5 Socio economic problems caused by D&D on community

S/no	Problems	Respondent's Response (%)						Total (%)
		SA	A	U	SD	D	NA	
1.	Loss of economic woody species	80.5	19.5	-	-	-	-	100
2.	Scarcity of fertile land	82	16	1	-	1	-	100
3.	Loss of medicinal plants	75.5	20	1.5	-	3	-	100
4.	Loss of water	58	40	2	-	0	-	100
5.	Loss of wild edible food sources	76.5	21	1	-	1.5	-	100
6.	Flooding and Erosion	46.5	22	15.5	6	2	8	100

Source: Field survey, 2020

The respondent's analysis showed that resident communities in the study area caused 97 percent (90% + 7%) of D&D activities. The influence of forest concession holders on D&D was huge and represented about 89 percent (73.3% +15.5) (Table 4.6).

Table 4. 6 Summary analysis on responsible body for deforestation and degradation in the area

S/no	Names	Respondent's response (%)					Total (%)
		VH	H	M	L	VL	
1.	Resident community	90	7	3	-	-	100
2.	Forest concession holders	73.5	15.5	6	5	-	100

#VH=very high, H=High, M=moderately =low and VL=very low

Source: Field work ,2020

The study found out how D&D activities were carried out in the study area. D&D was mainly undertaken through indiscriminate farmland expansion (92.5%), looking for new farmland by young farmers (75 %), illegal logging by concession holders (74%), fire (65%) and climate change (25%) (Table 4.7). This analysis indicates that the loss of forest resources was through indiscriminate farmland expansion and looking for new farmland by young farmers in the study area. The removal of forest resources through the mentioned factors not only destroys the forests but could also affect the socio-economic activities of the people in the study area.

Table 4. 7 Summary analysis on the factors accounting for D&D

S/no	Names	Respondent's response (%)					Total
		SA	A	U	SD	D	(%)
1.	Indiscriminate farm land expansion	92.5	6	1.5	-	-	100
2.	Looking new farm land by young farmers	75	14.5	7	-	3.5	100
3.	Illegal logging	74	21	4.5	-	0.5	100
4.	Fire	65	28.5	4.5	1	1	100
5.	Climate change	20	5	75	-	-	100

Source: Field work,2020

All respondents reported that some woody species were endangered due to D&D in the park's buffer zone. They also reported that animal species which live in the trees no longer have their habitat, cannot relocate in the study area, and therefore become exposed to extinction, which affects the biodiversity of plant and animal species in the area.

Most FGD participants were aware of D&D and its socio-economic impacts on the community's livelihood. KIIs and FGDs participants noted that long years ago, the area had good forest cover, which is not the case currently. They mentioned that this unpredictability had affected forest cover, crop and animal production, which according to them, had become more severe than in the past. Some of the changes mentioned included drying up of trees and other vegetation, an increase in crop diseases and pests, increase in the outbreak of disease, which was not the case previously. Participants also reported a reduction in crop productivity, mainly maize, cassava and beans on their farms. They also reported that they observed that wild fruits and most indigenous fruits, which were abundant in the past, had also disappeared due to D&D. According to FGDs and KIIs, there is no rule or management system established to regulate the use and access to the forest of in the buffer zone of the park. Forest in the buffer zone is seen as a shared resource everyone can access and benefit from. This open access situation encourages competition amongst different users rather than cooperation and leads to destructive practices.

According to KIIs and FGDs, the community perceived six significant consequences of D&D in the buffer zone of GNAP. These include the decline of agricultural yield, biodiversity, habitat loss, low and decreasing profitability of farmers, land and soil degradation, water resource decline, and extended aridity and drought. Losses of soil fertility have caused a decline in agricultural yields.

Group discussions with the community and interviews with experts from the GNAP and agricultural office on the ecological impact of D&D were added as follows:

"*Forests in the buffer zone of the park are home to thousands of unique flora and fauna that can't be found in any other ecosystem. Because they house such a diverse variety of life, the destruction of forests can have a devastating impact on those biodiversity". "as community clear forested land for farming, and illegal logging expanded in the area, it represents the decimation of millions of animals' habitats".*

"Trees help to control flooding, its roots hold soil firm in heavy rains, and the trees absorb some of the rainwater. Their absence can cause disastrous floods". Trees balance the world's carbon dioxide (CO_2) levels as the gas cycles through the atmosphere and into the oceans, soil, and other living organisms. Cutting down trees releases their stored CO_2 back into the atmosphere. Moreover, we lose out on their continued removal of excess carbon from the atmosphere, which leads to the excess carbon emissions that contribute to the greenhouse effect and accelerate climate change. Removing trees on a mass scale through D&D takes away one of the most critical buffers we have against climate change. When forests are removed, we lose out on their vital protection against climate change, soil erosion, and natural disasters like flooding. The roots of trees stabilize the soil and keep it in place. Removing trees loosens the soil and leaves it exposed to damaging rains and wind. Removing trees on a mass scale through deforestation significantly speeds up soil erosion.

(Agricultural Officer from Pebane and Gile District, an expert from GNAP and Key Informant Interview, October 2021)

A 65-year-old man described the past & present situation of D&D in the buffer zone of the GNAP as follows: "I was born and grew up in this area. When I was young, forestland, woodlands, and grasslands covered a significant portion of the area, and there were a variety of animals. I used to hunt animals like buffalo and bushbuck with my friends. But now, the forests are cleared, and it is difficult to find animals like buffalo in the area."

"The community used to destroy forests to have new farmland, to build settlements, for charcoal and domestic fuel, timber and woodworks. Further, farmers expand agricultural lands to natural forests, Consequently, forest covers are reduced to remnants and are remained around inaccessible areas, and along streams and valleys areas."

(Natural Resource Management officers from Gile and Pebane District, Key Informant Interview, October 2021).

The other implication of D&D revealed in the study area was the decline of water resources. "In several areas within the study area, rivers is an important source of water supply. In areas where wetlands are drained, the springs are dried out." (Key Informant Interview, October 2021).

4.5. Discussions

The study examined the socio-economic characteristics of the community of the study area. We observed that almost all respondents were predominantly farmers involved in agricultural activities. Most of their activities depend on the extraction and utilization of forest products (timber and non-timber forest products), while few respondents were involved in off-farm economic activities. The study identified that few local people and members of the households in the area were involved in multiple economic activities to make life more meaningful.

Forest products can provide subsistence and cash income for households in the study area. Although various forest products were collected from the park's buffer zone, firewood, thatch grass, medicinal plants, and wild fruits were the most collected products by all respondents. *Annona senegalensis, Erythrophleum africanum*, *Pericopsis angolensis*, and *Parinari curatellifolia* were the top-ranked woody species used for fruit (food), fuel wood and charcoal production, construction materials for home and medicinal values. In contrast, *Gardenia volkensii*, *Lannea schimperi, Gardenia thunbergia* and *Sclerocarya birrea* were culturally untouched woody species in the study area.

Most respondents strongly agreed that D&D are the primary cause of the loss of economic woody species and fertile land in the study area. The respondent's analysis showed that almost all D&D activities were caused by resident communities and forest concession holders around the study area. The result that the community contributed to D&D may be attributed to farming, which is the primary occupation of the people in the study area. In contrast, problems related to forest concession holders may be attributed to illegal logging and buying timber wood for their saw mill from the park's buffer zone, which was a significant opportunity for the community to get new farmland. D&D were mostly through indiscriminate farmland expansion, looking for new farmland by young farmers and illegal logging by timber-based concession holders. The removal of forest resources through the mentioned factors not only destroys the forests but could also affect the people's socio-economic activities and ecology in the study area.

The study results revealed that households generally depended on forests for livelihood. Hence, the area's forest products and other natural resources are paramount to household sustenance. The Year of residency, age and educational level of the respondents significantly influences the forest dependency of the communities. Concerning the place of residency, community residents from the south, north and east part of the park were relatively more dependent on forests as their source of income. This observation is attributed to access to market opportunity, while the community from the west part of the park do not have such opportunity. This finding is consistent with other studies from South Africa, Ethiopia and Bangladesh, which reported that having access to the market increases the likelihood of households exhibiting greater reliance on forest products as a source of income (Baiyegunhi et al., 2016; Fikir et al., 2016; Mukul et al., 2016).

The relationship between the age of the household head and forest dependency revealed an inverse relationship. The odds ratio for the coefficient of age implies that, as the age of the household head increase, the chance of depending on forest resources can be decreased. Hence, the youth were more likely to depend on forest products than the older people. The possible explanation for this unexpected observation of the youth being more likely to depend on forest resources than the elderly could be attributed to the following reasons in the study area. The energetic nature of the young people gives them to indulge in forest extraction activities which are often labor intensive and require physical strength. Moreover, the older people may have enough farmland and less expense to cover their homes compared to young people in harvesting activities. This result agrees with the finding of (Adam et al., 2014; Fonta & Ayuk, 2013) , who reported that in the light of the exhausting nature of forest extraction activities, the youth are advantaged in traversing longer distances going into the forest for harvesting forest products.

The high unemployment rate coupled with poverty and other social shocks in the study area requires young people to rely heavily on endowed forest resources. Moreover, young people are highly reliant on forest resources since they may have multiple uses of forest products compared to the elderly. For example, forest products collected for subsistence consumption may be added value and sold at the nearby town of Pebane and Gile.

Although the observed inverse relationship between age and forest dependency in this study deviates from the normal, the finding agrees with a small but growing body of empirical evidence demonstrating a shift in collection and utilization of forest resources from being an activity predominantly undertaken by the older people to a broader one encompassing people across various age brackets (Adam et al., 2014; Mujawamariya & Karimov, 2014; Ofoegbu et al., 2017; Suleiman et al., 2017; Wen et al., 2017) , with young people posed to exhibit greater dependency on forests compared to their counterparts. Our study and the studies mentioned above argue that increases in household age have a diminishing effect on forest extraction activities. Since forest extraction activities are often tedious and laborious, young people have the upper hand in collecting more forest products and sustaining the collection activities for a while compared to the elderly. As argued by André & Platteau, (1998), younger households are being trapped in social disadvantages due to inequitable distribution of resources such as landholding and limited access to alternative economic opportunities. That is why younger households are likely to rely more on forest resources for their livelihood sustenance.

There was a statistically significant positive association between HH educational level and forest dependency. The findings infer that higher educational attainment lessened reliance on forest resources. Higher levels of educational attainment reduce households' reliance on forest products in this study and might be attributed to the notion that people with formal education have diversified livelihood options which may generate significant returns compared to forest-related activities (Masozera & Alavalapati, 2004). This finding agrees with other studies conducted in South Africa, Nigeria and Kenya (Baiyegunhi et al., 2016; Fonta & Ayuk, 2013; Kabubo-Mariara, 2013) who reported that higher education offers better employment opportunities, hence diverting livelihood options away from gathering forest products.

On the other hand, the predictors' household size, sex and employment did not reach statistical significance but showed both positive and negative relationships with forest dependency. Length of residency had a positive relationship with forest dependency, suggesting that long-term residents were more reliant on forest resources than short-term residents. Pattanayak et al. (2003) found that residency length positively influences households' reliance on forests in Nepal. According to Pattanayak et al. (2003) people who stayed longer on the forest border were highly dependent on forests compared to the one who lived a short time, which was attributed to their familiarity with the complexities of their proximate environment. Forest dependency and sex were negatively related. Therefore, the negative coefficient of sex implies that females were more dependent on forest resources than males. Generally, women depend highly on common pool resources, including forests (Grossman, 1981; Uberhuaga et al., 2012). In contrast, studies from Sudan, Rwanda and South Africa found that males were more likely than females to depend more on forests and other environmental resources (Adam et al., 2014; Masozera & Alavalapati, 2004;

Thondhlana et al., 2012). In these studies, men were associated with selective harvesting of forest resources, especially those with market value, such as pols. Furthermore, men mainly used to animal-drive carts to gather forest products, which allowed them to extract more resources.

Although not significant, Household size had a positive relationship with forest dependency. Thus, the likelihood of reporting higher forest dependency increased with an increase in household size. This finding agrees with the finding of other studies (Adam et al., 2014; Fonta & Ayuk, 2013; Kabubo-Mariara, 2013; Mamo et al., 2007; Prado Córdova et al., 2013) who reported that larger families were more dependent on forest resources in Sudan, Nigeria, Kenya, Ethiopia and Guatemala respectively. Since forest activities are labor intensive, larger families have adequate human resources to allocate across gathering activities. However, it disagrees with the finding of Garekae & Thakadu (2017) , who reported that Household size had a negative relationship with forest dependency in Botswana. Therefore, the likelihood of reporting higher forest dependency decreased with an increase in household size. The possible explanation for this counterintuitive finding may be attributed to differences in demographic profiles, such as household sizes, between the current study and the studies mentioned above. The current study's household size was generally smaller than the former, comprising relatively larger household sizes, averaging six members.

The variable employment was negatively associated with forest dependency, suggesting that employed households were less dependent on forest products. Employment opportunities may offer better income-generating options than the forest benefits. Possibly, those employed could afford alternative products from the market, hence reducing reliance on forest products. Studies conducted elsewhere found income from employment and regular paid activities to be negatively associated with households' forest dependency (Hegde & Enters, 2000; Tieguhong and Nkamgnia, 2012; Mamo et al., 2007). The variable awareness of forest management showed a negative association with forest dependency, suggesting that households with awareness of forest management were less dependent on forest products. Awareness of forest management may offer diversified income-generating options compared to benefits derived from the forest and even teach the people how to use forest sustainably. Those aware of forest management could afford alternative products from the market, reducing reliance on the forest.

Variable access to the market showed a positive association with forest dependency, suggesting that households with access to the market for forest products were more dependent on forest products than those without access to the market. Market access may offer the chance of getting income generation options by opening the chance to selling forest products. This finding agrees with Mamo et al, (2007) who reported that communities with market access depend more on forests.

4.6. Conclusions

The results suggest that local communities in the buffer zone of GNAP are highly dependent on forest resources for their livelihood sustenance. Therefore, forests were critical in livelihood diversification in the study area. In this study, socioeconomic factors such as length of residency, age and education significantly influenced household forest dependency. The observed inverse relationship between age and forest dependency provides an encouraging insight. This study portrays the youth as a critical stakeholder and change agent in sustainable forest management. Therefore, young people could be capacitated with the skills and ability to initiate activities to enlighten communities on the importance of forests and the need for conservation. On the other hand, people who attained higher education levels were observed to be less dependent on forest resources. Therefore, education could be used to divert household pursuits away from gathering activities. The community uses woody species for more than one purpose. D&D are the primary cause of loss of economic woody species in the study area and is primarily caused by resident communities and forest concession holders and mostly happened through indiscriminate farmland expansion and illegal logging. The study results contribute to local management and conservation strategies in the following manner: the key factors bringing about a variation in forest dependency can be considered and factored into the planning, designing and implementation of programs and activities for forest sustainability. On the other hand, policies should facilitate the active participation of local communities in forest management and conservation. In order to foster a balance between forest dependency and biodiversity conservation, the provision of alternative livelihood opportunities and access to higher education aimed at diversifying young people's livelihood portfolios are vital in reducing forest dependency, hence protecting forests for posterity. Lastly, this study has expanded the forest dependency literature, particularly in the central part of the country where the intricate relation between people and their immediate environment has been relatively understood.

CHAPTER 5. LAND USE AND LAND COVER CHANGES OF GILE NATIONAL PARK BUFFER ZONE FROM 1999 TO 2019, CENTRAL MOZAMBIQUE.

This Chapter is based on a slightly modified version and published article

Ameja, L. G., Ribeiro, N & Sitoe, A. A (2021). Land Use and Land Cover Changes of Gile National Park Buffer Zone from 1999 to 2019, Central Mozambique, Department of Natural Resource Management, Faculty of Resource Management and Economics and, Department of Forest Engineering, Faculty of Agronomy 21(1), 39–52. https://doi.org/10.5829/idosi.aejaes.2021.39.52.

5.0. ABSTRACT

Land use/land cover change (LULCC) is a major issue in global environmental change. Loss of functionality of protected areas from surrounding land use modification is a daunting problem. The objective of this study was therefore to investigate LULCC and its causes in the buffer zone Gile National Park, central Mozambique. Landsat imagery of 1999, 2009 and 2019 were used. Study area was categorized in to six LULC classes. Supervised classification was used for image classification whereas analysis and quantification of spatio-temporal dynamics of the LULCC were done through Landsat image pre- processing, classification, and post-processing using QGIS 2.8.1 and ArcMap 10.1. Dense Miombo wood lands are mainly distributed in the western and southern part of the park, while agricultural land is concentrated in the northern, eastern and south west of the park. The overall accuracy for 1999, 2009 and 2019 were 90%, 90%, and 91% respectively. Kappa statistics showed a strong agreement. Dense and open Miombo woodland are the most dominant land cover classes, covering 6655 ha (43.61) and 44190.09 ha (28.95%) of the total land use in 1999. From 2009 to 2019 agricultural land expanded by 15.3% of its 1999 area coverage. Of the total land cover about 34.57% and 40.86 % of land covers remained unchanged for 1999 to 2009 and 2009 to 2019 correspondingly. Within 20 years about 14.85 % of dense Miombo woodland has been changed to other land uses which means degraded. The rate of forest loss from 1999-2019 were 1,237.14 ha/yr. The highest annual rate of deforestation (4.05%) recorded during the period of 1999 to 2009. The result of House hold interview, focus group discussions and key informants also showed that slash and burn agriculture, settlement and forest concession were the major causes of LULCC. The adverse impacts of LULCC were associated with the underlying factors related to human activities. To reverse these challenges, there must be broad-scale restoration projects around the area supported by awareness creation and incentive mechanisms to conserve forests for forest users.

Key words: Miombo Woodland, Land Use Land Cover Change, Buffer Zone of National Park

5.1. Introduction

Miombo woodland is a vernacular word that has been adopted by ecologists to describe those woodlands dominated by trees of the genera Brachystegia, *Julbernardia*, and *Isoberlinia Leguminosae*, subfamily *Caesalpinioideae* (Campbell et al., 2007). It is a vast African dry land forest ecosystem covering close to 2 million km^2 across southern Africa (Ribeiro et al., 2020) and are highly valued of its ecological functions and ecosystem services (Chiteculo et al., 2018b; Pullanikkatil et al., 2020). The designation of protected areas is one of the most important conservation strategies available to societies. However, long-term conservation of biodiversity cannot be achieved if the relationships between protected area and the buffer zone are not considered (Palomo et al., 2013).

Protected area's buffer zones are used for activities that are compatible with ecologically sustainable practices that directly or indirectly support conservation and research, and importantly serve ecological buffering functions (Atsri et al., 2020). Although some management activities are undertaken to enhance the conservation values of the area and to provide benefits to neighboring rural communities, the main goal of buffer zones is still to protect biodiversity, but this protection has to be harmonized with the derivation of benefits to local people (Martino, 2001).

Land use/land cover change (LULCC) is a major issue in global environmental change (Anchan et al., 2018; Andualem et al., 2018). LULCC has become a central and important component in current strategies for managing natural resources and monitoring environmental changes (Rawat et al., 2013). LULCC is an important factor affecting carbon cycling process and bringing changes to carbon sources and sinks in terrestrial ecosystems through changes in biophysical properties of the land-cover (Ge et al., 2008; Lai et al., 2016; Quesada et al., 2018). A quarter of the total carbon emission by human activities is caused by land use changes as a result of deforestation and forest degradation (IPCC, 2001; Quesada et al., 2018). land use and cover change in Miombo woodlands are reducing global carbon sink strength (Lupala et al., 2015). The complex and dynamic land use/land cover change at various scales has environmental implications (Bufebo & Elias, 2021). Causes of landscape change and conservation strategies to protect biodiversity will vary, but it is apparent that economic, political, and conservation forces at local, national, and global scales are drivers of land cover change (Kintz et al., 2006). Rapid worldwide population growth accompanied by human activities has led to rapid LULCC (Anchan et al., 2018; Shah et al., 2017; Yirsaw et al., 2017).

Remote sensing and geographic information system technology are emerging technologies that have been important for the assessment of land use land cover change (Pokhrel, 2018). Remote sensing has been widely used to classify land cover and played a key role in determining the loss of forest cover at a landscape level since the 1990s (Chiteculo et al., 2018; Mercier et al., 2016). Understanding landscape patterns, changes and interactions between human activities and natural phenomenon are essential for proper land management and decision improvement (Kim, 2016; Kintz et al., 2006; Pullanikkatil et al., 2020).

5.2. Statement of the Problem

To play their roles fully and sustainably, protected areas should be managed in a way that considers the needs and concerns of local populations in the buffer (Atsri et al., 2020). Land use and forest cover change in the tropics and Miombo woodlands remain an enormous challenge with associated social, environmental, and economic implications (Lupala et al., 2015). The impacts of LULCC in buffer zones surrounding protected area have important implications for its management and conservation. LULCC surrounding a protected area can reduce its conservation capacity, and loss of biodiversity inside a protected area may be attributed to the size or isolation of the protected area. Buffer zones with limited or restricted land use have been suggested as a management strategy to reduce the influence of surrounding land-use activity on biodiversity within the protected area (Kintz et al., 2006). Loss of functionality of protected areas from surrounding land-use modification is a particularly daunting problem in developing nations. Land use conversion due to increasing human population is a common experience in protected areas of most African countries (Belay et al., 2014b). These areas are where land-use change has been occurring rapidly over the last 25 years and is projected to continue (Bailey et al., 2015). In opposite, the resources in and around protected areas are more critical to people living adjacent to it (Dibaba et al., 2020; Hartter & Southworth, 2009).

To ensure the effectiveness of protected areas, it is necessary to understand changes driven by the surrounding landscapes (Chiteculo et al., 2018b; Kintz et al., 2006). Knowledge of LULCC over a time horizon can be of great importance in the context of preparing concrete local, regional and national land management measures and can be used to reverse land use issues, illegal occupations, habitats destruction, ecological and natural resource deterioration, loss of biodiversity (Bamford et al., 2014; Mucova et al., 2018a). LULCC have increasingly become a key research priority for national and international research programs examining global environmental change and impact analysis of the changes, which is a standard requirement for land use planning and sustainable management of natural resources as highlighted by researchers (Fasika et al., 2019).

Mozambique is engaged in a pilot project for REDD+ in two provinces, including Zambézia, establishing a series of new management and monitoring programs such as restoration of degraded lands; strengthening protected areas management and the implementation of the Zambézia Landscape Program (ZILMP) (Mercier et al., 2016). In Mozambique little is known about land use land-cover changes at the national level, and are still very incipient(Mucova et al., 2018; Sitoe et al., 2012). Drivers of LULCC following deforestation and forest degradation varies per province, based on forest type, economic, social and natural characteristics. Shifting agriculture has a greater impact on emissions (60%) in the central part of the country (Sitoe et al., 2016). A first order estimation of emissions resulting from the three most important causes of forest degradation (timber exploration, production of firewood and charcoal and wildfires), predicted that forest degradation is responsible for almost 30% of total carbon emissions (Government of Mozambique, 2018) . This scenario reveals the importance and urgent need of further studies about LULCC in different areas of the country to provide useful and timely information for better understanding of LULCC (Mucova et al., 2018a).

Gile National Park (GNAP) which hosts various endangered wildlife species was created in 1932, originally as a game reserve for hunting and proclaimed as a conservation area in 1999, first as a National Reserve (Nourtier et al., 2016) , and very recently (May 2020) as a National Park (Montfort et al., 2021). The GNAP is divided between a fully protected core area (2,861 km2) and a buffer zone (1,671 km2). It is the only protected area in Mozambique with no permanent settlements in its core area and represents one of the largest areas of uninterrupted Miombo woodland in the northern part of the country. But now a day it has been suffering from severe threats of LULCC at its buffer zone. Community living in the buffer zone regularly open new fields through clearing forested areas, this phenomenon with demographic pressure is worsening on forest land (Nourtier et al., 2016).

Land use/cover change detection is very essential for better understanding of landscape dynamic during a known period of time (Rawat & Kumar, 2015) and its study has been emerged as an important research concern as hence it cause serious environmental changes (Mondal et al., 2016). This requires the present and past land use/ cover data of the area. The objective of this study was therefore (1) to analyze land use and land cover changes in the past 20 years in the GNAP buffer zone and (2) To identify causes of LULCC in the GNAP buffer zone, central Mozambique.

5.3. Materials and Methods

5.3.1. Description of the Study Area

The study was conducted in buffer zone of GNAP in Zambezia Province, central Mozambique. GNAP is found in the north-eastern part of the Province situated between Pebane and Gile districts (Figure 5.1). About 12,500 inhabitants live in the GNAP buffer zone (Mercier et al., 2016a) .

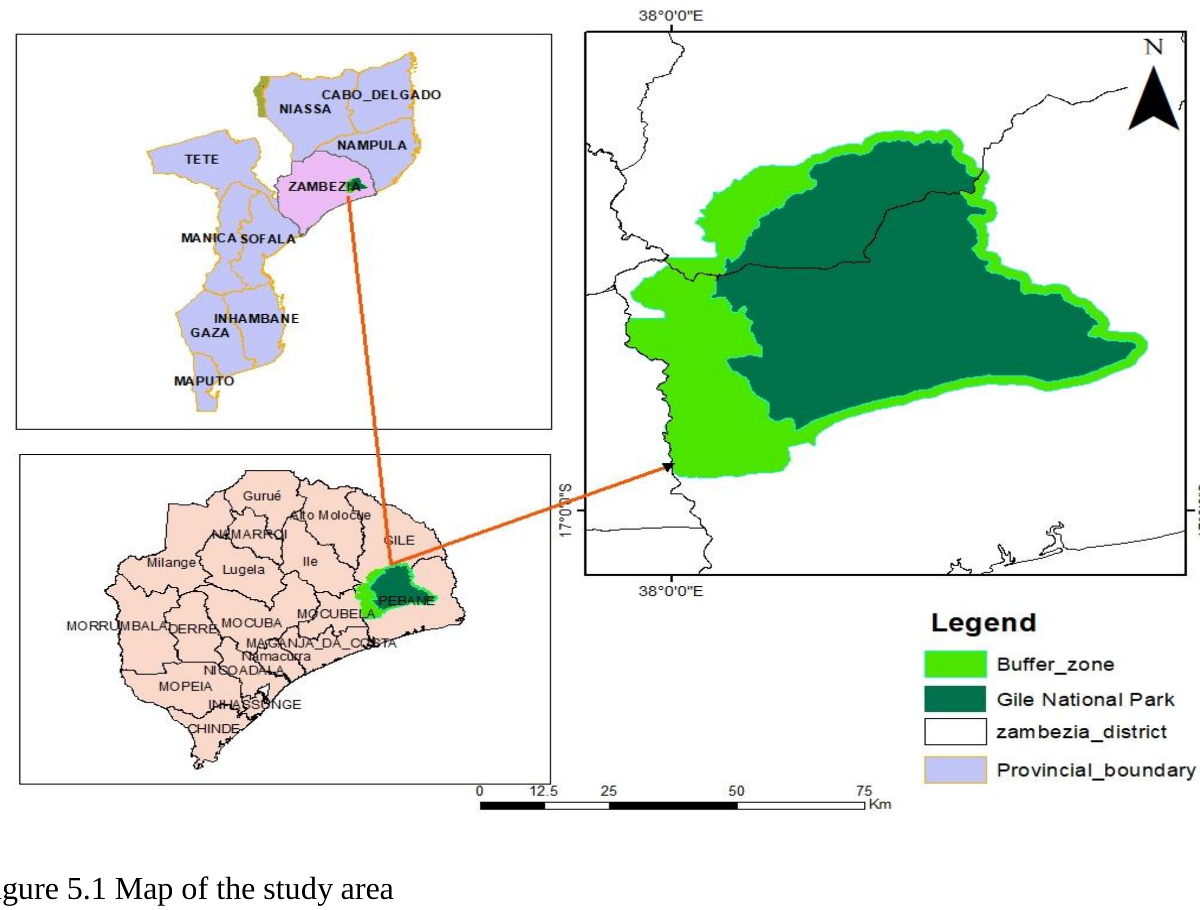

Figure 5.1 Map of the study area

5.3.2. Study Design and Data Collection Methods

5.3.2.1. Remote Sensing Data

Landsat TM (Thematic Mapper) and Landsat 8 OLI (Operational Land Imager) imagery with a 30-m spatial resolution for the years of 1999, 2009, and 2019 were downloaded from United States Geological Survey (USGS), archive at https://ers.cr.usgs.gov/ and used (Table 5.1). To minimize the effects of seasonal variations in vegetation patterns throughout a year, the image selection was made for the same season for all years. Landsat 5 images was used for 1999 and 2009 whereas Landsat 8 was used for 2019 for evaluating LULCC. The images were geo-referenced for WGS 84/UTM zone 37S, and the general images processing were shown (Figure 5.2).

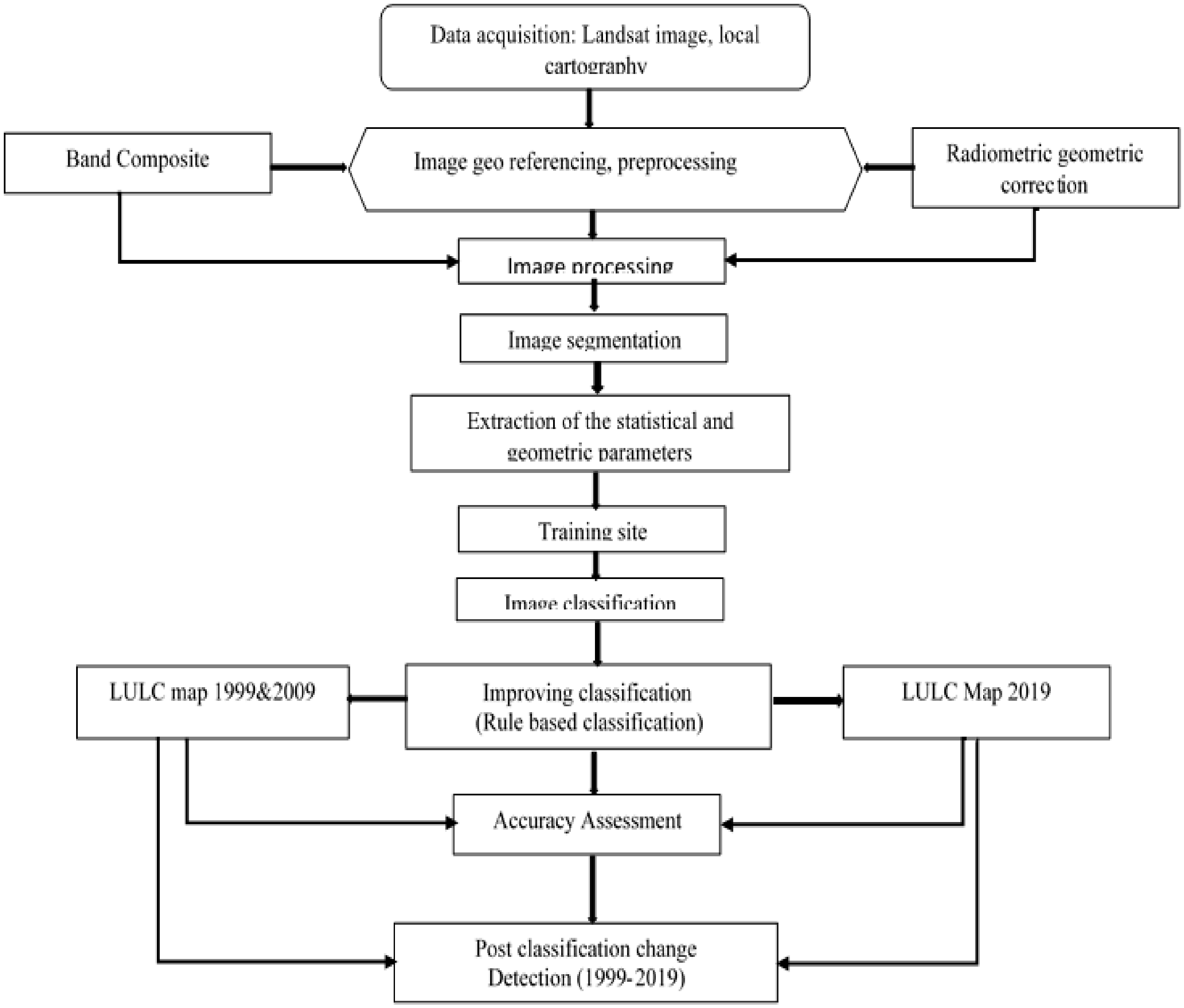

Figure 5.2. Flowchart of land use land cover/change detection.

Table 5.1 Landsat's scenes, sources, and specifications used in this study (Path/row =165/071, 165/072 for all image

No	Acquisition Date	Satellite Image	Sensor	Spatial Resolution	Used Bands	Sources
1.	January 1999	Landsat TM	TM	30	1-5,7	USGS
2.	November 2009	Landsat TM	TM	30	1-5,7	USGS
3.	October 2019	Landsat8 OLI	OLI-TIRs	30	1-7,9	USGS

TM: Thematic Mapper; OLI-TIRs: Operational Land Imager and Thermal Infrared Sensor).

Based on Mozambique forest classification system, National Directorate of Geography and Cadastre (DINAGECA) 1998 and GNAP land use management plan, the study area was categorized in to six land use land cover (Table 5.2). All land use classes of interest were selected and defined carefully to classify remotely sensed data into the intended land use and land cover categories.

Table 5. 2 Land Use/Land Cover (LULC) classes used and their descriptions.

No	LULC Classes	General Description
1.	Dense Miombo woodlands	Part of the Mozambican forest category of Semi-Deciduous Forests with a canopy cover above 50%. Usually correspond to an undisturbed state of Miombo (Ribeiro et al., 2020).The classic Miombo trees *Brachystegia*, *Julbernardia*, and *Isoberlinia* dominate the woodlands
2.	Open Miombo woodland	Part of the Mozambican forest category of semi-deciduous forests with a canopy cover between 30-50% (Ribeiro et al., 2020). The classic miombo trees *Brachystegia*, *Julbernardia*, and *Isoberlinia* dominate the woodlands with other tree species such as *Pterocapus angolensis, Albizia sp*. and *Afzelia quanzensis*.
3.	Shrub land	Refers to stands of broad-leafed (semi)-evergreen or (semi)-deciduous shrubs (height < 5 m) with canopy cover less than 40%. Emergent trees may occasionally occur(FAO, 2010a)
4.	Agricultural land	Areas used for crop cultivation (both annual and perennial), fallow plots, scattered rural settlements, some pastures and plantations around settlements. Sparsely located settlements and roads constructed from earthwork were included here as it was difficult to separate them from agricultural lands.
5.	Water Bodies	All natural water bodies (rivers, inland water, etc.).
6.	others	Rocks, bare soils and all land use not considered in the above class

5.3.2.2. Socio-Economic Data

Socio-economic survey was used to collect data from local community about local resources, resources use and causes of LULCC. Household interview, key informant interview (KII) and focus group discussion (FGD) were used (Dibaba et al.,2020 and Miegel , 2020).

There is about 40 communities in the buffer zone of GNAP of which 10 communities were randomly selected for formal interviews as there was no major differences among community in their activities. Households' sample frame was established by collecting complete list of HH head record from their respective administrative post office. The sample frame were all household heads living in the identified community and finally the selections of sample households was proportional to each community. Accordingly, the total numbers of household living in selected community for target area was 700. After getting the total number of household heads living in each selected community, a total of 200 respondents which was about 28% of the selected household were chosen using simple random sampling techniques from the total household (Cochran, 1977). Allocations of the number of sample households to each community was proportional to the number of household head living in each community.

Based on community's settlement and proximity of their locations to national park, four communities from each direction of the national park (North, South, West and East) at the buffer zone were selected for FGD. These community cover district of Pebane and Gile (Figure 5.1). A total of four FGDs, one in each community were carried out. Each FGDs comprises eight to ten participants drawn from the members of the community. Members of FGD were selected with the help of community leaders, knowledgeable person about their background and expert from the National Park. Twelve KIIs were held with district level and National Park experts of forest and land use administration. During KIIs and FGDs, open-ended questions having information about status of LULCC in the buffer zone, driving cause of LULCC, the relationship among the biophysical environment, institution, socio-economic activities and demography were used. The main focuses were to get enough information about the past and present trend of LULCC and identify driving cause of the changes.

To better understand the major observed problems of the study area and resource use and management practices, field walks and informal talks with people in their farms/fields were used. Farmers were asked to explain which area of the buffer zone were changed and explained why the change had occurred. They were also asked to explain how their socio-economic activity contributes to the land-use land cover change. Field observation was carried out based on checklists designed in advance to observe the situation in the buffer zone, and photographs of important sites were taken to enrich the study.

5.3.3. Data Analysis

5.3.3.1. Remote Sensing Data Analysis

The analysis and quantification of the spatio-temporal dynamics of the LULCC from 1999 to 2019 were achieved through Landsat image pre- processing, classification, and post-processing. The general procedure in the pre-processing stage has include compositing, mosaicking (masking), the detection and restoration of bad lines, geometric rectification, radiometric calibration, atmospheric topographic correction using ArcGIS 10.1 and QGIS 2.8.1 (Tewabe & Fentahun, 2020). Compositing refers to the process of combining spatially overlapping images into a single image based on an aggregation function whereas masking refers to the process of spatially assembling image datasets to produce a spatially continuous image. Six spectral bands of TM (band 1–5 and 7) and eight spectral bands of Landsat 8 OLI (bands 1–7 and 9) were used for image processing.

Supervised classification method using maximum likelihood classifier was used to classify each pixel based on the known ground objects using ArcGIS 10.1 (Dibaba et al., 2020; Tewabe & Fentahun, 2020; Yirsaw et al., 2017). Maximum likelihood algorithm (MLC) is one of the most popular supervised classification methods used with remote sensing image data (Rawat & Kumar, 2015). The procedures used for image classification was as follows. The primary step was selecting training sites (ERDAS Inc., 2005). Polygon sampling method was used to sample the training sites from the processed images as it allowed the drawing of polygons for a particular spectral class. Different combinations of bands, image enhancement and color compositions were used to discriminate and interpret the surface features of the images during the process. Band combinations were selected based on the applicability of each band as each band have a set of a data file for a specific portion of the electromagnetic spectrum in identifying the features of the study. The extracted signatures from the samples were evaluated using the histogram technique, and different trials were taken until unimodal distribution was achieved. Then after, signatures of the same class were merged by selecting all the signatures of each class. The supervised classification used the merged signature for the land cover map production (Dibaba et al.,2020; Tewabe & Fentahun, 2020). The training data set were used for generating class signatures and for classification of the whole image into meaningful information classes.

With regard to land use/land cover change analysis, once the land cover classifications were derived, ArcGIS 10.1 was used to prepare the land use land cover maps of 1999, 2009 and 2019 (Feyera Senbeta, 2018). Then, the areas of the land use land cover (LULC) classes were calculated from the maps, and analysis of LULCC and rates of changes were computed using Equ 5.1 and 5.2. Total LULCC between the three periods (1999, 2009 and 2019) were calculated as follows (Dibaba et al., 2020).

Total LULC Gain/loss = Area of the final year - Area of the initial year.…………………….... (5.1)

Percentage of LULC Gain/loss = $\frac{(\text{Area of the final year} - \text{Area of the initial year})}{\text{Total area of the study area}}$…..……….……….….... (5.2)

LULCC matrix was developed by ArcGIS 10.1 to analyze the LULCC inter-category transitions and examined the buffer zone experience in LULCC transitions. The matrix was developed for the 1999–2009 and 2009–2019 transitions. Through the matrix, the area of gains, losses and persistence between the land use land cover types was calculated.

Accuracy assessment

An error matrix was created for accuracy assessment to measure the quality of the information derived from remotely sensed data. It was performed by comparing the results created by remote sensing analysis to a reference / ground truth data for selected sample points (Foody, 2002) . About 240 random points were generated to yield random x, y coordinates within the study area using ArcGIS 10.1 and the random points were converted to KML and exported to Google Earth to provide detailed assessment of the agreement between the classified results and reference data, with the information of how the misclassification happened (Feyera Senbeta, 2018). For accuracy valuation, overall classification accuracy and Kappa coefficient were calculated from the error matrix (Afify, 2011; Islam et al., 2018).

Overall classification accuracy was computed as the total number of correctly classified pixels divided by the total number of sample points. Kappa coefficient is a measure of overall statistical agreement of an error matrix, which takes non-diagonal elements into account. Kappa analysis is recognized as a powerful method for evaluating a single error matrix for it indicates the probability of correct classification after removing the probability of accidentally correct classification. Normally Kappa coefficients lie between 0 and 1, on the other hand kappa value characteristics of values from 0.4-0.60,0.61-0.80 and 0.81-0.99 denote moderate, substantial and strong agreement respectively whereas value below 0.4 represents poor agreement (Viera & Garrett, 2005).

5.3.3.2. Socio-Economic Data Analysis

Descriptive statistics of simple frequency analyses were used using SPSS (version 25) to describe ranking response of respondents on cause of the land use/land cover changes. Data collected through FGD and KII were analyzed qualitatively. Qualitative data analysis involved both thematic and content analysis based on how the results related to the research questions. Content analysis was used to edit qualitative data and reorganize it into meaningful shorter sentences. Thematic analysis was used to organize data into themes and codes were identified. After data collection, information of same category by giving emphasis for the past and current situations of LULCC and its causes were assembled and their similarity with the quantitative data created after which a report was written.

5.4. Results

5.4.1. Land Use Land Cover Change

Land use land cover classification for the years1999, 2009 and 2019 are shown in Figure 5.3. Dense Miombo woodlands are mainly found in the western and southern part of the park, while Agricultural land are found in the North East, North West and South Eastern part of the Park. Shrub land were more covers eastern part of the area. Waterbodies are found in the south western part of the site.

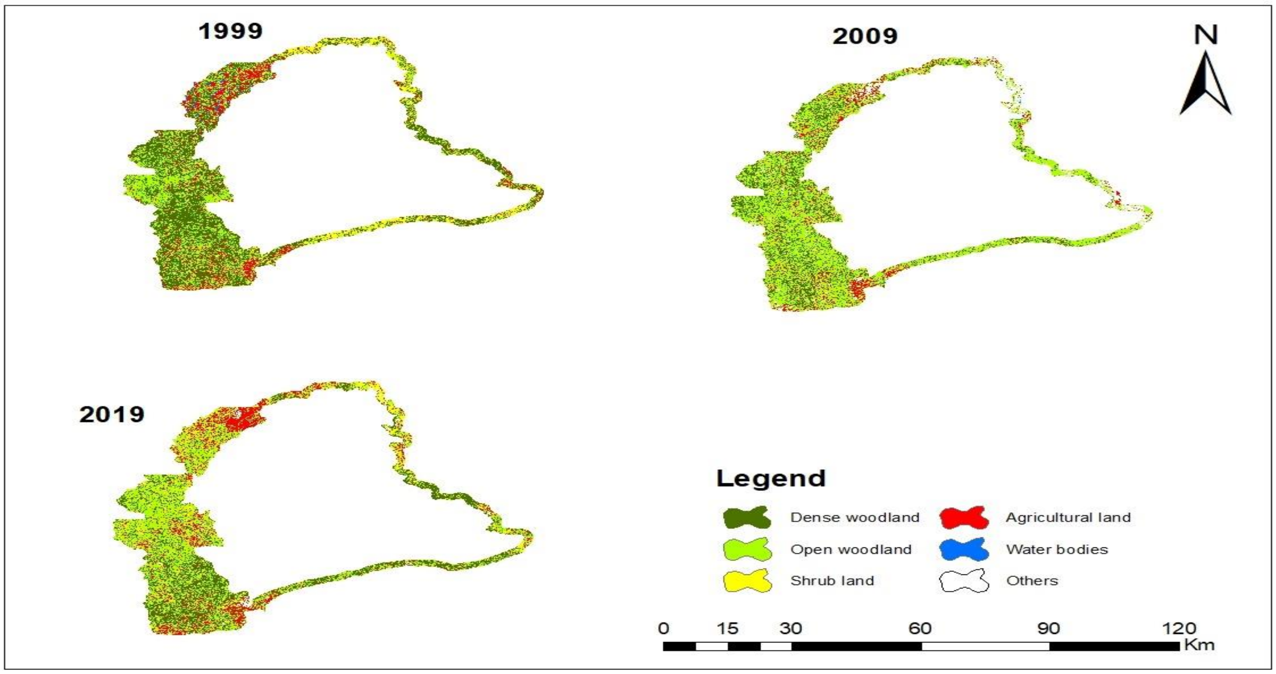

Figure 5.3 Land use land cover map of GNAP Buffer zone in 1999, 2009 and 2019

Accuracy assessment

The confusion error matrix and Kappa statistics used for classification accuracy of 1999, 2009 and 2019 LULCC are presented in table 5.3. The overall accuracy for 1999, 2009 and 2019 were 90%, 90%, and 91% respectively. The Kappa statistics were 0.87, 0.88, and 0.89 for 1999, 2009 and 2019 respectively. Kappa statistics showed a strong agreement between classification result and reference values of land use land cover location. The recommended accuracies for the classification should be ≥85% (Kamusoko & Aniya, 2007).

Table 5.3 Accuracy of land use/land cover maps for 1999, 2009, and 2019.

Years	LULC	DMWL	OMWL	SL	AL	WB	OT	Actual Sum	UA (%)	K
1999	DMWL	**53**	1	2	1	1	1	59	90	0.87
	OMWL	2	**42**	1	1	1	0	47	89	
	SL	0	2	**34**	1	1	0	38	89	
	AL	1	1	0	**31**	0	1	34	91	
	WB	0	1	1	0	**30**	2	34	88	
	OT	1	1	0	1	0	**25**	28	89	
	Actual sum	57	48	38	35	33	29	240		
	PA (%)	93	88	89	89	91	86			
Years	LULC	DMWL	OMWL	SL	AL	WB	OT	Actual sum	UA (%)	K
2009	DMWL	**52**	2	2	1	0	0	57	91	0.88
	OMWL	2	**46**	1	0	1	1	51	90	
	SL	1	0	**36**	0	2	1	40	90	
	AL	1	2	0	**34**	1	0	38	89	
	WB	0	1	0	2	**25**	1	29	86	
	OT	0	0	1	1	0	**23**	25	92	
	Actual sum	56	51	40	38	29	26	240		
	PA (%)	93	90	90	89	86	88			
Years	LULC	DMWL	OMWL	SL	AL	WB	OT	Actual sum	UA (%)	K
2019	DMWL	**48**	2	0	1	1	1	53	91	0.89
	OMWL	0	**45**	1	1	0	2	49	92	
	SL	1	0	**32**	1	0	0	34	94	
	AL	0	0	2	**36**	0	1	39	92	
	WB	1	1	0	1	**26**	1	30	87	
	OT	1	2	0	0	1	**31**	35	89	
	Actual sum	51	50	35	40	28	36	240		
	PA (%)	94	90	91	90	93	86			

DMWL—Dense Miombo Woodland, OMWL—Open Miombo Woodland, SL—Shrub Land, AL—Agricultural Land, WB—Water Body, OT—Others, UA—User’s Accuracy, PA—Producer’s Accuracy, K—Kappa Statistics.

Land uses land-cover Inter-Category Transitions and Changes Trajectories

Land use and land cover classification of GNAP buffer zone from 1999 to 2019 are summarized in table 5.4 and graphically the distribution of LULCC for the 20 years is shown in

Figure 5.4. The areas are arranged by year and land use categories as of 1999, 2009 and 2019. Dense Miombo woodland and open Miombo woodland are the most dominant land cover classes, covering 66,555.99 and 44,190.09 ha in 1999 respectively, which represents about 43.61 and 28.95% of the total land use. In the same year area coverage of agricultural land was 19,517.13ha which was about 12.79 % of the total land cover.

Table 5.4 Land use land class area coverage, status and changes between 1999, 2009 and 2019 in ha and percent

LULC class	Area						Change (Gain/Loss)					
	1999		2009		2019		1999-2009		2009-2019		1999-2019	
	ha	%	Ha	%	ha	%	ha	%	ha	%	ha	%
DMWL	66555.99	43.61	35665.83	23.37	43897.86	28.76	-30890.16	-20.24	8232.03	5.39	-22658.1	-14.85
OMWL	44190.09	28.95	83032.74	54.40	62700.12	41.08	38842.65	25.45	-44190.09	-28.95	18510.03	12.13
SL	17438.67	11.43	4487.67	2.94	18493.92	12.12	-12951.00	-8.49	14006.25	9.18	1055.25	0.69
AL	19517.13	12.79	14681.61	9.62	23385.42	15.32	-4835.52	-3.17	8703.81	5.70	3868.29	2.53
WB	3295.44	2.16	410.31	0.27	237.6	0.16	-2885.13	-1.89	-172.71	-0.11	-3057.84	-2.00
OT	1633.32	1.07	14352.48	9.40	3915.72	2.57	12719.16	8.33	-10436.76	-6.84	2282.4	1.50
Total	152630.64	100	152630.64	100	152630.64	100						

DMWL—Dense Miombo Woodland, OMWL—Open Miombo Woodland, SL—Shrub Land, AL—Agricultural Land, WB—Water Body, OT—Others, Negative (-) indicates extreme loss

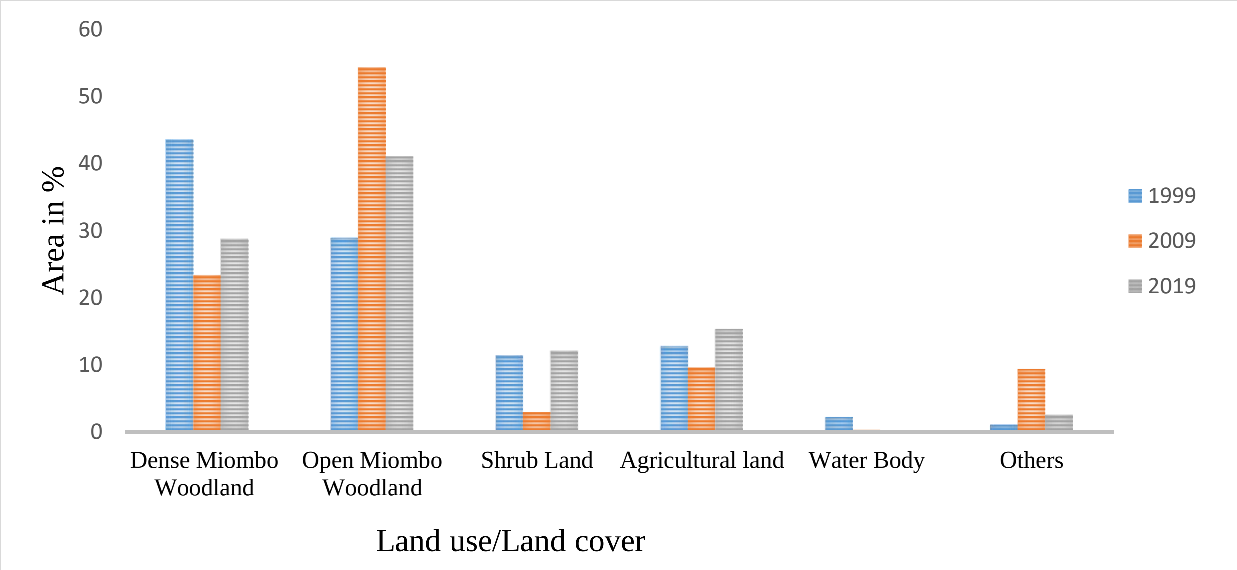

Figure 5.4 Land use /land cover distribution at GNAP buffer zone

A change matrix between 1999 and 2019 were produced by post-classification comparison from the classification results, which yield "from-to" change information identifying where, and how much, change has occurred (Appendix 2). Of the total land use land cover about 34.57 and 40.86 % of land covers remained unchanged from 1999 to 2009 and 2009 to 2019 respectively, as the values reported along the diagonal written in bold express the unchanged area or persistence and shown on figure 5.5.

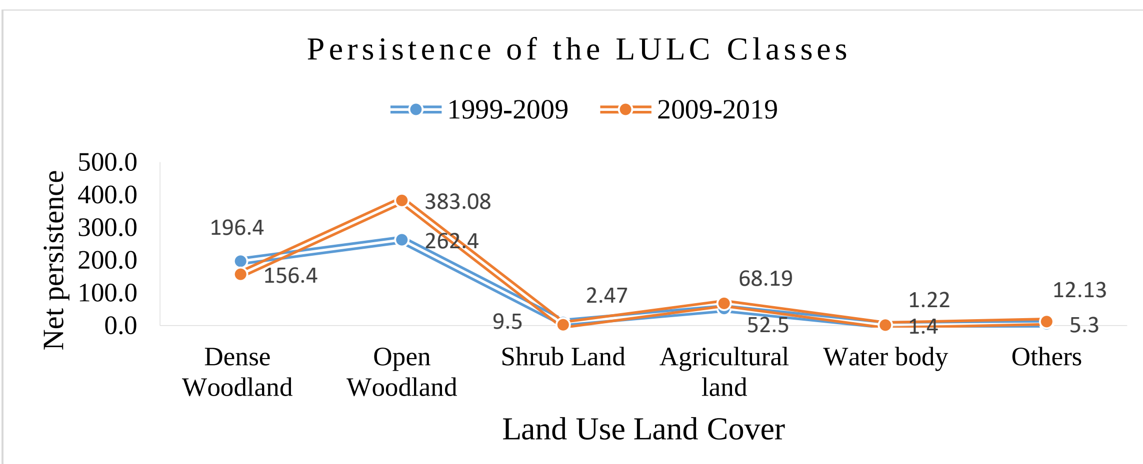

Figure 5.5 Persistence (Unchanged) land use land cover classes

Regarding net persistence, the ratio of the net change (gain–loss) to diagonals of each class, water bodies have shown the highest net change to persistence ratio during the study period (1999-

2019). The highest net change to persistence ratio implies the lowest persisting class of the land use land cover, so in this regard the lowest persisting land use land cover class in the buffer zone of GNAP was registered in water body followed by shrub land. From 2009-2019 dense Miombo woodland and open Miombo woodland showed the highest persisting land use land cover class (Appendix 2).

Forest (Miombo woodland) Loss

Miombo woodland loss and its deforestation rate in the buffer zone of GNAP from 1999 to 2019 at three- decade intervals showed an increment. In 1999, forested land (dense Miombo woodland, open Miombo woodland and shrub land) were estimated as128, 184.75ha which was about 83.98 % of total area on GNAP buffer zone. Since then, the dense Miombo woodland has decreased by 30,890.16 ha between 1999 and 2009, which means that 20.24 % of 1999 dense Miombo woodland has changed to other land uses, and it was decreased by 8,232.03ha from 2009 to 2019, which means that 5.39 % of 2009 dense Miombo woodland has changed to other land uses within ten years. Within 20 years or the study period dense Miombo woodland was decreased by 22,658.1 ha, which tell us that 14.85 % of 1999 dense Miombo woodland has been changed to other land uses. The rate of forest loss (Miombo woodlands) for the entire study period (1999-2019) was 1,237.14ha/yr.

The highest annual rate of deforestation (4.05%) recorded from 1999 to 2009. Agricultural land expanded at the buffer zone of GNAP from 1999 to 2019 by 3868.29 ha representing 16 % of 1999 agricultural land cover and this expansion was from clearing forest land (Table 5.5). In the buffer zone of GNAP, major tracts of land have been cleared in the last decade due to slash-and-burn agriculture and significant population growth. Much of this forest has been dense and open Miombo wood lands (Berton et al., 2013; Mondal et al., 2016) . Small frontier farmers living on the edge of forests drive much of the developing world's deforestation by cutting down forests for expanding agricultural land and settlement (FAO, 2010b; Hartter & Southworth, 2009) . Most land conversion from natural states to human uses is happening in the developing world, where population growth is most prevalent. The case of GNAP buffer zone also verifies this situation. Data about agricultural land size during 1999, 2009 and 2019 is described in (appendix 3).

4.4.2. Cause of Land Use Land Cover Change

Totally five causes LULCC were identified and reported by the respondents (N = 200) in the study area. However, there were variations about each causes to which the local people viewed as cause for the LULCC. In particular, almost all respondents reported all the listed causes play their own role for the problem of LULCC to be happen, however they ranked looking for fertile Agricultural land and new settlement as the first and second main cause of LULCC respectively (Table 5.5). The population of the Mozambique has increased from17, 244,188 in 1999 to 29,496,004 in 2019. Indicating an increase of 41.54 % during the period (1999 to 2019). A similar trend has also been observed in the area cover of agricultural land were expanded from area that existed in 1999 (appendix 3).

Table 5.5 Cause of LULCC ranking in order of influence with 1 being the most influential cause

Cause of LULCC	Numbers	Mean	Std.Dev	Rank
Looking for Fertile Agricultural Land	195	1.06	0.426	1
Settlement	180	3.00	0.413	2
Fire	166	3.08	0.533	3
Awareness Gap	117	3.15	1.430	4
Illegal Logging	115	3.80	1.451	5

The results of FGDs, KIIs, and field observation showed that anthropogenic activities were the predominant and immediate causes of LULCC in the study area. From a range of different causes, respondents perceived five human-related activities as major cause of LULCC (Table 5.6). The ranks are derived based on how the variables were selected frequently by the respondents.

Responses from KIIs and FGDs showed that slash and burn agriculture, settlement and forest concessions were among the major socio-economic and institutional causes of LULCC. Community in the area were based on slash and burn agriculture system to produce crops. Following population growth, new settlement was created in many areas of the buffer zone. According to KIIs and FGDs concession holders around GNAP were posing a serious pressure on buffer zone forest cover, hence they already finished theirs, they get log and wood from GNAP buffer zone. This can be directly a main cause for LULCC and also by favoring conditions for farmers to open new farm land following forest degradation caused can indirectly cause of LULCC in the study area.

Table 5.6 Cause of LULCC Ranking based on Response of KIIs and FGDs

Cause Of LULCC	Percent %	Rank
Slash and Burn Agriculture	42.5	1
Settlement	25	2
Forest Concession	15	3
Weak Environmental Considerations	10	4
Fire	7.5	5

Group discussions with the community and Key informants on how slash and burn agriculture, the forest concession (timber and wood products) and settlements caused LULCC were summarized as follows:

Group member's mentioned that the only way community gets access to agricultural land when the needs to expand and want to have new land is through slash and burn agriculture. They said that young farmers who grew in the area also get access of land by clearing forest land. This all poses pressure on forest land and responsible for LULCC in the area.

Previously Concession holders surrounding the buffer zone were used their wood for timber production, but after certain year they already finished theirs and started to do illegal logging in the buffer zone, Then, those who have got chance to sell log to them also started doing illegal logging, meanwhile attract peoples of the area to expand such activity and create competition among concession holders to log the wood illegally, and finally it created LULCC.

Regarding settlement, "they said that free areas which have been created due to illegal logging attracted people to settle there as a new settlement for looking new agricultural land. About weak environmental considerations, they said that, there was shortage of awareness creation about conservation of forest and sustainable use of the forest, there is no attempt from the side of government to encourage the community's participation on plantation forest. They said that fire is the least cause as compared to the other causes, because the impact of fire was mostly happened following the happening of the other causes".

5.5. Discussions

Land use land cover analysis of GNAP buffer zone over 20 years (1999–2019) revealed a dramatic change (Figure 5.3 and Table 5.4). Dense Miombo woodland are continuously decreasing, with the highest rate in recent years. In1999 dense Miombo woodland coverage of the area was relatively in good position as compared to its coverage of 2019 which showed decrement by 14.85 %. But open Miombo woodland and shrub land showed increment in size from its coverage from 1999 to 2019 by 12.13% and 0.69 % respectively. Open Miombo woodland is a transition state between dense Miombo woodland and the other land use class like agricultural land and shrub land, and the reverse is also true (from agriculture and other land use type to dense Miombo woodland) that is why the area coverage for this land use class showed increment. Classifying shrub land as a distinct subclass in this study is based upon the local context of land use changes. Food and Agriculture Organization (FAO) guidelines generalize land cover to forest, other wooded land, and other land uses in monitoring the world's forests through the Forest Resources Assessment Program (FAO, 2011). Here, shrub land is categorized as a sub-class of other wooded land, which refers to land not classified as "forest" an area that has only a sparse tree.

Area covered by water bodies in the study area shows decrement from its position of 1999. Its area coverage in 1999 represents 2.16 percent of the total land use class of the area, however by 2019 within 20 years it decreased to 0.16 % of total land use class of the area (buffer zone). Other land use types which include settlements, bare areas, rocky substance and roads according to this study increased from its coverage within 20 years by 2.57 %. The result showed that most of the conversion during this period were from dense Miombo woodland to open Miombo woodland, others land use class and agricultural land proportionally. This kind of scenario is the likely implication of slash and burn agriculture and logging of large trees from the dense and open Miombo woodland for livelihood demands by community and concession holders. It was also confirmed during the FGDs that Slash and burn agriculture was a tradition of the native peoples and now a day there is serious competition on illegal logging between concession holders and community in the study area.

The temporal rate and spatial extent of forest loss were largely affected by expansion of agricultural land, population increment and climate change (Crouzeilles & Curran, 2016). In general, areas of high population growth have experienced high forest loss over the years (FAO, 2010a) . Population growth has increased demand for agricultural land and firewood energy, and rural poverty restricts the ability to invest in sustainable land use practices. Population of Mozambique increased by 32.77% from 1999 to 2009 and by 28.83 % from 2009 to 2018 (FAO, 2010a).That is why growth of population exerted high pressure on the forest resources in order to derive people's livelihoods, higher population makes land for settlement and agriculture inadequate and consequently resort to the forest land. The need of agricultural land expansion following population growth and climate change problem, forces community for looking new agricultural land which they directly/indirectly accessed by clearing forest. Increased agricultural land to forest land without proper management practices potentially have increased the vulnerability of the land to erosion and sedimentation in water bodies which plays significant role in LULCC to be happen.

The present study has also shown that continued new settlements, expansion of agricultural land illegal logging by forest concession holders, and shortage of information about natural resource management has accelerated LULCC in the study area. These situation (illegal logging by concession holders and illegal loggers who sale to concession holders) forced community to compete on the left over forest instead of conserving. Similarly, population growth and demand for agricultural land expansion were associated with biophysical degradations like soil productivity, water, and environment. Equally important to the environmental problem, socio-economic and institutional problems were also posed a significant impact on the Miombo woodland's sustainability in buffer zone of the park and generally the adverse impacts of LULCC were associated with the underlying factors related to human activities. Cause of LULCC related to slash and burn agriculture in the study area is linked to looking for fertile and productive land according to response from the households. It also linked with absence of alternative source of income and luck of awareness on diversification of source of income and in the study area.

The study area was once in good position of forest cover (Mercier et al., 2016a) and described by the FGDs and key informants as shown in LULC maps. Studies conducted in Rwanda by Akinyemi, (2017) confirm that resources exploitation, agriculture, population growth, built-up, are considered as main carriers landscape change in north-western Rwanda. The result of this finding was also in agreement with (Mucova et al., 2018a) who showed that vegetation reduced by about 41.67%, in Quirimbas National Park, Northern Mozambique due to population growth and agricultural expansion. It also in agreement with Grinand *et al*. (Grinand et al., 2019) who found that currently, the periphery and the buffer zone of the Gile national reserve are subject to strong and growing anthropogenic pressures, due mainly to a significant demographic growth, and to slash-and-burn agriculture practices. Similar impacts of investment activities on forest (concession holders)on land use land cover change were reported in Ethiopia (Betru et al., 2019).

5.6. CONCLUSIONS

As revealed in the present study, LULCC severely threatened Miombo woodland in the study area. The quantitative spatio-temporal evidence obtained through interpretations of satellite images shows that Buffer zone of GNAP has undergone significant LULCC since 1999. Between 1999 and 2019, the spatial distribution of LULCC shows a continuous expansion of agriculture and a reduction of Miombo woodland and water bodies. The transition matrix developed to assess inter-category transitions and the change trajectories highlight the dominant dynamic events and internal conversions between LULC classes. Most of the change takes place in this study area were from dense Miombo woodland to open Miombo woodland and finally to the other identified land use class like agricultural land, shrub land and other land use type (settlement, bare land). Uncontrolled expansion of agricultural land and unsustainable exploitation of woodland due to population growth as well as presence of forest concession holders in the area were indeed the major causes of LULCC in the study area. The adverse impacts of LULCC were associated with the underlying factors related to human activities. Luck of awareness creation together with settlement and earning income from illegal logging have reduced forest land. To reverse these challenges, there must be broad-scale restoration projects around the area supported by awareness creation and incentive mechanisms to conserve forests for forest users.

CHAPTER 6. REGENERATION AND RESTORATION STATUS OF MIOMBO WOODLAND FOLLOWING LAND USE LAND COVER CHANGES AT THE BUFFER ZONE OF GILE NATIONAL PARK'S CENTRAL MOZAMBIQUE.

This Chapter is based on a slightly modified version and published article

Ameja, L. G., Ribeiro, N., Sitoe, A. A., & Guillot, B. (2022). Regeneration and Restoration Status of Miombo Woodland Following Land Use Land Cover Changes at the Buffer Zone of Gile National Park, Central Mozambique. Trees, Forests and People, 9, 100290. https://doi.org/https://doi.org/10.1016/j.tfp.2022.100290.

6.0. Abstract

In the context of the current intensified disturbances of Miombo woodland, its regenerating capacity is fundamental to endure such disturbances. Miombo woodland in the buffer zone of Gile National Park (GNAP) is facing land cover change. This study aimed to assess regeneration structure, the status of restoration, and factors affecting the regeneration of Miombo woodland in the buffer zone of GNAP. In total, 12 transects, 48 plots, and 240 subplots were sampled in dense Miombo woodland (DMWL), open Miombo woodland (OMWL), and abandoned agricultural land (AAL) to collect data. Household interviews, focus group discussions (FGD), and key informant interviews(KIIs) were used to collect socio-economic data. Descriptive statistics, Kruskal-Wallis, chisquare, and regression, were used to analyze data. A total of 1863 matured woody individuals representing 85 species and 29 families were identified. Matured woody species density was significantly different between AAL&DMWL and DMWL & OMWL. However, there was no significant difference between OMWL and AAL. Nine hundred three regenerated individuals representing 70 species and 23 families were registered. Regeneration density was significantly different between land-use types. The mean regeneration density in DMWL, AAL, and OMWL were 39.87±13.82, 50.25±21.1, and 23 ± 9.98 stems ha− 1, respectively. The most regenerated family was Fabaceae. All respondents reported that no assisted restoration activity was/is taking place in the area. The five most important factors affecting the regeneration of Miombo woodland were identified. Slash and burn agriculture and animal grazing were ranked first and last, respectively. Increasing pressure for land demand is determining factor for Miombo woodland regeneration. The buffer zone of GNAP is characterized by a moderate diversity of woody species, with the number of regenerated woody species increasing in AAL. Our findings suggest the importance of diversifying sources of income, creating a market value chain for their product, and strengthening collaboration between the park and the community surrounding the park could reduce the dependence of the community on slash and burn agriculture as well as safeguard the park from degradation and at the same time maintain the livelihood of the community.

Key words: Regeneration density, Land use type, Fabaceae, disturbance factors

6.1. Introduction

The term "Miombo" is a colloquial term describing the vegetation unit dominated by *Brachystegia, Julbernadia,* and *Isoberlinia,* three closely related genera from the legume family Fabaceae (Gumbo et al., 2018; Williams et al., 2008). The floristic species richness of Miombo woodland is estimated at 8,500 species, of which 54% are endemic (Assédé et al., 2020). Miombo woodland regions are characterized by significant climatic and environmental gradients, ranging from dry to wet Miombo (Ribeiro et al., 2020). It is an extended tropical seasonal woodland, savanna and dry forest (Chiteculo & Surovy, 2018; Pienaar et al., 2015; Tarimo et al., 2015), and constitute the largest savanna area in the world (Gumbo et al., 2018; Ryan & Williams, 2011) covering about 10% of the African landmass (Malmer, 2007).

Miombo stretches from the northernmost tip of South Africa up to Tanzania, and from Mozambique in the east to Angola in the west (Njoghomi et al., 2020). It supports the livelihoods of more than 100 million rural and urban dwellers (Chirwa, 2014; Gumbo et al., 2018). For example this woodland is about 76% source of energy (Ryan et al., 2016b) ; source of Timber products and food (Fa et al., 2015; Ribeiro et al.,2019), carbon storage and sequestration (Grace et al., 2006), biodiversity habitats (Bond et al., 2010), and organic matter, which forms a large below ground pool of carbon (Walker & Desanker, 2004) in the region.

Regeneration refers to the process by which mature individuals of a plant population are replaced by new individuals of the next generation (Larson & Funk, 2016).To ensure the successive existence of tree species within different generations, regeneration is very important and a fundamental process which drives forest dynamics (Feldmann et al., 2020; Larson & Funk, 2016; Parveen et al., 2010). Miombo trees have the ability to regenerate naturally after disturbance (Afrifa *et al*., 2016), its regeneration is much stimulated by the presence of open patches created by disturbances and death or felling of mature trees (Mwansa, 2018). Regenerating capacity of Miombo ecosystem is a key to its productivity and ability to survive both natural and anthropogenic disturbances (Sangeda & Maleko, 2018 ; Chidumayo & Gumbo, 2013).

6.2. Statement of the Problem

Miombo woodland losses have been observed to varying degrees of intensity at landscape level, largely driven by land clearing for agriculture and wood extraction for energy (Campbell et al., 2007). LULCC following D&D in Miombo woodland ecoregion is increasing (Matowo et al., 2019). Regenerating forests on former degraded land can provide solutions for conservation of biodiversity, mitigation of, and adaptation to, climate change, and multiple ecosystem goods and services (Chazdon et al., 2020; Matos et al., 2020). The sustainability of the seriously threatened African Miombo woodlands depends on their capability to maintain sufficient natural regeneration (Njoghomi et al., 2020).

Knowledge of status of tree regeneration is essential for understanding the structural and compositional changes which can account for ecological stability and resilience in Miombo woodlands (Mapaure & Moe, 2009) . Tree regeneration is one of the key components of sustainability in all forest management regimes, and knowledge on regeneration is essential for understanding the structural and compositional changes which can account for ecological stability and resilience in Miombo woodlands (Mapaure & Moe, 2009). Although sustainability of Miombo stand depends on the regeneration potential, stand structure and species composition, knowledge on the regeneration dynamics of Miombo forests is quite insufficient in most cases (Njoghomi et al., 2020).

Miombo woodland is threatened by direct and indirect human activities including conversion into agricultural land, charcoal production, overgrazing and fire (Assédé et al., 2020). It is important to consider that Miombo is a resilient ecosystem and thus can return to its original state in 15-20 years after disturbances are removed (Ribeiro et al., 2020). The survival of regeneration of individual of Miombo has ability to influence plant population and community dynamic (Larson & Funk, 2016). Regeneration as a survival strategy of individuals after disturbance (Syampungani et al., 2017) is an important plant functional trait in many ecosystems (Johnstone et al., 2016). Despite their importance for biodiversity and for the livelihoods of millions of inhabitants, Miombo woodland has received little attention from the scientific community (Siyum, 2020).

Around 40 million people lived in areas covered by, or once covered by, Miombo woodland, with another 15 million urban inhabitants in Africa relying on Miombo as a source of energy (Chidumayo, 1996; Mehl et al., 2010). Rural communities depend on Miombo woodland for income and consumption (Dewees et al., 2010). Despite its significance, this woodland is frequently disturbed by fires and land clearing (Williams et al., 2008). Mambo's dynamics are primarily influenced by social, cultural, economic, and ecological forces (Zolho, 2005). Several studies in the Miombo region show that fires every 3 to 4 years are vital for sustaining structural and compositional aspects of this ecosystem. However, climate change and human population development may impact (Ribeiro et al., 2020).

In Mozambique, forest covers about 40 % of country land, and 33.7 % corresponds to semi-deciduous forests, of which the majority is Miombo (DINAF, 2018). Given the fast land use and land cover changes in the last 10-20 years in Mozambique, Miombo has been substantially intervened by human activities (Ribeiro et al., 2020) and is considered vulnerable to climate change impacts (Ribeiro et al., 2015). Institutional factors such as weak enforcement of rules and regulations also contribute to Mozambique's forest cover change (Sitoe et al., 2012). Although GNAP is the only protected area in Mozambique with no permanent settlements in its core area and represents one of the largest areas of uninterrupted Miombo woodland in the northern part of the country (Mercier et al.,2016), the degradation of Miombo forest in its buffer zone is causing problems (Montfort, Nourtier, et al., 2021). For example, between 2003 and 2013, around 267,000 ha of forest were lost in Mozambique owing to deforestation, with about 613.97 ha of that loss occurring in the GNAP buffer zone (World Bank, 2018b). Fire, poaching, and illegal logging are the main causes of understory vegetation removal in GNAP and its buffer zone (Amaya et al., 2021; Fusari & Carpaneto, 2006a; World Bank, 2018a).

In the buffer zone of the GNAP, vegetation is a complex mosaic of post-cultivation Miombo regrowth of different ages, cropland, mature Miombo woodland and wooded savannas (Montfort et al., 2021). Although, Gile National park is the only protected area in Mozambique with no permanent settlements in its core area and represents one of the largest areas of uninterrupted Miombo woodland in the northern part of the country (Mercier et al.,2016), it has been one of the flash points for illegal logging, in 2016 alone, the park apprehended 5 tractors and 23 trucks involved in illegal logging inside the park (GNR, 2017). To that end the buffer zone of the park is suffering by degradation of Miombo woodland (Montfort, Nourtier, et al., 2021).

According to Montfort et al (2021) in Mozambique, specifically Zambezia province, around GNAP, regeneration of Miombo woodland have been studied only in the abounded agricultural land. This study, there for intended to full this gap by analyzing status of Miombo woodland regeneration in different land use type namely (DMWL, AAl and OMWL). The specific objective of this study was to assess the status of woody species diversity, stand structure and regeneration structure, status of restoration and factors affecting regeneration in the buffer zone of GNAP. In so doing, the following analytical questions were answered: How is the status of Miombo woodlands regeneration looks like? What type of disturbances that triggers or hinders Miombo regeneration? What are the other factors affecting regeneration in Miombo trees? Which tree species regenerate well and what about its diversity looks like? Is there any sign of restoration in the study area?

6.3. The Conceptual Framework of the Study

The sustainability of Miombo trees in correspondence to today's intensified disturbances and meeting human demands requires clear understanding on dynamics, magnitude and the impact of these disturbances together with the knowledge of factors affecting its resilience (Matowo et al.,2019). In this paper, we propose a conceptual framework for understanding Miombo regeneration status in relation to disturbance factors (Figure 6.1). In so doing, it answers the following analytical questions: How is the status of Miombo woodlands regeneration looks like? What are the factors affecting regeneration in Miombo trees? Which tree species regenerate well and what about its diversity looks like?

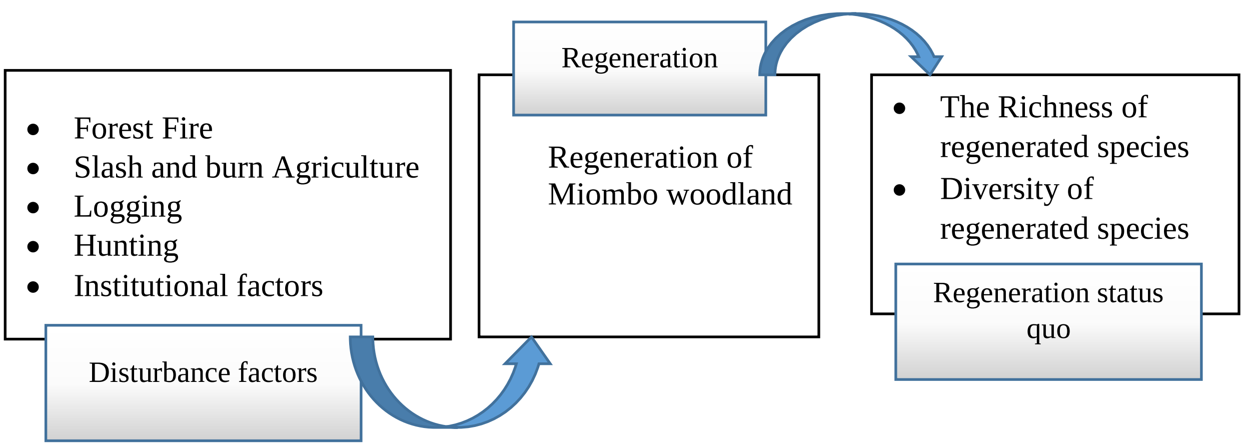

Figure 6. 1 A conceptual framework of the relationship between regeneration and factors affecting regeneration in Miombo ecosystem.

Source; Adopted from Matowo et al (2019).

6.4. Materials and Methods

6.4.1. Description of the Study Area

The study was conducted in buffer zone of GNAP in Zambezia Province, central Mozambique. GNAP is situated between Pebane and Gile districts in the north-eastern part of the province Figure 6.2. About 89% of the population living in the study area are dedicated to subsistence agriculture (Mercier et al., 2016a) .

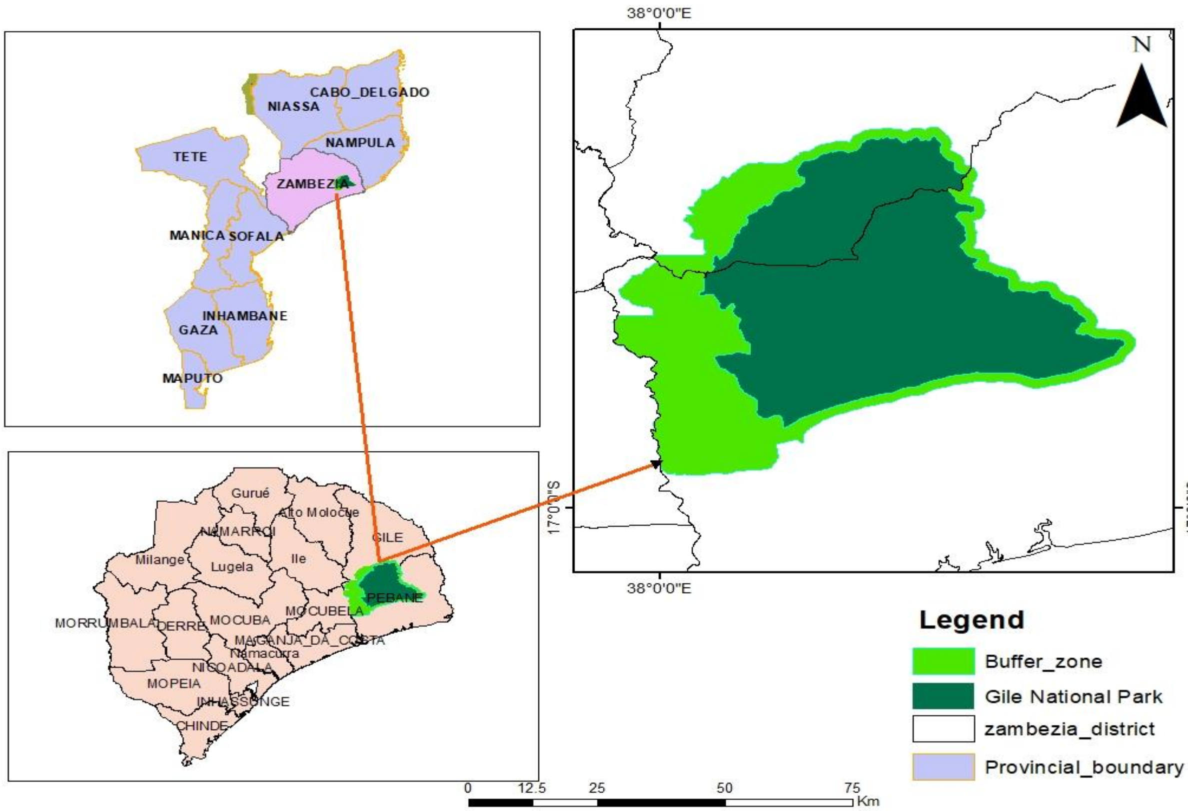

Figure 6.2 Map of the study area

6.4.2. Methods of Data Collection

6.4.2.1. Woody Species Diversity and Composition

Both qualitative and quantitative data collection methods were utilized to assess the status of regeneration and restoration. According to Fusari & Carpaneto (2006), the GNAP buffer zone has six different types of land cover. The classification of Miombo woodland as open or closed is based on its land use for settlement and infrastructure development, which includes arable and pastoral agriculture, as well as the harvesting of live wood for construction materials (Nduwayezu et al., 2015). Purposively, we took DMWL, OMWL, and AAL with the help of a knowledgeable guide from the area for this study, as used by Williams et al. (2008). DMWL is part of the Mozambican forest and corresponds to semi-deciduous forests, usually an undisturbed state of Miombo (Ribeiro et al., 2020), which have not been cleared or cultivated in living memory (Montfort et al., 2021; Syampungani et al., 2016). OMWL is part of the Mozambican forest that corresponds to semi-deciduous forests and can be a transition state between degraded and intact Miombo (Ribeiro et al., 2020). AAL is areas abandoned after slash-and-burn agriculture with tree regeneration and without evidence of removing some trees after abandonment (Montfort et al., 2021; Syampungani et al., 2016).

At the park's buffer zone, 500m long transects were established in each land-use type in the north, south, west, and east directions. 20x50 m sampling plots were laid at 100 m along these transects (Gonçalves et al., 2018; Felfili et al., 2005). Subplots of 10x5m were employed to measure regeneration status (Figure 6.3).

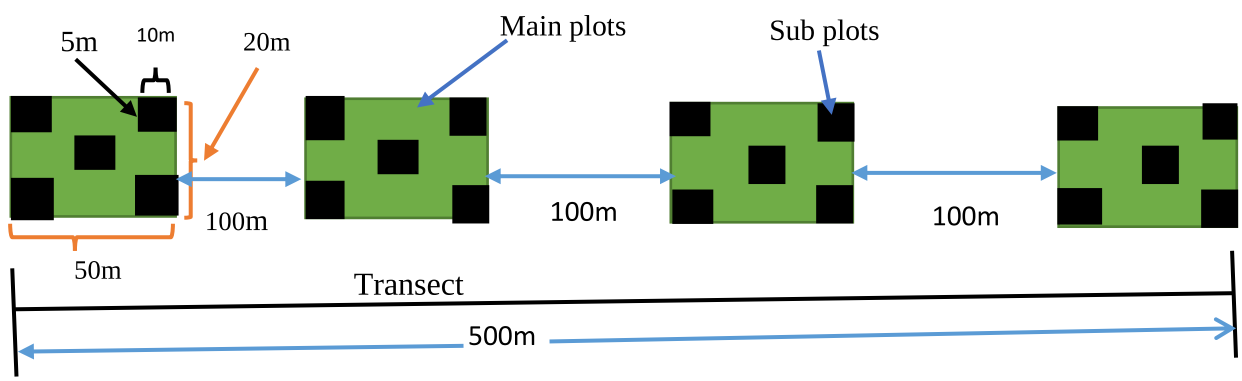

Figure 6.3 Schematic representation of a transect, plots, and subplots.

On every plot, we registered matured woody species with DBH ≥ 5 cm, stumps, and dead woodies, whereas in subplots, we registered all regenerations, which refers to young woody species with a DBH of < 5 cm and ≥ 3.5 cm (Feldmann et al., 2020; Gonçalves et al., 2018; Elifuraha et al., 2020; Syampungani et al., 2016). DBH was measured in cm at 1.3 meters above ground level, while height was measured in meters. Species names were documented in the Lomwe language with the help of local field guides. A record generated by Montfort et al. (2021) for woody species of GNAP and its sounding was used to identify the scientific names. Unidentified species in the field were collected and later identified using a family key checklist of vernacular plant names in Mozambique (Koning, 1993). Finally, a Botanist from the Mozambique agricultural research center confirmed their botanical names using a list of native and Portuguese names.

6.4.2.2. Socio-Economic Data

The socio-economic survey was used to collect data from local communities about restoration activities and factors affecting regeneration. Household interviews, KIIs, and FGD were used for data collection.

From 40 communities living in the buffer zone, ten communities were randomly selected for formal interviews. Next, the households'(HH) sample frame was established by collecting the list of HH head records from their respective administration with the help of an expert from GNAP. The sample frame was all HH living in the identified community, and finally, the selections of sample HH were proportional to each community. As a result, the total number of HH living in the selected community was estimated to be around 700. Using simple random sampling techniques, 200 respondents, or about (28 %) of the selected HH, were chosen (Cochran, 1977).

In the districts of Pebane and Gile, eight focus groups with 8 to 10 participants were chosen. Twelve KIIs were held with forest and land-use experts from the district and national parks. Closed and open-ended questions about restoration status and factors affecting regeneration were employed in KIIs and FGDs. Open-ended questions were utilized to gather more information, allowing respondents' comments to be qualified and clarified, resulting in more accurate data and actionable insight. It allows respondents to express their thoughts and feedback in their own words. It is the only way to collect in a situation that requires contextualization, complex description, and explanation (Hyman & Sierra, 2016). Field walks and informal conversations with farmers were also used to understand the restoration and regeneration status better. Farmers were asked if they had any restoration information, if there were any ongoing restoration activities in the area, and if they participated in restoration activities. They were also asked to explain how their socio-economic activities and environmental factors influence Miombo woodland regeneration in the area. Field observations were made using checklists (things to keep in mind so that we do not stray too far from our research's goal) to monitor the situation in the buffer zone (Annex-1). Photographs of the sites were taken to enrich the study.

6.5. Data Analysis

The total number of matured woody species and regeneration recorded in each plot were used to calculate species richness. On the other hand, species diversity was quantified using the Shannon–Wiener diversity index (Magurran, 2004) and calculated in Eq.6.1 .The Shannon–Wiener diversity index H’ considers species abundance.

$$H' = -\sum_{i=1}^{n} pi * lnpi \text{ ………………………………………………………… } 6.1$$

Where

H' = Shannon Diversity Index

n = number of species,

pi= the number of individuals of species in a given plot divided by the total number of individuals in the plot

ln=the natural logarithm, and

∑=the sum of the calculations

Species evenness was measured by Pielou’s Evenness Index given in Eq. 6.2. The most accepted measures of evenness measures index (H'/H' max) (Pielou ,1966).

$$E = \frac{H}{H\,max} = \frac{H}{\ln S} \text{ ……………………………………………………………………… } 6.2$$

H = Shannon index

H max = Maximum Shannon Index

ln = Natural logarithm

S = number of each species identified in the study area

All data were checked for normality, and a nonparametric test was used if the assumption was not met. A nonparametric (Kruskal- Wallis) test was used to test differences in woody species density between land-use types (Gonçalves et al., 2017). The Kruskal- Wallis test is a prominent nonparametric rank-based test comparing outcomes among more than two independent groups. It is the best solution when the data does not match the requirements of parametric tests , such as data normality and homogeneity of variance (Ostertagová et al., 2016).

The association between height and DBH was investigated using regression analysis (Nogueira et al.,2016). The selection of the regression model was based on the coefficient of determination of the model (R^2) and the standard error of estimate (Syx) in all statistical analyses, a confidence level of P=0.05 was used for statistical significance (Avsar, 2004; Nogueira et al., 2007; Nogueira and Fearnside,2016). The analyses were done using Microsoft excel.

The importance value index (IVI) is an important parameter that indicates the ecological significance of species in a given ecosystem (Ayanaw & Dalle, 2018). It is widely used to assess floristic composition in forest systems, including African savanna and woodlands. It shows how a species' distribution happens at a certain location and the size and abundance of trees. Each species was determined using the equation (Eq. 6.3), which is a sum of the relative values of frequency, density, and dominance.

$$\text{IVI} = \frac{\text{RF+RD+RDo}}{3} \qquad 6.3$$

Where:

RF is the relative frequency of species and is calculated using (Eq.6.4)

$$\text{RF} = \frac{\text{Frequency of respective woody species}}{\text{The total frequency of all woody species}} \times 100 \qquad 6.4$$

RD is the relative density of species and calculated using (Eq.6.5)

$$\text{RD} = \frac{\text{The abundance of respective woody species}}{\text{Total abundance of all woody species}} \times 100 \qquad 6.5$$

RDo is the relative dominance of species and calculated using (Eq.6.6)

$$\text{RDo} = \frac{\text{Basal area of respective woody species}}{\text{Total basal area of all woody species}} \times 100 \qquad 6.6$$

The IVI was calculated for all species at each land-use type, and the value that is produced is a score, which is then ranked against the other species within that class – i.e. a rank of 1 demonstrates that the species is ecologically important (Gonçalves et al., 2017, 2018; Jew et al., 2016a). The top five ranking species for each land use type were identified to recommend the status of Miombo woodland in the study area.

The similarity of woody species between different land-use types was calculated by the Jaccard similarity index (Eq. 6.7), as it is a useful measure to determine the extent of overlap of woody species between two forest communities, in this case, land use type (Kalaba *et al*., 2013). Species similarities between the land use type were studied between DMWL and OMWL, DMWL and AAL, and OMWL and AAL.

$$SJ = \frac{A}{A+B+C} \qquad \text{......} 6.7$$

Where

SJ is a similarity index,

“A” is the number of species found in both land-use type (shared species),

“B” and “C” are species unique to each land-use type.

The index assumes that the more species both sites have in common, the more similar they are, and values between 0 and 1, with value 1 indicating that all species co-occur.

The stumps occurrence

Stump occurrence was assessed in each land-use type across the sampled study area. It highlighted the presence of disturbance and its percentage by comparing it to the number of living trees which had been registered. The percentage of occurrence of the stumps was assessed using Eq.6.8 adopted from Muller-Landau et al. (2009);

$$\text{OS }(\%) = \frac{\text{total number of stumps registered}}{\text{total number of living individuals registered in sample}} \times 100 \qquad \text{......} 6.8$$

Where

OS = occurrence of stumps

Dead woody specie’s occurrence

In each land-use type, the presence of dead woody species was examined in all plots in the study area. It highlighted the presence of disturbance and its percentage by comparing it to the number of living trees which had been registered. It identified whether woody species have died due to natural and human-caused causes. The percentage of dead woody individuals was calculated using Eq.6.9, adopted from Muller-Landau et al. (2009);

$$DWI(\%) = \frac{\text{the total number of dead woody species registered}}{\text{total number of living individuals registered in the sample}} \times 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 6.9$$

Where

DWI = Dead woody individuals

The De Liocurt "q" coefficient, the ratio between the number of woody individuals in successive diametric classes, was calculated for each to check the stability of diametric distribution (DINAF, 2018; Hofiço et al., 2018; Kerr, 2014). The result of diametric distributions was shown using a line chart. The number of individuals per hectare was assigned on the y-axis, whereas the DBH class, divided into six diameter classes with size class intervals of 10 cm, was assigned on the x-axis (Gonçalves et al., 2018; Neelo et al .,2015).

Regeneration limitation

Regeneration limitations highlighted the percentage of species that failed to occur/regenerate at each subplot. Regeneration limitation was assessed using Eq.6.10 (Muller-Landau *et al*., 2009);

$$RL(\%) = \left(\frac{\text{Total number of subplots where regeneration was not registered}}{\text{Total number of subplots in the sample}}\right) \times 100 \ldots\ldots\ldots\ldots\ldots 6.10$$

Where

RL= Regeneration limitation

Descriptive statistics of simple frequency analyses were used using SPSS (version 25) to describe respondents' responses about restoration and factors affecting regeneration. The responses of respondents on factors affecting regeneration were compared using Chi-square tests. The information collected through FGD and KIIs was quantitatively examined. Thematic and content analysis was used in qualitative data analysis to determine how the results related to the research questions. Content analysis was used to edit qualitative data and reorganize it into meaningful shorter sentences (Vaismoradi et al., 2013). Thematic analysis was used to organize data into themes and identify codes (Kiger & Varpio, 2020). After data collection, information of the same category emphasizing current restoration situations and factors affecting regeneration were assembled. Their similarity with the quantitative data was created, after which a report was written**.**

6.6. Results

6.6.1. The Structure and Composition of Mature Woody Species

From the sampled area, 1863 matured individuals representing 85 species from 29 families were identified, specifically 974 individuals in the DMWL, 480 in the AAL, and 409 in the OMWL. In DMWL, the mean density was 574 ± 158 stems ha^{-1}, with stems ranging from 320 to 800 stems ha^{-1}; in OMWL, the mean density was 256 ± 122 stems ha^{-1}, with stems ranging from 110 to 460 stems ha^{-1} and, in AAL, the mean density was 301±190 stems ha^{-1} with stems ranging from 60 to 670 stems ha^{-1}. There was a significant difference in stand density between DMWL and OMWL ($H = 20.62$; $p = 0.005$) and DMWL and AAL ($H = 18.00$; $p = 0.00$), but no significant difference between OMWL and AAL ($H = 2.60$; $p = 0.59$). The density of stems in all land-use types is shown in (Figure 6.4).

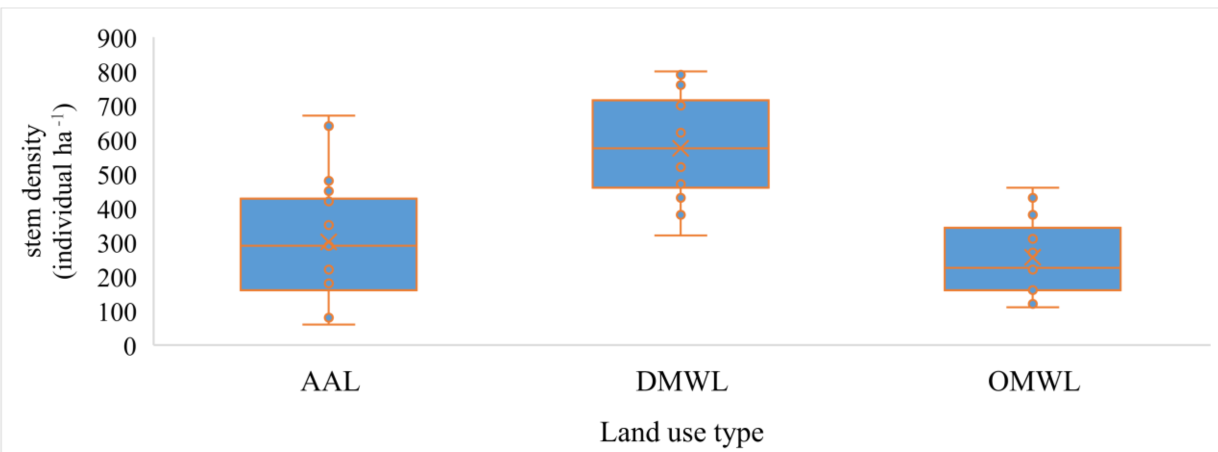

Figure 6.4 Matured woody density (individuals/ha) in each land-use type, the bounding box of each variable in the boxplot reflects quartile values; the straight line represents the mean value.

Diametric structure

The diametric distribution in all land use types shows an inverted J-shaped size class distribution (Figure 6.5). Most woody individuals were found in the lower diameter classes, with

58.4 % in DMWL, 55.99 % in OMWL, and 62 % in AAL. There was heterogeneity in the De Liocurt "q" coefficient among diametric classes in all land-use categories, showing that the decline was not uniform.

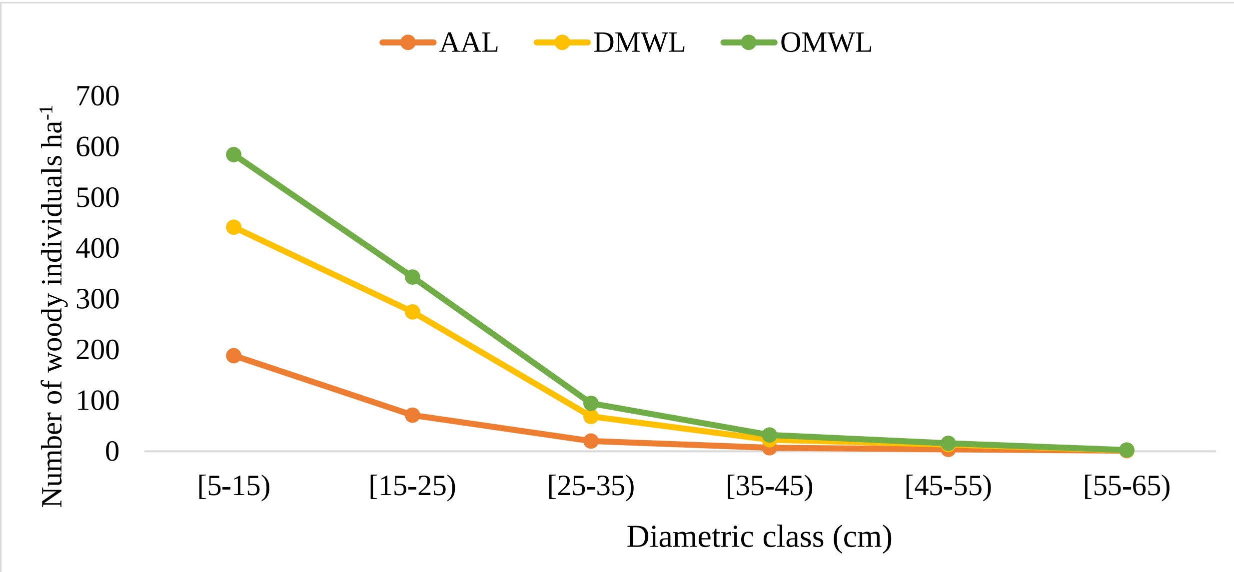

Figure 6.5 Diametric distribution of matured woody individuals in each land use type

Height-DBH relationship: when matured woody individuals (DBH >5cm) were taken into account, the second-degree regression model created between height and DBH was statistically significant in AAL (F=459.12; P0.0001), DMWL (F=2002.02; P0.0001), and OMWL (F=589.41; P0.0001). For each land use, the regression equation is shown in (Figure 6). The coefficient of determination and the standard error of estimate for AAL, DMWL, and OMWL were R^2 =0.97 and Syx=0.55, R^2 =0.97 and Syx=0.66, and R^2 =0.96 and Syx=0.71 respectively. The regression coefficients (b0, b1, and b2) were statistically significant. As a result, height and DBH have a significant positive, nonlinear relationship (Figure 6.6).

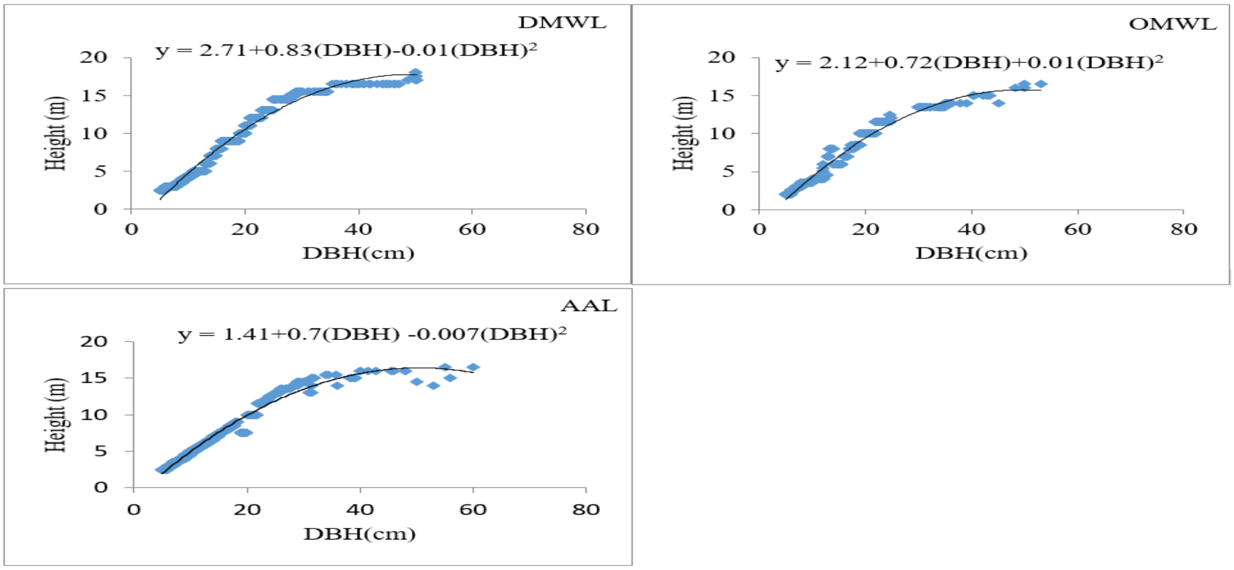

Figure 6.6 The relationship between height and DBH

With 25 species, Fabaceae is the most diverse family, followed by Rubiaceae (9 species), Anacardiaceae and Combretaceae (6 species), Euphorbiaceae (5 species), Ebenaceae and Loganiaceae (3 species), Ochnaceae, Olacaceae, Phyllanthaceae, Zygophyllaceae, Annonaceae, and Apocynaceae (2 species). Fabaceae dominated the number of individual woody species per family across all land-use types, with 906 woody species accounting for 48.6% and Loganiaceae with 172 woody species accounting for 9.2%. The structural study of matured woody species was summarized using relative values of frequency, density, dominance, and IVI for all species and the top five matured woody species, which were ranked using IVI, and shown in Appendix 4 and (Table 6.1) respectively.

Table 6.1 Structure of matured woody species and the most top-five IVI

Species Name	Important Value Index (IVI)		
	AAL	DMWL	OMWL
Annona senegalensis	17.69	4.83	10.91
Brachystegia boehmii	33.61	47.93	36.21
Brachystegia spiciformis	37.84	28.99	15.79
Erythrophleum africanum	10.88	10.38	37.94
Julbernardia globiflora	19.79	38.67	13.76
Millettia stuhlmannii	3.88	10.56	3.58
Pterocarpus angolensis	4.39	9.37	35.12
Strychnos madagascariensis	34.11	19.22	13.38

Species similarities registered between AAL&DMWL, DMWL&OMWL, and AAL&OMWL were 57.14%, 53.97, and 47.88%, respectively. The lowest similarity was found between AAL and OMWL, while the highest was between AAL and DMWL.

6.6.2. The Diversity of Matured Woody Species.

Regarding species richness, there were around 66 species in the DMWL, 54 in the AAL, and 51 in the OMWL. In DMWL, OMWL, and AAL, the overall species diversity measured by H' was 3.45, 3.40, and 3.35, respectively. In OMWL, AAL, and DMWL, the evenness value (E) was 0.86, 0.84, and 0.82, respectively.

Twenty woody stumps and twenty-one dead woody individuals were identified from the total sample plots (Table 6.2). Causes for occurrences of woody stumps and dead woody individuals were linked to natural and anthropogenic. The community used the bark of a tree for home equipment, taking it while the tree was still standing and eventually killing it; they also ringed and killed the tree (Figure 6.7).

Table 6.2. Result of the stumps and dead woody individuals

land-use type	Occurrence of the woody stumps		Occurrence of dead woody individuals	
	Frequency	Percentage	Frequency	Percentage
AAL	10	2.08	4	0.83
DMWL	4	0.41	9	0.92
OMWL	6	1.46	8	1.95
Total	20	1.07	21	1.12

Figure 6.7 Figure showing the way community kills the trees

6.6.3. Density and Composition of Regenerations

In terms of regenerations, there were 903 individuals registered, representing 70 species and 23 families, with 402 in AAL, 319 in DMWL, and 182 in OMWL. In DMWL, the average regeneration density was 39.87±13.82 stems per hectare, with stems ranging from 10 to 70 stems per hectare. The mean stand density in AAL was 50.25 ± 21.1 stems per hectare, ranging from 10 to 100 stems per hectare, while the mean density in OMWL was 23 ± 9.98 stems per hectare, with stems ranging from 10 to 60 stems per hectare (Figure 6.8). Regeneration density was significantly different between OMWL and AAL (H = 98.15; p = 0.000), OMWL and DMWL (H = 73; p = 0.000), and AAL and DMWL (H = 25.15; p = 0.02).

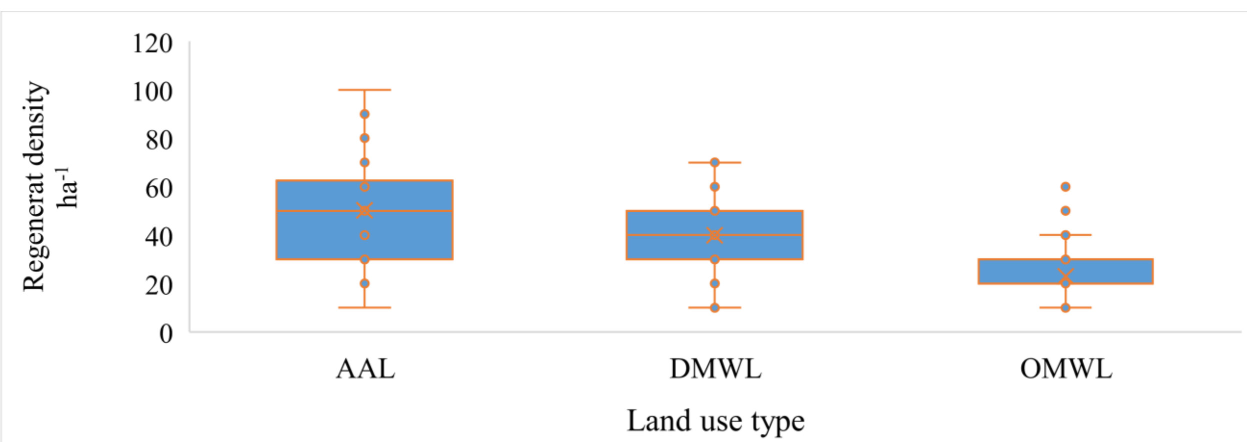

Figure 6.8. Each land-use type's regeneration density (individual ha^{-1}). The bounding box of each variable in the boxplot represents quartile values; the straight line represents the mean value.

With 20 species, the Fabaceae family was the most regenerated, followed by Anacardiaceae (6 species), Euphorbiaceae and Rubiaceae (5 species), Combretaceae (4 species), Loganiaceae (3 species), and Ebenaceae (3 species). In terms of the number of woody individuals per family, Fabaceae ranks top with 433 regenerated woody individuals, accounting for 47.9% of all recorded families, followed by Euphorbiaceae with 60 regenerated woody individuals, accounting for 6.6 %. The structural study of regenerated woody species was summarized using relative values of frequency, density, dominance, and IVI for the top five and all species were shown shown in Appendix 5 and (Table 6.3) respectively.

Table 6.3 The top five dominant regenerated woody species ranked using IVI in all land use type

Species	Importance Values Index (IVI)		
	DMWL	OMWL	AAL
Lannea stuhlmanii	22.01	5.00	5.30
Brachystegia spiciformis	18.62	3.33	12.45
Albizia versicolor	17.15	0.00	4.52
Annona senegalensis	15.23	18.33	10.83
Pteleopsis myrtifolia	15.14	25.00	5.39
Brachystegia boehmii	5.16	22.22	41.97
Commiphora africana	0.68	15.00	8.81
Diplorhynchus condylocarpon	6.00	23.33	7.41
Erythrophleum africanum	4.16	23.88	2.42
Hugonia orientalis	11.14	1.67	13.82
Julbernardia globiflora	3.19	11.67	26.77
Millettia stuhlmannii	8.60	1.0	19.15
Strychnos madagascariensis	11.43	6.67	20.03

6.6.4. Diversity of Regenerated Species

Regarding regeneration species richness, 70 species were registered in the sample area, with 59, 54, and 39 registered in DMWL, AAL, and OMWL, respectively. High species diversity was recorded in DMWL, whereas high species evenness was recorded in AAL and OMWL.

6.6.5. Regeneration Limitation

There was no regeneration in 12 plots out of 240 used to measure regenerations, accounting for 4.58 % of the total plots, with 7.5 %, 3.75 %, and 2.5 % regeneration limitations in AAL, DMWL, and OMWL, respectively.

6.6.6. Status of Restoration in the Study Area

Of all respondents interviewed, 137 reported they had information about restoration, whereas 63 reacted as they did not have any information about it. There was a significant difference (2 = 27.38, df = 1, P 0.01) in respondents' replies on having information on restoration, with 68.5 % and 31.5 % saying yes and no, respectively. According to them, there was no assisted restoration activity in their area. All respondents who said they did not know anything about restoration cited "no one shares the information" as the explanation for their lack of knowledge, implying a lack of awareness in the area.

6.6.7. Factors Affecting Regeneration of Miombo Woodland

Concerning factors affecting the regeneration of Miombo woodland in the study area, respondents listed, identified, and ranked five factors by justifying the first as the most and the 5th as the least (Table 6.4). The rankings were determined by the respondents' frequency with which the variables were chosen (Dibaba et al., 2020). There was a significant difference in respondents' responses to each ranking component ($\chi 2 = 95$, df = 4, $P < 0.01$), in which 45.5% and 6.5% of them ranked slash and burn agriculture and grazing by animals as first and last factors affecting regeneration respectively.

Table 6.4 Factors affecting regeneration of Miombo woodland

S/no	Factors	Frequency	Per cent	Rank
1.	Slash and burn agriculture	89	44.5	1
2.	Building materials harvesting and sales	51	25.5	2
3.	Fire	26	13.0	3
4.	Wooden furniture production	21	10.5	4
5.	Grazing by animals	13	6.5	5
	Total	200	100	

The main factors affecting the regeneration of the Miombo forest, according to KII and FGD responses, were disturbances following looking for new agricultural land and fire. They also identified Hunting, shortening of the fallow period, nature of the environment, insufficient implementation of laws and regulations (institutional factors), and prolonged drought and rainfall variability as factors affecting regeneration. The following are the outcomes of discussions with FGD and KIIs about factors that affect Miombo woodland regeneration:

Group members responded that the only way the community could access agricultural land was by clearing forests and developing new farmland. Young farmers who grew up in the vicinity can only get land by destroying the forest. Following that, while clearing forest for new farmland, this action immediately destroys those regenerated woody species. After removing the forest, they used fire to remove debris from their newly opened land, damaging newly regenerated woody species outside the boundary of their newly opened farmland.

Regarding Hunting, they said, "most communities used fire during hunting to catch or kill what they intended to hunt from the buffer zone and/or even the national park". This activity has an impact on the area's newly regenerated seedlings. Although they utilize fire for their unique hunting area, due to the nature of the location and the fire capabilities, it spreads and causes the buffer zone and even the park to burn.

About the shortening of the fallow period, they said, "currently community in buffer zone exhaustively used available land around their locality and don't have a chance of getting new land near to their village". Consequently, they do not have an alternative than re-using the land they have by giving a short time for fallowing/resting. These phenomena (giving a short time for fallowing) have directly affected the newly regenerated Miombo forest, specifically in the AAL. Regarding implementation and weak enforcement of rules, KIIs reported that in the study area, there is no fear or respect for forest laws; the community can go and open farmland wherever they want in the park's buffer zone. This action of the community negatively affected the regeneration of Miombo woodland.

They also stated that the nature of the environment has an impact on regeneration. Again due to the cumulative effect of the factors stated above, the park's buffer zone forest cover and soil fertility have decreased compared to its prior stand. Following that, a GNAP buffer zone is transformed from dense forest cover to sparse forest cover and from fertile to infertile soil, impacting newly regenerated seedlings' survival. According to KIIs, the regeneration of the Miombo forest is similarly affected by prolonged drought and rainfall fluctuations.

6.7. Discussions

The species composition of Miombo woodland in the GNAP buffer zone varied by land-use type, which can be explained by the fact that all land-use types were not exposed to the same disturbance factors and have different capacities for disturbance resistance (Gonçalves et al., 2017; Gumbo et al., 2018; H. A. Wale et al., 2012).

Woody species diversity: Species diversity is the most often used depiction of ecological diversity (Gonçalves et al., 2017; Hamilton, 2016). The species diversity in our study area was similar to that in other Miombo forest studies (Gonçalves et al., 2017; Lumbe, 2010). DMWL has a high species richness, which can be explained by the fact that it has not been cleared or cultivated in living memory (Montfort et al., 2021); thus, it is relatively available close to the GNAP border, relatively far from community settlements, and is not yet engaged by communities or even illegal loggers. This result is consistent with Jew et al. (2016), who found that woody species richness declined with increasing disturbance in Chunya District, Tanzania. According to the literature on Southern African forests, stem densities differ dramatically from one woodland type to another. Higher variations in stems ha^{-1} have also been observed in semi-arid and arid localities in Southern Africa (Chirwa, 2014).

Only three species, *B. boehmii, B. spiciformis,* and *J. globiflora,* were registered as common in all land use types among the top dominating species found using IVI, which may be explained by the fact that those species are Miombo-defining (Chidumayo, 2013; Kalaba et al., 2013; Ribeiro et al., 2013). It is also explained that Miombo species can recover disturbances due to their relatively good regeneration from surviving stems and rootstocks (Jew et al., 2016b; Lupala et al., 2015; Ribeiro et al., 2013). Although the presence of Miombo indicator species in degraded Miombo is surprising, it could be because these species are also resourced for local communities; on the other hand, they are extremely resilient and quickly regenerate once disturbances are removed (Ribeiro et al., 2020). Regarding the abundance of B. boehmii in AAL, our findings are consistent with Montfort et al. (2021), who reported the dominance of this species in AAL around GNAP in Mozambique.

However, our findings contradict those of Williams et al. (2008) regarding Miombo-defining species. They reported that no Miombo-defining species were found in regrowth from slash and burn (AAL) among Mozambique's top five dominating species. Furthermore, this can be explained by the fact that discrepancies between similar studies are most likely related to differing land histories in the study area (Montfort et al., 2021). This discrepancy could also be explained by the distance between regrowth areas and mature Miombo woodland, which was further away from the plots studied (Kalaba et al.,2013).

P. *angolensis* is listed as vulnerable on the IUCN red species list in countries like Malawi and Namibia. In contrast, in Zimbabwe and South Africa, it is considered at low risk of extinction and least concern, respectively, indicating that the distribution of this species may vary from country to country (Barstow & Timberlake, 2018; Jew et al., 2016a), but in our study area, it is among the top dominant species ranked by IVI which may be explained by the fact that the utilization of this species varies from region to region (Mehl et al., 2010).

Species Composition: The structure and species composition of the woodlands in our study area reveal a typical Miombo ecosystem dominated by *J. globiflora*, *B. boehmii*, *B. spiciformis*, and *E. africanum* (Ribeiro et al., 2013; Shirima et al., 2015; Timberlake & Chidumayo, 2011). Compared to DMWL, species richness and diversity were low and almost similar in OMWL & AAL and, explained by the fact that DMWL is found near the national park's border and has not yet been exploited by users like the other land-use type. DMWL corresponds to an undisturbed state of Miombo (Ribeiro et al., 2020). These results disagree with the finding of Williams et al. (2008). They reported that species richness and diversity were higher in abandoned agricultural land (machambas) than in mature woodland (DMWL for us). The evenness values found were similar in the AAL and OMWL, implying that the individuals of different species recorded had relatively similar abundances at both land-use types.

Regenerated species diversity

Regarding regeneration, the DMWL had a high species richness. In contrast, the OMWL had a low species richness and can be explained by the fact that disturbance factors like illegal logging and harvesting small size diameters for home and fence construction may be lower in DMWL compared to the other land-use type. It is also explained that in terms of location, it is near the border of GNAP and far from communities' settlements, and not easy for them to visit and harvest frequently. There is also an attempt to control all activities related to Miombo woodland degradation by rangers from the park and safeguard the park from encroaches by illegal forest users. DMWL is close to the GNAP 's border and far from communities' settlements, making it difficult for people to travel and harvest regularly. The main problem for reducing species richness in the forest as general and Miombo as specific is user exploitation (Chirwa et al., 2014; Williams et al., 2008); that is why in our result, DMWL has more species richness than the other two land-use types. This finding is consistent with Montfort et al. (2021), which found that matured Miombo in and around GNAP, Mozambique, have a higher species richness of regeneration than disturbed Miombo. Williams et al. (2008) also reported that due to proximity to human settlements, it is likely that abandoned agriculture has less species richness than woodland.

In terms of species diversity, AAL has a high level of diversity, OMWL has a low level of diversity, and DMWL has a medium level of diversity, which can be explained by the fact that Miombo woodland regenerates quickly and prolifically (Dewees et al., 2011; Ifo et al., 2016). According to Gonçalves et al. (2017), the high diversity value discovered in AAL is unexpected. However, it can be explained by its high environmental variability at early successional stages and its ability to recover relatively quickly. Montfort et al. (2021) found that after disturbances caused by slash-and-burn agriculture, Miombo woodland has a high regeneration capability. Chirwa et al. (2014) and Chidumayo (2013) also found in their studies that Miombo regeneration, primarily through regrowth of coppice and root suckers rather than seeds, allows for rapid woodland recovery, which could explain the rapid regrowth and high species diversity of Miombo species following disturbance (in AAL). Our findings support Williams et al. (2008) finding of substantial species diversity in AAL. They found a similar outcome in Mozambique Gorongosa National Park's buffer zone.

Compared to DMWL, AAL and OMWL have a high evenness value (E). In both AAL and OMWL, the evenness values were similar, meaning that the recorded individuals of different species had nearly similar abundances. Open Miombo can be explained as a transition state between degraded (AAL for us) and intact Miombo (DMWL for us) (Ribeiro et al., 2020), implying that AAL and OMWL exhibit similar species evenness.

The composition and density of regenerated woody species

AAL had the most regenerated individuals, followed by DMWL, while OMWL had the least. The high environmental heterogeneity of AAL can explain this in early successional stages than woodland (Gonçalves et al., 2017). Miombo woodland regrows virtually unchanged following clearing because regeneration consists of stumps/root sucker shoots and recruitment from old stunted seedlings already present in the grass layer at the time of cutting; following this, tree density in regrowth Miombo woodland is higher than in mature Miombo woodland (Ribeiro et al.,2020).

L. stuhlmanii, *P. myrtifolia*, and *B. boehmii* were the top dominating regenerated individuals found by IVI in DMWL, OMWL, and AAL. The most prevalent regenerated species in the area was B. boehmii. Our findings on *B. boehmii* agree with those of Kalaba et al. (2013) and Montfort et al . (2021). They showed B. boehmii as the most dominant species in early regrowth in Zambian and Mozambican Miombo woodlands, respectively. Miombo species can remarkably regrow, even when disturbed regularly (Ribeiro et al.,2020). Luoga et al. (2004) state that most Miombo species sprout vigorously from stumps after cutting.

AAL had a high mean regeneration density, while OMWL had a low one. There was a considerable variation in regeneration density between the three land-use types. Species in each land use type exhibited many variations in regeneration, indicating that each species has a varied ecological relevance (H. A. Wale et al., 2012), and disturbance factors could influence how species regenerate (Gonçalves et al., 2017). This result agrees with Gonçalves et al. (2017) finding, which reported that the regrowth of Miombo woodland (AAL) and DMWL had high species density, while the intermediate stages (OMWL) had low species density. It also agrees with Williams et al. (2008) finding, which reported differences in density between abandoned machambas and DMWL.

According to KIIs, FGDs, and physical inspection by the researchers' team, no assisted restoration activity took place in their area. They also reacted as regeneration is sufficient for the area's Miombo woodlands since it returns to their natural state if disturbance causes are controlled. They also mentioned that there is an effort to diversify communities' income by working on bee farming, producing cashew nut seedlings to distribute to communities, and teaching the community about mushroom production so that the community's reliance on slash and burn agriculture will be reduced so that regeneration of Miombo woodland in the area is sufficient to improve the buffer zone's forest cover.

Agriculture in the study area is based on slash and burn; the FGD members identified it as the most important factor affecting Miombo woodland regeneration. Harvesting and selling building materials were the second most important factors affecting Miombo woodland regeneration, which may be explained by the fact that villages mostly used woody species of small size to build their home and fence and sell to towns for the same purpose. This result agrees with Campbell et al. (2007) regarding clearing Miombo woodland for agriculture. They reported that clearing for agriculture threatens Miombo woodland.

The problem-related fire was caused when farmers wanted to clear their new farmland and intended to hunt animals from the area. The fire they normally use for their intended objective may sometimes get out of their control, expand to the entire area and affect the regeneration of Miombo woodland. Most communities used hunting to get meat from the buffer zone and even from the park, and they used fire to catch or kill what they planned to hunt. This action is a way by which fire can affect the newly regenerated woody species in the area. Ryan & Williams (2011) reported that fire affects Miombo trees of smaller DBH. Mercier et al. (2016) and Fusari & Carpaneto, 2006) reported that communities in the buffer zone of GNAP used fire for hunting and clearing ground from grass and bushy vegetation. This result agrees with the Maquia et al. (2013) finding, which reported that anthropogenic fires represent one of the threats, compromising the stability of Miombo woodland by affecting its regenerations.

Young farmers who grew up in the area can only access farmland by clearing forests, and finding new farmland near their settlement is not easy. Consequently, communities in the park's buffer zone are currently unable to obtain new farmland. As a result, they are forced to re-use land they already have by allowing only short periods of fallowing/resting. Giving a short period for fallowing has a direct impact on newly regenerated Miombo species in agricultural land, which is supposed to regrow and develop into a Miombo woodland ecosystem; this may be explained by the study area's farmers' lack of alternative sources of income other than agriculture.

Communities can clear forests and open farmland wherever they want in the park's buffer zone without fear of repercussions; no one can stop them. This action impacts the area's Miombo woodland regeneration. It could be attributed to the lack of implementation and enforcement of forest policy regulations. Concerning the difficulties that weak people face, Sitoe et al. (2012) reported that forest operations have been occurring without credible control due to weak enforcement and institutional capacity, particularly at sub-national levels (provinces and districts) forest policies. Weak local institutional capacities, a lack of local resource rights, and the inability of local actors to enforce control mechanisms to prevent overuse, According to Campbell et al. (2007), weak local institutional capacities, a lack of local resource rights, and local actors' inability to enforce control mechanisms to prevent resource overuse hurt the Miombo eco-resource region's sustainability.

The lack of an alternative source of income, the area's inaccessibility to facilities such as extension services and roads, which prevents them from diversifying their source of income generation, and even the lack of a good market for what they produce and intend to sell were all mentioned as factors affecting regeneration. As a result, slash-and-burn agriculture is their best option for survival. The interaction of these factors impacts Miombo woodland regeneration. "slash and burn agriculture and harvesting building materials in the area have its impact as mentioned above and optimize the expansion of fire to the entire area. Shortening the fallow period also resulted in a shortage of building materials that the community was supposed to get from their surroundings, forcing them to move to new areas and exposing them to damage to the new forest, which facilitates fire spread due to harvest leftovers. This finding is consistent with Chiteculo & Surovy (2018), who found that anthropogenic activities are the most important factors influencing the structure and dynamics of Miombo forest regeneration in Angola.

6.8. Conclusions

The structure and species composition of Miombo woodland in the study area reveals a typical Miombo ecosystem, as Miombo-defining species dominate it. We discovered that all land use types in the area are dominated by an abundance of young woody individuals in the lower diameter classes, which characterizes the most natural and will be promising for the future of forest cover in the areas. The AAL land-use type had more regenerated individuals than the other two, indicating that Miombo is a resilient ecosystem.

Fabaceae was the dominant species in all land-use types in matured, and regeneration stands. Regarding species richness, DMWL and OMWL had high and low species richness, respectively, whereas AAL had a medium species richness. Miombo species have a remarkable ability to regenerate, even when disturbed regularly. The intensity and frequency of disturbance factors may influence the recovery process. Although Miombo-defining species dominate the area, different disturbance factors affecting Miombo woodland regeneration have been identified, most of which are linked to human activities. Even though most communities have access to restoration information, there are no assisted restoration activities in the park's buffer zone. Our findings highlight the importance of diversifying income streams, such as tourism, and creating a market value chain for the community's products to reduce their reliance on slash-and-burn agriculture. We also believe that the park's integration with the surrounding community should be strong enough to protect the park from degradation while also ensuring the community's livelihood.

CHAPTER 7. GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

7.1. Introductions

This study sought to assess the causes of the loss of Miombo woodland and factors affecting its regeneration in the context of human livelihoods and sustainable conservation in the buffer zone of GNAP, central Mozambique. The study's overall objective was to contribute toward the sustainable conservation of Miombo woodland and associated ecosystem services in a semi-arid savanna ecosystem dominated by varying human activities using a case study at the buffer zone of GNAP, central Mozambique. The specific study objectives were: (i) to evaluate Land Use and Land Cover Changes of GNAP Buffer Zone Central Mozambique, (ii) to identify the Socio-economic and ecological impacts of deforestation and forest degradation on Resident's community livelihood at GNAP buffer zone, (iii) to explore the regeneration and restoration status of Miombo woodland in the buffer zone of GNAP central Mozambique, and (iv) To identify and measure the diversity of regenerated woody species in the buffer zone of GNAP. In this Chapter, the significant findings of the study (Chapters 4-6) discussions on the scientific contributions, societal and policy implications are integrated and synthesized.

7.2. Summary of Findings and Discussions

In Chapter 4, the case study highlighted Socio-economic and ecological impacts of deforestation and forest degradation on local livelihoods as well as measuring household's forest dependency at the buffer zone of GNAP, central Mozambique. It was reported by the respondents as D&D impact the communities' livelihood socio-economically and ecologically through loss of economic woody species, loss of wild edible food sources and creating the scarcity of fertile land in the study area. Though, the ultimate impact of D&D is on human health it impacts socially, economically, ecologically and agriculturally on the overall quality of life of any nation (Wajim, 2020). Although various forest products were collected from the buffer zone of the park, it was reported that firewood, thatch grass, medicinal plants, and wild fruits were the most collected products by communities in the area. The study identified that all communities used forest products home utilization and selling to get cash, which is a clear indication that the area's forest helps regulate the area's economy. The majority of all households' primary income came from agriculture. Income derived from the forests contributes about 33 % to the total income of all households. The average annual income derived from forest resources per household was

US$161.25. It was identified that age, number of residing years in the area and educational level of the respondents, made a statistically significant contribution towards predicting forest dependency of the communities in the study area. Although communities used most of the woody species for more than one purpose, in respective to most preferred species for different uses they listed *Annona senegalensis, Erythrophleum africanum, Pericopsis angolensis,* and *Parinari curatellifolia* as most preferred one.

In Chapter 5, significant differences were recorded on Land use land cover change across the five defined land use categories, at the buffer zone GNAP central Mozambique. It was identified that Dense Miombo woodland and open Miombo woodland are the most dominant land cover classes, in 1999 representing about 43.61 and 28.95% of the total land use respectively whereas agricultural land covers only 12.79 % of the total land cover. But by 2019 the coverage of open Miombo woodland and agricultural land were increased than dense Miombo woodland proportionally, indicating that LULCC is intensified in the area. It was identified that Miombo woodland loss and its deforestation rate in the buffer zone of GNAP from 1999 to 2019 showed an increment. In 1999, forested land was about 83.98 % of total area on GNAP buffer zone. Since then, the DMWL had decreased by 20.24 % from1999 t0 2009 and decreased by 5.39 % from 2009 to 2019. Within 20 years or the study period dense Miombo woodland was decreased by 22,658.1 ha, which tell us that 14.85 % of 1999 DMWL has been changed to other land uses. The rate of forest loss (Miombo woodlands) for the entire study period (1999-2019) was 1,237.14ha/yr. The highest annual rate of deforestation (4.05%) recorded from 1999 to 2009. Agricultural land expanded at the buffer zone of GNAP from 1999 to 2019 by 16 % of 1999 agricultural land cover. Much of this forest has been dense and open Miombo wood lands. Small frontier farmers living on the edge of forests drive much of the developing world’s deforestation by cutting down forests for expanding agricultural land and settlement (FAO, 2010b).

Most land conversion from natural states to human uses is happening in the developing world, where population growth is most prevalent. The case of GNAP buffer zone also verifies this situation. The temporal rate and spatial extent of forest loss were largely affected by expansion of agricultural land, population increment and climate change (Crouzeilles & Curran, 2016). The present study has also shown that continued new settlements, expansion of agricultural land illegal logging by forest concession holders, and shortage of information about natural resource management has accelerated land use land cover change in the study area. According to response from the household's, cause of LULCC related to slash and burn agriculture in the study area is linked to looking for fertile and productive land. Land-use patterns are considered the most direct indicators of human activities (Jiang & Yu, 2019). Land cover change has prompted major environmental changes at local, regional, continental, and global scales, and the magnitude of land cover changes at this historical moment is unprecedented (Grekousis et al., 2015).

Chapter 6, the study findings showed that there was a significant difference in stand density between DMWL and OMWL as well as between DMWL and AAL, nevertheless no significant difference between OMWL and AAL. Fabaceae is the most diverse family, followed by Rubiaceae. Across all land-use types about 48.6% and 9.2% of woody species were from the family of Fabaceae and Loganiaceae respectively. About 57.14 % of Species were similar between AAL&DMWL whereas the similarity between DMWL&OMWL, and AAL&OMWL were about 53.97, and 47.88%, respectively. High species diversity was registered in DMWL whereas low species diversity registered in OMWL. Species diversity is the most often used depiction of ecological diversity (Gonçalves et al., 2018; Hamilton, 2016). Concerning regenerations, about 70 species from 23 families was registered. Regeneration density was significantly different between each land use type and was high in AAL. Fabaceae family was the most regenerated family, followed by Anacardiaceae. Concerning species evenness high evenness was recorded in AAL and OMWL. The study findings identified that there was no assisted restoration activity in area. About 45.5% and 6.5% of the respondent ranked slash and burn agriculture and grazing by animals as first and last factors affecting regeneration of Miombo woodland respectively. The present study provided the scientific information on status of Miombo woodland under different land use categories as well as the present land use and land cover change for GNAP buffer zone and this could inform decision-makers in land use planning and zonation to delineate communal land use from the buffer zone of the park.

7.3. Scientific Contributions of the Study

Spatio-temporal assessment of the land use land cover change trends as demonstrated in the present thesis help in understanding land use change at the buffer zone of National park due to human pressure and natural disturbances under a varying land use categories (Ogato et al., 2021). The study propositions were confirmed that area with low disturbance hypothesis that stipulate that maximum diversity and infrequent disturbance can trigger low diversity due to competitive exclusion by dominant settlers, whereas, frequent disturbance cause low diversity (Chazdon et al., 2020). The results also support the argument that Miombo vegetation systems are inherently unstable and are maintained by interactive disturbances across scales (Gonçalves et al., 2018; Kalaba et al., 2013; Mapaure & Moe, 2009; Njoghomi et al., 2020).

In Chapter 6, a concept for the assessment of status of regeneration of Miombo woodlands at the buffer zone of GNAP is presented. This set of conceptual framework is expected to explain the relationship between regeneration, factors affecting regeneration, and regeneration status quo in the Miombo woodland under varying land use types. Based on this framework, this thesis explored three bodies that have evolved somewhat separately, yet are inherently interconnected: (i) disturbance factors, (ii) regeneration of Miombo woodland, and (iii) present circumstances of regeneration in the Miombo woodland. The thesis then developed an improved and modified conceptualization after the study findings about relationships among the three themes (regeneration, disturbance factors and regeneration status quo) within the context of a typical Miombo woodland ecosystem under buffer zone (Figure 7.1). Recognizing these interconnections can help in the development of policies that are more effective in programming for sustainable management of woodland resources in the buffer zone thereby enhancing livelihoods/ecosystem based adaptation in the face of equilibrium driven disturbances on woody vegetation (Mawdsley et al., 2009; Tuffa, 2022).

Based on the study findings, in the modified conceptual framework (Figure 7.1), the study proposed the process of participatory woodland management and diversifying income source to combat Miombo woodland degradation and warranty its regeneration which may need to incorporate the following: (i) establishing current woodland ecosystem outcomes/impacts influenced by the identified disturbance factors by taking in to account its seriousness at the buffer zone of the park which is critical for the formulation of relevant intervention strategies in the land use planning or zoning based on conservation or restoration ecology concept for the National Park as indicated in Chapters 4, 5 and 6, and (ii) undertake a legal review to incorporate land use planning for activities undertaken to be inclusive of considerations for land use planning designs to facilitate an enabling national framework as a basis for policy formulation of strategies to tackle impacts of human encroachment onto the protected areas.

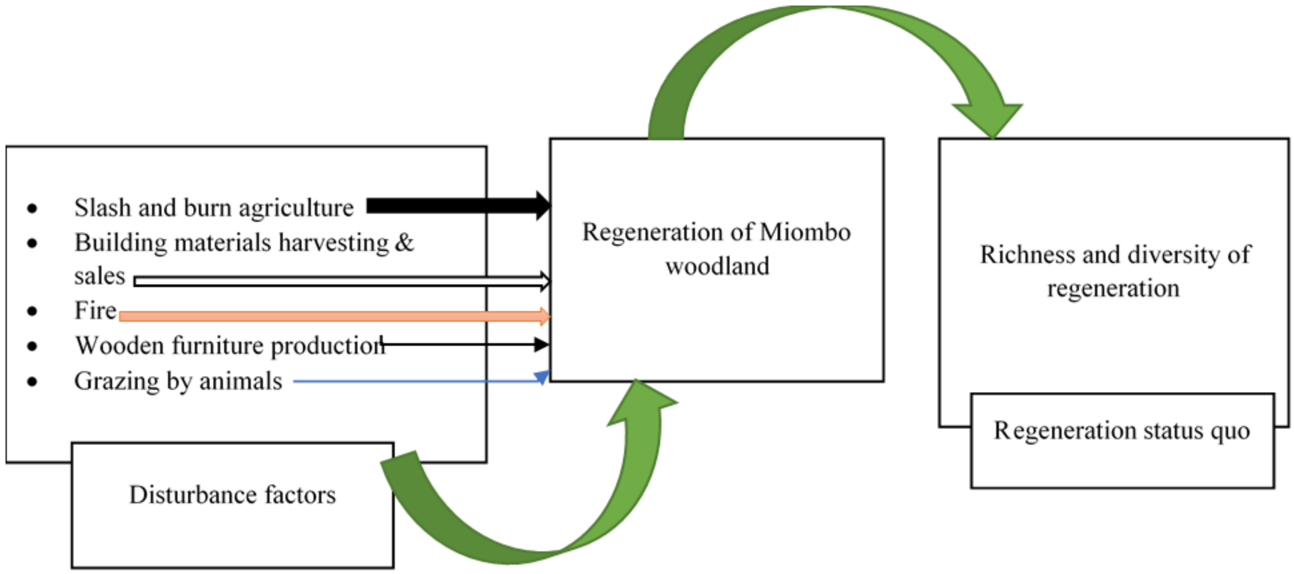

Figure 7.1. Modified general conceptual framework about regeneration of Miombo woodland and its disturbance factors, 1st ranked disturbance factors (large black arrows), 2nd ranked disturbance factors (Hallow arrow), 3rd identified disturbance factors (large orange color arrows),4th identified disturbance factors (black thin arrows) and 5th identified disturbance factors (blue arrows).

The modified framework enhances understanding the type and rank of disturbance factors on Miombo woodland regeneration and its influence on land use and land cover changes plus sustainable conservation in an African savanna (Balehegn & Hintsa, 2018) The study results can also be the basis to (i) monitor the status of woody vegetation in the buffer zone of the park against the free intrusion of all activities in Mozambique which are evidently free and open for exploitation in most of the country's protected areas buffer zone example like GNAP National Parks and Gorongosa National Park (Matos et al., 2021; Montfort et al., 2021), (ii) incorporating the requirements of policy enactment to address Land use land cover change and D&D as it impact on the socio-economic aspects of sustainable human livelihoods in the buffer zone of protected areas, and (iii) promoting awareness and implementation of community based woodland management, equity and good governance of Miombo woodland in buffer zone.

The conceptual framework shows that in a Miombo woodland ecosystem, anthropogenic and natural disturbance factors can interact under uniform climatic and edaphic factors to influence the woody vegetation dynamics as well as availability and importance of the woody vegetation ecosystem goods to contribute to the human well-being as postulated by the sustainable human livelihood theory (Hart & Kleinman, 2018; Meigs & Keeton, 2018). The conceptual framework of the study confirms that there are non-climatic stressors like land clearance for agriculture, fire and illegal logging which give rise to biophysical and socio-economic impacts within a Miombo woodland. The framework further shows that national and local responses are critical in addressing disturbance impacts for promotion of ecosystem based adaptation and restoration ecology.

Moreover, the thesis outlined the literature and theoretical foundations of the thematic areas which can be used to understand the status of socio-ecological systems in the face of utilization of woody vegetation in savanna ecosystem (Baker et al., 2018). The thesis contributes knowledge to three complementary theories (sustainable livelihood, social exchange, and the intermediate disturbance) related to global environmental change in regards to woody vegetation, socio-ecological systems, and sustainability (Baker et al., 2018; Turkelboom et al., 2018). This approach of scientific knowledge contributions applied by the present study is based on the premise that understanding woody vegetation dynamics entails complex ecological knowledge which is the biggest threat to global sustainability, applying the complex and interdisciplinary concept of sustainability of both human livelihood and natural ecosystems (Meigs & Keeton, 2018). Dovie et al. (2008), discovered how communities apply the social, political, or economic capital to implement known solutions to the impacts of disturbances on woodlands. The present study gathered existing knowledge and revealed critical knowledge gaps on potential pathways of influence to improve social, environmental, and economic conditions for sustainable utilization and management of woodland which is suitable particularly for the rapidly developing regions of the world. In doing so, the present study identified key synergies between sustainable human livelihood strategies, land use cover change and sustainable woodland management under tropical savanna vegetation.

The study also contributed knowledge to the link between land use land cover change and its causes as similarly done by (Meigs & Keeton, 2018) . The variation of LULCC due to the different causes in a serious of time were characterized by Landsat image pre- processing, classification, and post-processing change assessment values for the period 1999-2019 (Chapter 4). The large prominence of decreasing area coverage of DMWL and OMWL were a sign of an ongoing degradation/fragmentation of Miombo woodland cover, which was a confirmation of previous related studies on woodland vegetation in Mozambique (Matos et al., 2021; Montfort et al., 2021). The decreasing area coverage of DMWL was more found in the area, which revealed the relevant role played by humans in buffer zone in the context of anthropogenic causes on woody vegetation. Whereas, the increasing area of AL in the buffer zone of the park was relatively intact with an increasing population number and consecutively demand for agricultural land expansion through the study period.

The study also contributed knowledge to the linkage between Miombo woodland regeneration and factors affecting its regeneration. The variation of regeneration sapling across each land use type due to the different disturbance factors were discovered by measuring and recording number of regenerated sapling of all species for each land use type (Chapter 6). The increased number of sapling in AAL were a sign of an ongoing degradation/fragmentation of Miombo woodland, which was a confirmation of previous related studies on Miombo woodland in Mozambique (Montfort et al., 2021; Ribeiro et al., 2020) and in Angola (Gonçalves et al., 2018).

The study equally contributed knowledge about restoration of Miombo woodland in the study area. Although restoration is the basic for the recovery of forest degradation, by this study we identified that there are no any restoration activities takes place. So the result of this finding will help the policy developers and decision makers (be a government or NGOs) to take action as a remedy for the degrading woodland in the study area as particular and in country as general. It also contributed information about household's forest dependence by identifying that community in the area have no option than forest resource for their livelihood and suggesting maintaining and conserving forest resources should be mandatory as it connected to community's day to day life.

7.4. Societal Contribution of the Study

The study findings provided evidence of the importance of Miombo woodland ecosystem goods for human well-being, especially in terms of sustainable livelihood's and beyond just provisioning services in buffer zone of GNAP of Mozambique, where it was recorded woodland resources contribute 33 % annual Income per household. As such evidence is availed by the present study, it provides a solid platform with which to engage decision-makers on sustainable Miombo woodland ecosystem management and land use planning (Duguma et al., 2019). Moreover, direct dependence on goods from woodland ecosystems is high amongst people living in remote, arid and semi-arid lands where alternative livelihood options are often limited and environments are particularly fragile and risky (Millennium Ecosystem Assessment, 2005; Piabuo et al., 2018) . It is identified by the present study that D&D were mostly caused by the resident community and forest concession holders, which used for decision makers while they try to take action for solving the problem. These actions can range from policy, i.e., creating the enabling conditions for integrated responses and successful implementation, to specific livelihood strategies, programs, planning frameworks or 'tools' for intervention that may operate at a variety of scales, to processes such as multi-stakeholder decision-making, and finally to local innovations and adaptations at community and household level e.g., education and awareness raising for behavioral change, cooperation and integration between sectors, building capacity, economic incentives for more sustainable use of woodland ecosystem goods, local land and woodland resource management approaches, research and monitoring for decision-making, technological solutions as outlined in broad areas by the Millineium Assessment on Ecosystems (see Millennium Ecosystem Assessment, 2005).

Some interventions may be designed as proactive, i.e., designed to promote better Miombo woodland ecosystem management for enhanced livelihoods security and poverty alleviation (such as devolved, participatory and integrated responses to woodland ecosystem management like CBNRM, while others may be reactive in response to a crisis or in recognition of the declining capacity of natural ecosystems to deliver services (e.g., rehabilitation and restoration programs). Sometimes the entry point may be poverty alleviation (as in Poverty Reduction Strategy Papers (PRSPs) or other poverty action plans), while in other instances natural ecosystem management may be the key objective with subsequent positive impacts on poverty (Brashares and Gaynor, 2017).

Societal significance contribution of the present study can lie in the recommendation diversifying the source of income for the community which reduce the pressure from Miombo woodland of the buffer zone and lastly reduce exploitation chance of the National Park. The present study highlighted that woodland ecosystems in as much as they are threatened by disturbances are among the world's most productive land-based ecosystems and are essential to sustainable human livelihood. The United Nations Strategic Plan for Forests 2017-2030 (UNSPF) provides a global framework for actions at all levels to sustainably manage all types of natural forests and woody vegetation outside forests and halt deforestation and woodland degradation (UNESCO, 2015).The UNSPF also provides a framework for natural forest and woodland related contributions to the implementation of the 2030 Agenda for Sustainable Development, the Paris Agreement adopted under the UN Framework Convention on Climate Change, the Convention on Biological Diversity, the United Nations (UN) Convention to Combat Desertification, the United Nations Forest Instrument (UNFI), and other international forest and woodland related instruments, processes, commitments and goals (Climate Focus, 2017).

The present study highlighted that woodlands, however, are inextricably linked to the livelihoods of human communities for sustainable human livelihood development. Conversely, conservation sometimes directly opposes both livelihood development and the use of their natural resources (Malhi et al., 2014). As the global population continues to rapidly expand and the world becomes increasingly globalized and politically polarized, the trade-offs between the conservation of forests and the extraction of their resources will become ever more complex (Seymour & Busch, 2016). As habitat to many of the globe's most biodiverse ecosystems, most expansive carbon stores, and most heavily depended-upon ecosystem services, many ecologists take a strict non-consumptive conservation approach standpoint when it comes to the management of tropical savanna vegetation (Hartshorn, 1995). Thus, the present study provokes the need to balance the harvesting versus protection dichotomy to manage the remaining woodland at the buffer zone and even the National Park. Competition for resources and lack of incentives to act for the common good, argued Hardin (1968) lead individuals to make decisions that have negative impact for the conservation of resources. However, as pointed out in Chapter 4-6, cause for LULCC, D&D as well as factors affecting regeneration of Miombo woodland linked to human activities like looking for agricultural land and state-centric technical approaches to natural resource management showed not to be the cure implied in Hardin's arguments in relation to common resource property management.

7.5. Management and Policy Implications

Knowledge on the socioeconomic and ecological impacts of D&D, about regeneration dynamics of Miombo woody species and land use land cover change at the buffer zone of National Park are vital in sustainable human livelihood, conservation biology and management of protected area (Habtamu et al., 2017; Matowo et al., 2019b; Mekonnen et al., 2018), particularly for practical management and formulation of conservation status decisions (Molnár et al., 2010). The natural resource conservation sector needs supporting policy documents which can be used as a basis to identify and respond to the socioeconomic and ecological impacts of D&D on human livelihood. The National Parks sectors should also needs supporting policy documents by forming cooperation with community at the buffer zone to safe the National Park from degradation and equally maintaining the livelihoods of the community surrounding the park. Assessing the relationship between power dynamics on right and access to woodland resources is important for the improvement of the ability of National Park managers to mitigate predicted woodland degradation in the buffer zone of protected area (Nyirarwasa et al., 2020).

This study reported in Chapter 5, on increasing LULCC, and deterioration of Miombo woodlands as some of the key impacts of excessive usage of the buffer zone. The findings can complement future scientific studies to inform management on the most appropriate response strategies in forest and land use management in Mozambique. The key management implication is that Mozambique and related southern African countries need to mainstream international legislation on natural forestry and wildlife management legislation while taking advantage of the knowledge and technologies available to monitor woodland dynamics, land use and land cover changes to manage the wildlife sector and human livelihoods more sustainably (UNESCO, 2015).

In this study, local communities, demonstrated their reliance on Miombo woodland ecosystem for sustainable human livelihoods, however, there is need to address power dynamics at play which is in favor of the traditional rural leadership in claiming and accessing woodland resources in the buffer zone with responsibly and sustainably. Based on the study findings, the policy development should process to facilitate household engagement with care and responsible to claim and access to woodland resources and getting their share from what they conserved in rural Mozambique.

Dependent on the woodland resource base and their understanding of the options available, different land use categories develop and pursue different strategies for the utilization of woody vegetation. These strategies include short-term considerations such as ways of coping with shocks and managing risk. Woodland utilization in buffer zone of National Park can be positive, helping households become more resilient or negatively threatening woody vegetation as the case of the present study findings in GNAP of Mozambique.

7.6. Limitations of the Study

Generally, for the whole study issue of language was very challenging for the researcher. In addition to language barriers the outbreak of COVID-19 also was another challenging the study faced. For Chapter 4, As it is reported there are some standard methods for image preprocessing, it is also reported there are no super image classifiers that can be uniformly applicable to all applications (Rozenstein & Karnieli, 2011). Thus, it was a challenging task to apply effective classifiers or to produce new classifiers suitable for specific applications of the study area for land use and land cover mapping. However, ancillary data, topographical features, environmental characteristics were used to get a more satisfactory result or to increase classification accuracy. Furthermore, for Chapters 5 and 6 less literature specific to that area regarding Miombo woodland and implementation of buffer zone rules. Therefore, the researcher constantly had to make intuitive links and interpretations based on local information derived from the local people of the study area. Similarly, government departments and non-state agencies are not well structured to deal with Miombo woodland ecosystem and sustainable human livelihood in an integrated manner in the area.

7.7. Conclusions

The study sought to assess the Socio-Economic and Ecological Impact of Deforestation and forest degradation, Regeneration and Restoration Status of Miombo Woodland Following Land Use Land Cover Changes at the GNAP buffer zone in central Mozambique. It aimed at identifying the cause of land use land cover change and D&D as well as the status of restoration for contributing towards the sustainable conservation of woodland communities and associated ecosystem goods in the Miombo ecosystem dominated by varying land use types using a case study of the buffer zone of GNAP, Mozambique. The assessment of the Regeneration and Restoration Status of Miombo Woodland following Land Use Land Cover Changes across varying land use types concluded that there were differences in the vegetation structure, abundance and diversity. Different disturbance factors in each land use type are likely to persist in the buffer zone of the GNAP.

Determining the Socio-Economic and Ecological Impact of D&D in the area concluded that local people and concession holders derive economic benefits from woodland resources, with the role of traditional leaders in woodlands governance still neglected by government forestry extension services giving room for over exploitation. The decisive intervention of local government extension agents and clearly defined roles and responsibilities for the involvement of traditional leadership in buffer zones woodland management is a promising way to combat the loss of Miombo woodland cover and ensure sustainable Miombo woodland management across the study area. The analysis of the socio-economic and ecological impact of D&D on livelihood in the buffer zone of GNAP concluded that the farming community incur economic and financial gain per household, which is likely valuable to household food security. The main drivers of LULCC in the study area were linked to human activities like agricultural expansion. In order to establish historical and future land use and land cover dynamics across the buffer zone of GNAP in central Mozambique, the study highlighted the resultant diminishing woodland cover mainly due to agricultural land clearance over time.

The study highlighted knowledge gaps by recording that woodland resources contribute 33% of Annual Income per household. As the present study avails such evidence, it provides a solid platform to engage decision-makers on sustainable Miombo woodland ecosystem management and land use planning (Duguma et al., 2019). It was recorded that the current land use and land cover change provide short-term survival and benefits rather than sustainable management of the natural resource capital of Miombo woodlands. It was highlighted that the prevailing land tenure, local governance controls on access and the current utilization of Miombo woody vegetation is detrimental to the stable state of woody vegetation in the buffer zone of GNAP, central Mozambique.

Based on the study's overall findings, it was generally concluded that anthropogenic induced disturbances were the main drivers of Miombo woody vegetation dynamics across the study area as woodland resources are utilized for socio-economic benefits linked to human livelihood. The study results confirmed the intermediate disturbance hypothesis (IDH) theory on Miombo woodland utilization across different land use categories, with the buffer zone recording the highest diversity of woody species.

The study highlighted the resultant diminishing woodland cover mainly due to agricultural land clearance from 1999 to 2009 across the buffer zone of GNAP of Mozambique. The study also concluded that formal and informal institutions in the study area do not adequately implement policy pronouncements related to sustainable Miombo woodland management as they focus more on agricultural land use management and the socio-economic use of woodland resources for human resources' livelihood.

7.8. Recommendations

It was recommended that there was need to revisit and explain the land use management plan and policy measures associated with woodland ecosystem services and goods provision for both protected areas and the rural communities in Mozambique. To reduce the effects and associated impacts of anthropogenic disturbances on Miombo woodland ecosystem in buffer zone of GNAP, the following is recommended: (i) revisit the community based woodland management concept, policy measures and law enforcement associated with woodland ecosystem services and goods provision for rural communities to allow for equal rights and equitable utilization and benefits derived from communal woodlands, (ii) engage the local communities and National Park authorities on woodland ecosystem management for sustainable goods and services promotion derived from protected area planning process, (iii) the local authorities could delineate the resettled the buffer zone of the park for human and agricultural settlement, whereas, the more intact part of the buffer zone can be exclusively reserved and protected, and (iv) local projects to secure woodland ecosystem services can certainly be useful (e.g., some CBNRM programs), but the functional scale of woodland ecosystems and their drivers is typically at larger spatial and temporal scales than at which such projects operate. Consequently, better management and appreciation of woodland ecosystem services and their role in alleviating poverty will be best achieved by interventions at the policy level, that serve to change the understanding, attitudes and values that policy-makers, planners and land managers have towards woodland ecosystem services. National Poverty Reduction Strategy Papers and Policy pronouncements need to explicitly include environmental components (Piabuo et al., 2018) ,while the importance and value of woodland ecosystem services needs to be mainstreamed into planning and decision making processes from local to national levels. It was overall recommended that Mozambique should consider aligning its woodland management policies and legislation with the Mozambique’s National Policy and Strategy for Management of Wildlife and Forestry through adopted by Cabinet Resolution Number (8/97 of April 1),which sets some principles for wildlife and forestry management which include: (a) conserving basic resources, including biological diversity; (b) involving people who are dependent on forestry and wildlife resources in the planning and sustainable use of such resources;

and (c) ensuring that communities benefit from wildlife resources. Similarly, the Wildlife and Forestry Law adopted in 1999 recommends an integrated management of natural resources that ensures effective participation of local communities, associations and the private sector. The study further recommended the need to revisit the Mozambique land reform policy associated with agricultural resettlement and law enforcement agents to be effective in sustainable conservation of woodlands and protected area areas in the country.

7.8.1 For Research

- Future studies could be undertaken on evaluating the association between the park and its boundaries with consideration of communities' livelihood and ecology of the area.
- Future studies could be undertaken on land use and land cover changes by considering policy related factors in buffer zone of GNAP, central Mozambique based on biophysical and socioeconomic factors, policies that influence the behavior of local people on encroaching into protected area or communal woodland utilization.

7.8.2. For Policies

- The land use and land cover change maps produced in this study can be used as reference tools for decision making to enforce laws on Miombo woodland conservation at the buffer zone of the park. These maps can be used to highlight the issue of woodland loss which should necessitate the need for awareness campaigns to combat desertification and to take appropriate decisions for sustainable woodland management and practices in the buffer zone of the GNAP of Mozambique.
- The conservation organization takes the output of this finding which is about restoration and add to their plan and implement to protect forest of the country from depletion as general and National Park specifically with considering the livelihoods of the communities.

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APPENDIXES

Appendix-1A Average annual income earned from different sources in sampled communities in ($)

community	Forest income													Non-forest income			Forest dependency index
	Fire wood	Charcoal	Medicine	Fibers	Pols	thatch grass	Mushroom	wild fruit	Bush meat	fish	Wood (timber)	Honey	Total forest income	Agriculture	Labor	Total Non-forest income	
CM1(n=50)	11	9	20.4	18	19.5	17	6	22	16	16.6	26	7	190	267	62.5	329	0.6
CM2(n=50)	14	20.5	12	3.4	37.5	21.3	2.5	5	5.7	14	16.5	3.6	156	291	78	369	0.5
CM3(n=50)	-	14	17	-	14	12	15.6	12.6	23	23.5	24.7	25.7	181.68	293	-	292.7	0.6
CM4(n=50)	8.75	10.7	13.4	12	14.8	14.5	2.3	5	6	13	14	3	118	191	156	347	0.3

CM1=North, CM2=South, CM3=east and CM4=west

Appendix-1B Average annual income earned from different sources in sampled communities in (MNZ)

Community	Forest income													Non-forest income			Forest dependency index
	Fire wood	Charcoal	Medicine	Fibers	Pols	thatch grass	Mushroom	wild fruit	Bush meat	fish	Wood (timber)	Honey	Total forest income	Agriculture	Labor	Total Non-forest income	
CM1(n=50)	720	577	1303	1165	1250	1092	403	1415	1045	1063	1658	459	**12148**	17,063	4000	21,063	0.6
CM2(n=50)	883	1310	789	216	2403	1366	165	329	366	900	1053	233	**10012**	18627	5000	23627	0.5
CM3(n=50)	0	885	1086	0	900	742	1000	805	1466	1512	1583	1650	11628	18734	-	18734	0.6
CM4(n=50)	560	683	855	774	950	925	150	320	380	850	900	200	7547	12207	10000	22207	0.3

Appendix 2. Land cover transition matrix in GNAP buffer zone, 1999 to 2019 (km^2)

To	2009	DMWL	OMWL	SL	AL	WB	OT	Total	Loss
From 1999	DMWL	**196.37**	369.39	23.64	34.76	0.47	40.71	665.33	468.97
	OMWL	89.39	**262.44**	7.91	38.72	0.83	42.46	441.75	-88.12
	SL	38.02	89.33	**9.50**	14.27	0.45	22.76	174.33	164.83
	AL	23.83	86.49	2.40	**52.48**	0.48	29.42	195.10	142.63
	WB	7.51	16.63	0.99	3.61	**1.39**	2.81	32.94	31.55
	OT	1.42	5.76	0.42	2.93	0.48	**5.31**	16.33	11.02
	Total	356.54	830.04	44.86	146.77	4.10	143.48	1525.79	
	Gain	160.17	567.60	35.36	94.29	2.71	138.17		
To	2019	DMWL	OMWL	SL	AL	WB	OT	Total	Loss
From 2009	DMWL	**156.40**	151.29	23.56	21.86	0.13	3.29	356.54	200.14
	OMWL	226.22	**383.08**	102.06	102.23	0.64	15.81	830.04	446.96
	SL	31.74	8.31	**2.47**	1.40	0.11	0.84	44.86	42.40
	AL	10.49	46.42	15.08	**68.19**	0.02	6.56	146.77	78.57
	WB	0.69	0.42	0.87	0.38	**1.22**	0.52	4.10	2.88
	OT	13.29	37.26	40.84	39.71	0.25	**12.13**	143.48	131.35
	Total	438.83	626.79	184.88	233.77	2.38	39.14	1525.79	
	Gains	282.43	243.70	182.41	165.58	1.16	27.02		

DMWL—Dense Miombo woodland, OMWL—Open Miombo woodland, SL—Shrub land, AL—Agricultural land, WB—water-body, OT—others

Appendix 3 Information about Population, agricultural expansion and Miombo wood lands.

No	Items	Unit	**Year**		
			1999	**2009**	**2019**
1.	Population	Number	17,244,188	22,894,710	29,496,004
2.	Agricultural Land expansion	ha	19517.13	14681.61	23385.42
3.	Annual Change of Forest Area	ha	128184.8	123186.2	125091.9

Source: For population: (FAOSTAT_data_8-17-2020 for population data of the country, and own calculation for Agricultural Land expansion and Annual Change of Forest Area of GNAP

Appendix 4: Stand structure of woody species and IVI of the three land use type. DMWL = Dense Miombo Woodland; OMWL = Open Miombo Woodland and AAL = Abandoned Agricultural Land.

Species	Relative Frequency			Relative Density			Relative Dominancy			IVI		
	DMWL	OMWL	AAL	DMWL	OMWL	AAL	DMWL	OMWL	AAL	DMWL	OMWL	AAL
Acacia Karroo	0.21	-	0.42	0.74	-	1.17	-	-	0.01	0.94	-	1.59
Acacia Nilotica	0.31	0.49	0.63	0.74	0.49	1.17	0.01	0.01	0.23	1.05	0.98	2.03
Afzelia Quanzensis	0.82	-	-	0.37	-	-	0.10	-	-	1.29	-	-
Albizia Adianthifolia	-	-	1.25	-	-	1.17	-	-	0.33	-	-	2.75
Albizia Versicolor	0.51	0.24	1.46	1.10	0.24	1.75	0.14	0.04	1.16	1.76	0.53	4.37
Amblygonocarpus Andongenis	0.31	-	-	0.74	-	-	0.09	-	-	1.13	-	-
Anacardium Occidentale	-	-	2.08	-	-	1.75	-	-	1.77	-	-	5.61
Annona Senegalensis	2.05	4.40	6.67	2.21	4.40	5.26	0.57	2.10	5.76	4.83	10.91	17.69
Balanites Cf Maughamii	0.10	-	-	0.37	-	-	-	-	-	0.47	-	-
Balanites Pedicellaris	0.21	-	-	0.74	-	-	-	-	-	0.94	-	-
Bauhinia Petersiana	0.10	-	0.42	0.37	-	0.58	-	-	0.10	0.47	-	1.10
Brachystegia Boehmii	9.45	5.87	8.96	4.04	5.87	2.92	34.44	24.47	21.73	47.93	36.21	33.61
Brachystegia Bussei	0.21	-	-	0.37	-	-	-	-	-	0.57	-	-
Brachystegia Spiciformis	8.52	4.89	12.08	4.41	4.89	4.09	16.05	6.01	21.66	28.99	15.79	37.84

Brackenridgea Zanguebarica	0.72	-	-	1.10	-	-	0.08	-	-	1.90	-	-
Bridelia Micrantha	-	-	0.21	-	-	0.58	-	-	-	-	-	0.79
Burkea Africana	1.03	3.91	3.13	2.21	3.91	4.68	0.31	2.65	1.95	3.54	10.47	9.76
Byrsocarpus Orientalis	-	0.49	-	-	0.49	-	-	0.03	-	-	1.01	-
Caesalpinia Rubra	-	0.24	-	-	0.24	-	-	-	-	-	0.49	-
Cassia Petersiana	0.41	-	0.21	0.37	-	0.58	0.02	-	-	0.80	-	0.79
Catunaregam Obovata	1.75	3.91	2.08	1.47	3.91	2.34	0.18	2.38	0.34	3.40	10.20	4.76
Catunaregam Spinosa	1.64	0.73	-	2.21	0.73	-	0.13	0.05	-	3.98	1.51	-
Combretum Adenogonium	-	-	0.21	-	-	0.58	-	-	-	-	-	0.79
Combretum Molle	0.21	-	0.42	0.74	-	0.58	0.01	-	0.03	0.95	-	1.03
Combretum Zeyheri	2.87	1.71	3.13	2.21	1.71	2.92	0.73	0.65	1.56	5.81	4.07	7.61
Commiphora Africana	0.72	0.73	0.21	1.10	0.73	0.58	0.03	0.02	-	1.85	1.49	0.79
Crossopterix Febrifuga	0.10	-	-	0.37	-	-	-	-	-	0.47	-	-
Dalbergia Melanoxylon	0.10	0.73	0.63	0.37	0.73	0.58	-	0.13	0.08	0.47	1.60	1.29
Dalbergia Nitudila	4.11	0.98	1.67	1.84	0.98	2.34	1.12	0.11	0.57	7.07	2.06	4.58
Diospyros Mespiliformis	0.51	-	-	1.84	-	-	0.02	-	-	2.37	-	-
Diospyros Sp	-	-	0.21	-	-	0.58	-	-	0.07	-	-	0.86
Diospyros Verrucosa	1.33	0.98	2.29	2.21	0.98	2.34	0.46	0.29	1.48	4.00	2.25	6.11

Diplorhynchus Condylocarpon	2.98	5.38	1.46	2.94	5.38	1.75	0.68	2.28	0.45	6.60	13.04	3.67
Dombey Cf Rotundifolia	1.75	1.96	3.54	2.21	1.96	2.34	0.51	1.16	3.82	4.46	5.07	9.70
Entada Abyssinica	0.31	-	-	0.37	-	-	0.01	-	-	0.69	-	-
Erythrophleum Africanum	3.90	9.78	4.17	4.04	9.78	4.09	2.44	18.38	2.62	10.38	37.94	10.88
Flacoutia Indica	0.31	-	-	0.37	-	-	0.01	-	-	0.68	-	-
Garcinia Livingstonei	-	-	0.21	-	-	0.58	-	-	-	-	-	0.80
Gardenia Thunbergia	-	0.49	-	-	0.49	-	-	0.01	-	-	0.99	-
Gardenia Volkensii	0.10	0.49	-	0.37	0.49	-	-	0.01	-	0.47	0.99	-
Grewia Transzambesica	2.36	-	-	0.37	-	-	0.31	-	-	3.04	-	-
Holarrhena Pubescens	-	0.24	-	-	0.24	-	-	-	-	-	0.49	-
Hugonia Orientalis	0.82	0.24	0.42	2.94	0.24	0.58	0.04	-	0.03	3.81	0.49	1.03
Hymenocardia Acida	0.72	3.42	-	1.10	3.42	-	0.02	0.90	-	1.84	7.75	-
Hyphaene Coriacea	0.10	-	-	0.37	-	-	0.02	-	-	0.49	-	-
Julbernardia Globiflora	10.06	4.16	5.83	5.15	4.16	4.68	23.46	5.44	9.28	38.67	13.76	19.79
Keetia Venosa	0.21	-	-	0.74	-	-	0.01	-	-	0.95	-	-
Lannea Schimperi	0.31	-	1.04	1.10	-	1.75	0.03	-	0.20	1.44	-	3.00
Lannea Stuhlmanii	0.62	0.24	2.08	1.84	0.24	3.51	0.03	-	0.54	2.48	0.49	6.13
Locola-Mulupali	-	0.73	-	-	0.73	-	-	0.02	-	-	1.49	-
Mangifera Indica	-	-	2.29	-	-	1.17	-	-	0.83	-	-	4.30

Maprounea Africana	0.10	0.98	-	0.37	0.98	-	-	0.04	-	0.47	2.00	-
Margaritaria Discoidea Var. Triplosphaera	0.41	-	-	0.74	-	-	0.01	-	-	1.15	-	-
Markhamia Zanzibarica	0.21	1.22	2.08	0.37	1.22	2.34	0.02	0.30	1.57	0.59	2.74	6.00
Millettia Stuhlmannii	4.11	1.47	1.25	2.94	1.47	2.34	3.51	0.64	0.29	10.56	3.58	3.88
Mundulea Sericea	-	0.73	-	-	0.73	-	-	0.02	-	-	1.48	-
Ochna Natalitia	2.26	0.73	0.21	1.84	0.73	0.58	0.20	0.04	0.01	4.30	1.51	0.80
Ozoroa Obovata	0.92	0.49	0.63	2.21	0.49	1.17	0.06	0.03	0.06	3.19	1.00	1.85
Parinari Curatellifolia	2.46	3.18	0.83	1.84	3.18	0.58	0.88	0.94	0.05	5.18	7.29	1.47
Pericopsis Angolensis	1.85	1.22	1.25	2.94	1.22	2.92	0.55	0.48	0.82	5.34	2.93	5.00
Phyllocosmus Lemaireanus	0.21	0.98	-	0.74	0.98	-	-	0.05	-	0.94	2.01	-
Pseudolachnostylis Maprouneifolia	1.64	1.71	0.83	2.94	1.71	1.75	0.72	0.45	0.12	5.31	3.87	2.71
Ptaeroxylon Obliquum	-	0.24	-	-	0.24	-	-	-	-	-	0.49	-
Pteleopsis Myrtifolia	2.67	4.65	2.92	3.68	4.65	2.92	1.50	2.13	2.20	7.85	11.42	8.04
Pterocarpus Angolensis	3.39	8.80	1.67	3.31	8.80	2.34	2.67	17.51	0.38	9.37	35.12	4.39
Pterocarpus Rotundifolius	-	-	0.21	-	-	0.58	-	-	0.01	-	-	0.80

Rothmannia Engleriana	-	0.49	-	-	0.49	-	-	0.01	-	-	0.99	-
Sclerocarya Birrea	1.03	2.69	1.25	1.10	2.69	1.75	0.20	3.75	0.91	2.33	9.13	3.92
Securidaca Longepedunculata	-	0.24	-	-	0.24	-	-	-	-	-	0.49	-
Sterculia Quinqueloba	1.85	0.49	0.42	1.47	0.49	1.17	0.50	0.35	0.19	3.82	1.32	1.77
Strychnos Cocculoides	0.62	-	0.42	1.10	-	1.17	0.02	-	0.02	1.74	-	1.61
Strychnos Madagascariensis	8.52	4.89	10.83	4.41	4.89	8.19	6.28	3.60	15.09	19.22	13.38	34.11
Strychnos Spinosa	0.62	0.24	0.42	1.10	0.24	0.58	0.02	-	0.01	1.73	0.49	1.01
Swartizia Madagascariensis	1.03	0.98	1.88	2.57	0.98	2.92	0.24	0.19	1.23	3.84	2.14	6.03
Tamarindus Indica	-	0.24	0.63	-	0.24	1.17	-	-	0.16	-	0.49	1.95
Terminalia Cf Stenostachya	-	-	0.21	-	-	0.58	-	-	-	-	-	0.79
Terminalia Sericea	1.85	3.91	-	2.21	3.91	-	0.51	1.62	-	4.57	9.45	-
Uapaca Kirkiana	0.10	1.47	0.42	0.37	1.47	1.17	-	0.65	0.03	0.47	3.58	1.62
Uapaca Nitida	0.21	0.24	-	0.74	0.24	-	0.02	-	-	0.96	0.49	-
Vangueira Infausta	0.51	-	0.21	1.10	-	0.58	0.02	-	0.01	1.64	-	0.80
Vitex Payos	0.10	-	0.63	0.37	-	1.17	-	-	0.02	0.47	-	1.82
Ximenia Americana	0.10	-	-	0.37	-	-	-	-	-	0.47	-	-
Ximenia Caffra	0.10	-	0.42	0.37	-	0.58	-	-	0.01	0.47	-	1.01
Xylopia Aethiopica	0.10	0.24	0.42	0.37	0.24	1.17	-	0.01	0.01	0.47	0.50	1.60
Zanha Golungensis	0.21	-	0.63	0.37	-	1.17	-	-	0.18	0.58	-	1.97
Grand Total	100	100	100	100	100	100	100	100	100	300	300	300

Appendix 5. Regeneration species and IVI of the three land use type. DMWL = Dense Miombo Woodland; OMWL = Open Miombo Woodland and AAL = Abandoned Agricultural land

Species	Relative Frequency			Relative Density			Relative Dominancy			IVI		
	DMWL	OMWL	AAL	DMWL	OMWL	AAL	DMWL	OMWL	AAL	DMWL	OMWL	AAL
Acacia Nilotica	2.51	-	-	2.60	-	-	2.17	-	-	7.27	-	-
Afzelia Quanzensis	-	-	0.50	-	-	0.56	-	-	0.07	-	-	1.12
Albizia Adianthifolia	1.25	0.55	0.50	1.30	0.56	0.56	0.54	0.56	0.09	3.10	1.67	1.14
Albizia Versicolor	4.70	-	1.74	3.90	-	1.94	8.55	-	0.83	17.15	-	4.52
Amblygonocarpus Andongenis	-	-	1.24	-	-	1.39	-	-	0.38	-	-	3.02
Anacardium Occidentale	0.94	-	-	0.97	-	-	0.31	-	-	2.23	-	-
Annona Senegalensis	4.39	6.04	3.73	3.90	6.15	3.61	6.95	6.15	3.49	15.23	18.33	10.83
Balanites Pedicellaris	0.63	1.10	1.00	0.65	1.12	1.11	0.20	1.12	0.25	1.47	3.33	2.36
Bauhinia Petersiana	0.63	-	0.50	0.65	-	0.56	0.18	-	0.07	1.45	-	1.12
Brachystegia Boehmii	1.88	7.69	9.45	1.95	7.26	8.06	1.33	7.26	24.46	5.16	22.22	41.97
Brachystegia Bussei	-	1.65	1.74	-	1.68	1.67	-	1.68	0.93	-	5.00	4.34
Brachystegia Spiciformis	5.02	1.10	3.98	4.55	1.12	4.17	9.06	1.12	4.30	18.62	3.33	12.45
Brackenridgea Zanguebarica	0.31	1.10	1.00	0.32	1.12	1.11	0.03	1.12	0.25	0.67	3.33	2.35
Burkea Africana	0.31	0.55	-	0.32	0.56	-	0.03	0.56	-	0.67	1.67	-
Byrsocarpus Orientalis	0.63	0.55	0.50	0.65	0.56	0.56	0.14	0.56	0.07	1.42	1.67	1.13
Cassia Petersiana	2.19	1.10	0.75	2.27	1.12	0.83	1.87	1.12	0.17	6.33	3.33	1.75
Catunaregam Obovata	0.31	1.65	0.25	0.32	1.68	0.28	0.03	1.68	0.02	0.67	5.00	0.54
Catunaregam Spinosa	0.31	0.55	-	0.32	0.56	-	0.04	0.56	-	0.68	1.67	-
Combretum Molle	2.19	-	0.25	2.27	-	0.28	1.58	-	0.02	6.04	-	0.54
Combretum Zeyheri	1.57	-	1.24	1.62	-	1.11	0.86	-	0.45	4.05	-	2.81
Commiphora Africana	0.31	4.95	2.99	0.32	5.03	3.33	0.04	5.03	2.49	0.68	15.00	8.81
Crossopterix Febrifuga	0.31	-	-	0.32	-	-	0.05	-	-	0.68	-	-
Dalbergia Melanoxylon	-	-	1.24	-	-	1.39	-	-	0.49	-	-	3.12
Dalbergia Nitudila	2.82	-	2.74	2.92	-	2.22	2.99	-	2.05	8.74	-	7.01
Diospyros Kirkii	-	0.55	-	-	0.56	-	-	0.56	-	-	1.67	-

Diospyros Mespiliformis	1.57	-	0.25	1.62	-	0.28	1.11	-	0.02	4.30	-	0.55
Diospyros Sp	1.57	-	1.99	1.30	-	1.11	0.83	-	1.15	3.70	-	4.25
Diospyros Verrucosa	2.19	-	0.25	2.27	-	0.28	1.83	-	0.02	6.29	-	0.54
Diplorhynchus Condylocarpon	2.19	7.69	2.74	2.27	7.82	2.22	1.53	7.82	2.45	6.00	23.33	7.41
Erythrophleum Africanum	1.57	8.24	1.00	1.62	7.82	1.11	0.97	7.82	0.31	4.16	23.88	2.42
Garcinia Livingstonei	0.31	-	-	0.32	-	-	0.03	-	-	0.67	-	-
Gardenia Thunbergia	1.25	1.65	-	0.97	1.68	-	0.60	1.68	-	2.83	5.00	-
Gardenia Volkensii	1.25	-	0.50	1.30	-	0.56	0.70	-	0.07	3.25	-	1.13
Grewia Transzambesica	-	-	2.24	-	-	1.94	-	-	1.48	-	-	5.66
Hugonia Orientalis	3.45	0.55	4.23	3.25	0.56	4.44	4.45	0.56	5.14	11.14	1.67	13.82
Hymenocardia Acida	1.25	0.55	1.00	1.30	0.56	1.11	0.59	0.56	0.23	3.14	1.67	2.33
Hyphaene Coriacea	0.31	-	-	0.32	-	-	0.03	-	-	0.67	-	-
Julbernardia Globiflora	1.25	3.85	6.97	1.30	3.91	6.11	0.63	3.91	13.69	3.19	11.67	26.77
Lannea Schimperi	0.94	-	0.75	0.97	-	0.83	0.30	-	0.15	2.21	-	1.73
Lannea Stuhlmanii	5.33	1.65	1.99	5.52	1.68	2.22	11.16	1.68	1.09	22.01	5.00	5.30
Locola-Mulupali	-	-	0.50	-	-	0.56	-	-	0.07	-	-	1.12
Mangifera Indica	0.31	-	-	0.32	-	-	0.04	-	-	0.68	-	-
Maprounea Africana	0.94	3.30	1.24	0.97	3.35	1.11	0.34	3.35	0.40	2.25	1-	2.75
Margaritaria Discoidea Var. Triplosphaera	1.88	2.20	1.49	1.95	2.23	1.67	1.39	2.23	0.61	5.22	6.67	3.77
Markhamia Zanzibarica	3.13	0.55	0.75	3.25	0.56	0.56	3.26	0.56	0.15	9.65	1.67	1.46
Millettia Stuhlmannii	2.82	3.30	5.47	2.60	3.35	5.00	3.18	3.35	8.68	8.60	1-	19.15
Ochna Natalitia	-	-	1.74	-	-	1.94	-	-	0.91	-	-	4.60
Ozoroa Obovata	1.25	6.04	1.24	1.30	6.15	1.39	0.61	6.15	0.38	3.16	18.33	3.02
Parinari Curatellifolia	3.45	2.20	3.48	3.57	2.23	3.89	4.61	2.23	3.09	11.63	6.67	10.46
Pericopsis Angolensis	1.57	1.10	1.24	1.62	1.12	1.39	0.99	1.12	0.40	4.18	3.33	3.03
Phyllocosmus Lemaireanus	-	-	2.24	-	-	2.50	-	-	1.39	-	-	6.13
Pseudolachnostylis Maprouneifolia	-	0.55	2.74	-	0.56	3.06	-	0.56	2.06	-	1.67	7.85
Pteleopsis Myrtifolia	4.08	8.24	1.99	4.22	8.38	2.22	6.85	8.38	1.18	15.14	25.00	5.39
Pterocarpus Angolensis	0.63	3.85	1.99	0.65	3.91	2.22	0.14	3.91	1.16	1.42	11.67	5.37
Pterocarpus Rotundifolius	2.19	-	0.50	2.27	-	0.56	1.81	-	0.07	6.28	-	1.12

Rothmannia Engleriana	2.51	0.55	2.74	2.92	0.56	3.06	2.34	0.56	2.03	7.77	1.67	7.83
Sclerocarya Birrea	0.63	-	0.25	0.65	-	0.28	0.14	-	0.01	1.42	-	0.54
Securidaca Longepedunculata	1.25	1.10	0.75	1.30	1.12	0.83	0.60	1.12	0.18	3.16	3.33	1.76
Sterculia Quinqueloba	2.51	0.55	0.25	2.60	0.56	0.28	2.40	0.56	0.02	7.50	1.67	0.54
Strychnos Cocculoides	0.63	-	-	0.65	-	-	0.18	-	-	1.45	-	-
Strychnos Madagascariensis	3.45	2.20	5.72	3.57	2.23	5.56	4.41	2.23	8.75	11.43	6.67	20.03
Strychnos Spinosa	0.94	-	-	0.97	-	-	0.36	-	-	2.28	-	-
Swartizia Madagascariensis	0.94	-	0.75	0.97	-	0.83	0.36	-	0.13	2.28	-	1.71
Tamarindus Indica	0.31	0.55	-	0.32	0.56	-	0.04	0.56	-	0.67	1.67	-
Terminalia Sericea	-	4.40	-	-	4.47	-	-	4.47	-	-	13.33	-
Uapaca Kirkiana	0.94	2.75	1.99	0.97	2.79	2.22	0.34	2.79	1.05	2.26	8.33	5.26
Uapaca Nitida	2.51	-	-	2.60	-	-	2.24	-	-	7.34	-	-
Vitex Mombassae	0.63	-	-	0.65	-	-	0.15	-	-	1.42	-	-
Vitex Payos	1.25	3.30	1.24	0.97	2.79	1.39	0.60	2.79	0.51	2.83	8.88	3.14
Xylopia Aethiopica	1.57	-	0.50	1.62	-	0.56	0.94	-	0.08	4.13	-	1.13
Grand Total	100	100	100	100	100	100	100	100	100	300	300	300

Appendix -6: Household Survey

The aim of this questionnaire is to gather information from household related to cause of deforestation and forest degradation.

<u>Direction</u>: please tick the most appropriate answer and where necessary fill in the answer in the space provided.

Demographic Characteristics of Respondents

S/no	Description	Responses	skip
1	Age	1)<20,2) 21-30,3) 31-45,4) 46-60 5) >60	
2	What is your sex	[1] ……..… Male [2] ……… Female	
3	Level of education	[1] None. [2] Primary[3] Secondary [4] Tertiary/ University	
4	Religion	[1] Christian. [2] Muslim [3] Others (specify)	
5	Marital Status	[1] Married [2] Single [3] Widowed [4] Divorced [5] Separated	
6	Family size	[1] below 3 people [2] 3 to 5 people [3] 6-10people [4] 11people and above	
7	For how long have you been live in this area (Years)?	(1) <5 (2) 5-10 (3)10-20 (4)>20	

8. Which forest management intervention is found in your area? Possible to tick more than one option

1. Forest concession () 2. Community forestry () 3. state 4.all ()

9. Is deforestation and forest degradation problem is there in your area 1 yes 2 no

10. If your answer is yes for question number 9 please would you list and explain different types of derivers for deforestation and degradation in your area?

S/N	Derivers for Deforestation and Degradation	Degree of occurrence (DO)	Way of management (WM)	Responsible body(RB)
1	Slash and burn agriculture			
2	Timber production			
3	Charcoal production			

4	To defend wild animals from crop			
5	Fire			
6	Looking for new land			
7	Others			

DO, 1= serious 2=moderate 3=low, **WM**, 1=awareness creation 2=attaching to low 3=penalty

RB, 1=Government 2=community 3=both

11. How long have you been using land by clearing forest for different uses?

S/N	Types of use	Year of use
1	For agricultural land expansion	A) 3 years B) 3-5 years C) 5-10 D) >10
2	For timber production	A) Sometimes B) always C) not at all
3	Charcoal production	A) Sometimes B) always C) not at all
4	To defend wild animals from crop	A) Sometimes B) always C) not at all
5	others	

12. What are the most preferred forest product you are using from the forest?

S/N	Types of products	Remarks
1	timber	
2	Charcoal	
3	Non timber	
4	Wild edible animals and fruits	
5	pole	
6	Others	

13. What constraints do you face in using forest product?

S/N	Types of constraints you faced	Remarks
1	There are many animals in the forest	
2	Restrictions by village government leaders	
3	Nearby forests are protected forests	
4	There is scarcity of fertile land in the buffer zone	
5	Low of forest using	
6		
7		

14. Are you engaged on timber, charcoal, non-timber forest product and agricultural activity?

1) Yes **2)** No

15. If your answer is yes for question 14 above, list the activities in which you or any member of the household is engaged in. Rank the activities in order of importance (1, 2 and 3 being most important, important and least important respectively. What is the main reason for the assigned ranks?

Household activity	Rank	Reason for rank
Agriculture (crops)		
Agriculture (livestock)		
Agriculture (Crop and livestock)		
Non-timber forest products production		
Production of timber forests		
Production of charcoal and selling		
Other off farm activities (specify)		

16. When you want to expand or change your agricultural land how and from where you get free land?

Source of land	Way you get the land	constraints
Clearing forest	Legal, illegal…	low
Using fallow land	Own, rent…	
By maintaining fertility	Own, rent	

17. What are sources of your income?

Source	Rank	Source	Rank
Selling NTFPs			
Agriculture (crops)			
Agriculture (livestock)			
Timber selling			
Charcoal selling			
Off farm income source			
Par-time			

18. How do you increase your agricultural land productivity?

Ways you use to increase	Rank	constraints	solutions
Using SWC measures			
Application of inorganic fertilizers			

Application of organic fertilizers			
Giving rest (fallowing)			
Looking for new land always			

19. Regarding forest land and expansion of agricultural land please answer question listed in table below

In this section please tick in the box that corresponds to your opinion/view according to a scale of 1 = Strongly Disagree, 2 = Disagree, 3 = Not Sure, 4 = Agree, 5 = Strongly Agree

No	Statement	1	2	3	4	5
1.	The level of grazing in forests is very minimum in the area					
2.	The rate of finding new agricultural land in buffer zone is very minimum					
3.	The rate of finding new agricultural land in buffer zone very maximum					
4.	Searching of new land to forest land is very rare					
5.	The rate of cutting trees to construct houses is very rare					
6.	The rate of changing land to new forest area is very rare					
7.	The rate of cutting down trees to construct houses is very high					
8.	Agro forestry campaigns have been practiced in the area					
9.	Forest fires are very rare in this area					
10.	Illegal charcoal and timber production is very high					
11.	Illegal charcoal and timber production is very low					
12.	Hunting in the buffer zone is very well regulated in the area					
13.	The Park is a source of tourist attraction in the community					
14.	The Park is a great resource to educational institutions					
15.	The economic survival of a community relies on Forest Products from buffer zone alone					
16.	Forests provides home for some community members					

20. socio-economically is there any impact of D&D? 1. Yes 2.no

21**.** If your response is yes for question number 20 would you please list them?

22. A. negative impact

Negative impact	Rank	Suggested solutions

Loss of economic trees		
Shortage of fertile land		
Loss of medicinal plants		
Loss of water		
Loss of wild edible food sources		
Unemployment		
Flooding and Erosion		

23. B. Positive impact

Positive impact	Rank	Suggested solutions
Getting materials for houses buildings		
Getting short period fertile land and abundant production of food		
Selling wood product		
Hunting wild animals		
Protecting wild animals from their crop		

24**.** Do you use all tree species equally? 1 yes 2 No

25. If your answer for question number 24 above is no, at least list the top five species you prefer and why?

Local name of Species	Scientific name of Species	Use	Rank	Reason for preference

<u>Use</u>: - C=charcoal**, T=**Timber**, HC=**House construction**, FW=**Fuel wood**, NT=**NTFP

26**.** Based on your opinion what is the degree of degradation of the most preferred tree species especially ranked 1 to 3 in table of question number 24 above?

____

____

27**.** Do you take any action for conservation of the degraded tree species? 1 yes 2 no

28**.** If your answer is yes for question number 27 above would you list the action you took?

1) Planting new seedling 2) doing restoration 3) giving time to reestablish 4) others

29**.** If your answer is no for question number 27 above why?--

----

30**.** Is there any tree species protected culturally in your area? 1 yes 2 no

31. If your answer is yes for question number 30 above would you list the them?-------------------

----

32**.** Do you have information about restoration? 1/yes 2/no

33**.** If your answer is yes for ques number 32 above, is there any restoration activity takes place in your area? 1/ yes 2/ no

34. If your answer is no, why is that? Do you know the reason?

35. What is the main factors affecting regeneration for miombo wood land in your area?

1/fire 2/slash and burn agriculture 3/home construction 4/grazing

36. what are factors affecting regeneration of Miombo woodland in the buffer zone

No	Factors	1	2	3	4	5
1						
2						

37. cause of LULCC in the buffer zone

No	Cause	1	2	3	4	5
1						
2						

Appendix 7: Focus Group Discussion

District……………………… Number of participant……………………………………

Level of education ………… GPS coordinate………………………………………….

(a) What social services and infrastructure are available in the village?

………………………………………………………………………………………….……….

(b) Which types of forest ownership is found in your area?

……………………………………………………………………………………………………

………………………………………………………………………………………………..

(c) What are the main economic activities of community in your village?

……………………………………………………………………………………………………

……………………………………………………………………………………...……..

(d) What kinds of benefits community get from the forest?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

(e) What is the cause of forest degradation and deforestation in your area? Which species are more exposed to degradation?

Type of Forest ownership	Cause	Local Name of species more exposed to degradation	scientific Name of species more exposed to degradation

(f) For how long this forest is managed by this use right?

(g) Are there any bylaws guiding the use of this forest? What are they?

(h) What are the community's strategies to ensure sustainability of this forest?

(i) Are there any cultural/ traditional/ customs governing utilization of forest?

1. Yes 2.No.

(j) If yes mention them...
....

(k) How is the situation on the degree of forest degradation and deforestation in the past 10 years compared to now? A) Increasing B) Decreasing C) stable D) unknown F) no answer

(L) cause of LULCC

(M) factors affecting regeneration of Miombo woodland

Thank you for your co-operation.

Appendix 8: Checklist for Key informants

Village leaders, elders and natural resource expert members.

1) When did you start living in this village……………………………………………………?

2) In your area which forest use right is found a) concession b) community forest c) both d) others

3) In which forest use right D&D is more serious? Why? please put the reason

…………………………………………………………………………………………………
……………………………………………………………………………………..

4) Is community in your area is happy in forest concession? If No, why….

5) Does community get benefit from forest concession? If No, please would you explain the reason……………

6) What is the general condition of the forest now compared to the time you came in this village?

1. Increased **2**. Decreased **3**. Remained the same 4.I don't know

7) What are strategies to ensure sustainability and availability of forest resource?

....
....

8) Which important forests product community get from the forest? List Them

……………………………………………………………………………………

………………………………………………………………………………………

9) Is there any licensing system used to control extraction of forest product from any forest use right? 1. Yes 2. No

10) Are there any organized groups that deal with collecting and selling forest product from your village? 1. Yes 2. No

11) What are the village historical events in conserving the Forest resources and forest at large?

....

....

....

12) Is there village forests resources use conflict that had happened in this village and how did you resolve them (among village members/ between village members with wildlife conservationists)?

Type of conflict	Ways they solve the conflict

14) Is there any conservation actions taken towards the forest in your area?

1. Yes 2. No

15) If yes to question 14 above, mention the actions

……………………………………………………………………………………………………….
……………………………………………………………………………………………………….

16) In your opinion, what should be done to reduce D&D in your area?

17) what are factors affecting regeneration of miombo woodland in the buffer zone of the park

18) would you list cause of D&D

Thanks you for your co-operation.

Appendix 9 Questionnaire for GNAP workers/staff.

1) How long have you been working in this reserve…………………. years

2) What is the general condition of Gile NP forest cover now compared to the past 10 years?

1. Very good 2. Good 3. Bad 4. Very bad

3) What is the general condition of buffer zone of GNP forest cover now compared to the past 20 years?

1. Very good 2. Good 3. Bad 4. Very bad

4) What can you comment on the status of forest cover change around Gile NP buffer zone

……………………………………………………………….. ………………………………

6) Are community living in buffer zone satisfies their forest product need from buffer zone alone?

5) What are strategies have you put in place to ensure sustainability and availability of Forest in buffer zone since it is a major source of the community livelihoods?

....
....

5) What type of forest product do people use from the buffer zone of the park?

………………………………………………………………………………………………
……….……………………………………………………………………………………..

7) What could be the reasons for collecting forest product from buffer zone of the park?

....
....

8) Is there any licensing system used to control use of forest product from the buffer zone?

1. Yes 2. No

9) Is there any organized groups that deal with collecting and selling forest product in GNP buffer zone?

1. Yes 2. No

10) What are the community's historical events in conserving the Forest around the park?

....

....

11) What are the community forests resources use conflicts that have ever happened and how were they resolved? If any

Problem (conflict)	Ways through which they solve the conflict

12) Is there any conservation actions taken towards the buffer zone of the park?

1. Yes 2. No

13) If yes to question 12, mention the conservation actions

……………………………………………………………………………………………………
……………………………………………………………………………………………………

14) In your opinion what should be done to reduce degradation and deforestation from the buffer zone which directly influence GNAP?

....
....

15) Is there any activities of forest restoration in this area? 1 yes 2 no

16) If your answer is yes who under take restoration? 1) Government 2) NGO 3) Community $) others

17. If your answer is yes for question number 15 when they started restoration

18. If your answer is yes how do you express about the sustainability and continuity of this restoration

19. Is there any effort of establishing plantation forest in degraded areas?

20. Is there community nursery site for producing seedling?

21. is there any organization working on restoration (NGO or Gov't)? If yes pleases can you explain their relation with the surrounding community

Thank you for your co-operation.

Appendix –10 Field Data Collection (Diversity Assessment).

District……………………. land use class ………………Direction (N, S, W or E)

Transect Number…………. GPS coordinate……………………………

Canopy status = Open (**O**), Moderate (M) cloth (CL)

Date ………………………. Latitude ………………… Longitude ……………….

Plot Number	Code	Local name	Scientific Name	Estimate Age	DBH (cm)	Height(m)	Direction

Appendix –11 Field Data Collection regeneration of Miombo Woodland in buffer zone of GNAP (sub plot)

District……………………. land use type ………………………………

Transect Number…………. GPS coordinate……………………………

Main Plot Number ……… Longitude …………………………………

Date ……………………… Latitude ……………Direction ………………….

- Direction: North(N), south(S), West(W) and East(E)

No of Sub Plot	Code	Local Name	Scientific Name	DBH (cm)	Height

Key

DMWL=Dense Miombo woodland

OMWL=Open Miombo woodland

AAL=Abandoned Agricultural land