Rapid land use change, biodiversity and ecosystem services in miombo woodland: Assessing the challenges for land management in south-west Tanzania

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The candidate confirms that the work submitted is her own, except where work which has formed part of jointly-authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

PhD publications

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For this publication I collected all the data, conducted the analysis and wrote the paper. Jerome O'Connell conducted supervised classification of remote sensing images to enable the selection of potential ecological research sites. He also reviewed a revised draft of the paper. Andrew Dougill, Susannah Sallu and Tim Benton provided comments on earlier and final drafts and proof read final drafts.

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Graham Frederick Ramsey Jew

1951-2008

Abstract

The miombo woodlands of sub-Saharan Africa contain valuable wildlife populations, support the livelihoods of millions of people and contribute vital ecosystem services across local, national and international scales. Rapid conversion of woodland to agriculture is common, but knowledge gaps exist regarding what drives this land use change, how biodiversity responds, and how these responses affect the availability and accessibility of resources to communities. Such information is needed to make appropriate land use management decisions. This thesis aims to advance understanding by addressing these gaps using a case study from the Mbeya Region of south-west Tanzania, a remote region undergoing rapid land use change. An interdisciplinary, mixed methods approach was used to collect ecological and social data from the Kipembawe Division.

The thesis provides new contemporary insights on the context and nature of rapid change in this area, demonstrating that cultivation of the main cash crop tobacco (*Nicotiana tabacum*) is the significant driver of land use change. The thesis examines the impact that land cover change has on the availability of goods, services and biodiversity, providing new data on the interdependencies between local communities and woodland resources. The availability of crucial services such as firewood and water is perceived to be decreasing due to agricultural expansion and increased demand. Tree and butterfly species richness, abundance and diversity also decrease with increasing woodland utilisation; although an intermediate disturbance effect was identified, indicating that moderate levels of disturbance can be tolerated. Finally, the thesis draws together empirical insights and related studies to outline five contemporary challenges for the sustainable management of the miombo woodland landscape. These include the lack of knowledge about where the ecological 'tipping point' lies in relation to utilisation of miombo woodland, a lack of alternative livelihoods and products, high immigration rates, the remoteness of the area, and weak governance. To develop and implement sustainable land use management strategies an integrated landscape approach is suggested. Due to the ecological and social challenges identified land use management would need to be adaptive and encourage participation at differing governance levels, for which an adaptive co-management approach is appropriate.

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Table of Abbreviations

AMCOS	Agricultural Cooperative Marketing Society
DANIDA	Denmark's Development Cooperation
DBH	Diameter at Breast Height
ES	Ecosystem services
EU	European Union
IUCN	International Union for the Conservation of Nature
HHS	Household Survey
LULCC	Land Use and Land Cover Change
NGO	Non-Governmental Organisation
PCS	Primary Cooperative Society
PFM	Participatory Forest Management
REDD+	Reducing Emissions from Deforestation and Forest Degradation
SSA	Sub-Saharan Africa
SUA	Sokoine University of Agriculture
UN	United Nations
WWF	World Wide Fund for Nature

Chapter 1

Introduction

Chapter summary

This chapter introduces the main topics of the thesis - miombo woodlands, rapid land use change and the consequences for biodiversity and ecosystem services. It then outlines the aim and objectives of the thesis and introduces Tanzania as the study country. It finishes with the thesis contributions and outlines the thesis chapters, indicating how each meets the research objectives. Chapter 2 goes on to explore the subjects introduced in this chapter in greater detail.

1.1 Introduction

This thesis investigates rapid land use change in miombo woodland, focussing on the status, trends and challenges of land use change for biodiversity and ecosystem service provision. The thesis provides holistic case study information from a remote, understudied miombo woodland landscape in the Kipembawe Division, south-western Tanzania. To facilitate a broad and comprehensive understanding of the miombo woodland system the thesis reports an exploratory, interdisciplinary, mixed-methods research approach. This approach enabled ecological and social data to be gathered across the landscape, providing unique insights into land use change, the drivers of land use change, and the impact of this land use change on biodiversity and ecosystem service provision. Further evidence and analysis identified the main challenges for land use management within this landscape to guide the development and implementation of future management strategies. This chapter outlines the research problem and situates the thesis in the broader context of land use, biodiversity and ecosystem service debates, before explaining the research aim and objectives in relation to miombo woodland.

1.2 The research problem

1.2.1 Land use change, biodiversity and ecosystem services

Land Use and Land Cover Change (LULCC), the modification of the earth's surface by human actions, is occurring across the world, as cropland, pastures, plantation and urban areas expand to accommodate an increasing human population (Foley et al., 2005). These modifications have contributed 12.5% of anthropogenic carbon emissions (Houghton et al., 2012). The most recognised driver of land use change is agriculture, as large areas of natural vegetation are transformed into cropland and pastures to feed a rapidly growing population (Geist and Lambin, 2002). This is likely to continue; to feed the predicted global population of 9 billion by 2050 an estimated 70-100% more food must be produced (Godfray et al., 2010), although this does not take into account current inefficiencies in usage (Tscharntke et al., 2012). Such increases will come through intensification of production to increase yield and the expansion of agricultural land (Phalan et al., 2011b). Much of this expansion is likely to occur at forest and woodland frontiers (van Vliet et al., 2012); deforestation and land degradation are the greatest form of land use change (Lambin and Meyfroidt, 2011). Land use change is the primary cause of biodiversity loss (Jantz et al., 2015) which is occurring far above expected background extinction rates (Barnosky et al., 2011), leading to suggestions that we are entering a sixth mass extinction event (e.g. Thomas et al., 2004, Wake and Vredenburg, 2008). Not only are there moral reasons to preserve biodiversity for its own sake (Díaz et al., 2006), but biodiversity loss impedes ecosystem functioning, damaging the ability of ecosystems to provide vital ecosystem services (Cardinale et al., 2012). Ecosystem services are the benefits obtained by humans from ecosystems (MEA, 2005), such as the provision of food and fibres and the regulation of water resources (Díaz et al., 2006). The concept of ecosystem services was developed to increase the recognition of the benefits derived from natural resources (Wallace, 2007) in order to guide natural resource decision-making.

The value of biodiversity and ecosystem services to human wellbeing demonstrates that allowing land use change to occur unregulated may lead to undesirable consequences. Therefore land management is required to allow for agriculture, but also include habitat protection for biodiversity conservation and ecosystem service provision, urbanisation and production of non-food products (Smith et al., 2010). Land management must be site specific to facilitate positive multiple outcomes for these components, and will differ substantially between landscapes (Godfray et al., 2010, Hodgson et al., 2010, Norris, 2008).

Much of the initial focus of global debate and policy actions has been on the high biodiversity, high carbon and highly threatened tropical rainforests, in an attempt to protect as much as possible as quickly as possible (Myers et al., 2000, Albuquerque and Beier, 2015). However, there are many other wooded areas that have important roles in ecosystem service provision and contain relatively high biodiversity and carbon levels. These include the boreal forests of the northern hemisphere, the temperate forests of North America and the tropical deciduous woodlands in Africa, Central America and Australia. This thesis focuses on the extensive miombo woodlands of sub-Saharan Africa, which have received relatively little research attention.

1.2.2 Miombo woodlands

The tropical deciduous woodlands of sub-Saharan Africa cover 2.4 million km^2 (Frost et al., 2003), support over 100 million people (Campbell et al., 2007) and contain many threatened and endemic species (Conservation International, 2012). Miombo woodland is characterised by ectomycorrhizal (Desanker et al., 1997) tree species from three genera; *Brachystegia*, *Julbernardia* and *Isoberlinia* from the legume subfamily Caesalpinioideae (Frost et al., 2003). They are of global importance due to their potential for carbon storage and influence on human and environmental systems (Ribeiro et al., 2015). The large extent of this forest[1] type is reflected in the number of people whose livelihoods are dependent upon it, with 75 million people directly dependent and 25 million relying indirectly upon energy sources produced from the forest such as firewood and charcoal (Syampungani et al., 2009, Dewees et al., 2011). Direct dependence includes use of provisioning ecosystem services including consumption of forest products, use of medicinal plants, construction materials, livestock fodder and energy requirements (Jumbe et al., 2008, Dewees et al., 2010, Malambo and Syampungani, 2008).

With the population of sub-Saharan Africa expected to double by 2050 (Eastwood and Lipton, 2011) pressure upon miombo woodland is increasing, with deforestation and woodland degradation occurring from clearing for agriculture and fuelwood extraction (Cabral et al., 2011, Dewees et al., 2010). Miombo woodlands are therefore receiving increasing attention as areas where effective land management is required (Williams et al., 2008). However, the majority of

[1] The terms 'forest' and 'woodland' are used interchangeably throughout the thesis when referring to miombo woodland. 'Forest' is used throughout the literature in reference to miombo; additionally in Swahili there is no word to differentiate between 'forest' and 'woodland'.

research within miombo woodland addresses their role in carbon storage (e.g. Shirima et al., 2011, Williams et al., 2008); beyond this little is known about biodiversity, ecosystem services and their responses to land use change. To effectively design and implement land management strategies for miombo woodlands more understanding is needed about the social and ecological landscape, including fully understanding the drivers of land use change, how such changes will affect biodiversity and ecosystem service provision and what impacts these changes will have on local communities (Ribeiro et al., 2015). This thesis aims to fill this research gap using case study evidence from a miombo woodland landscape in Tanzania, sub-Saharan Africa.

1.2.3 Sub-Saharan Africa

Forests within sub-Saharan Africa (SSA) are likely to be lost faster than anywhere else in the tropics in the next 30 years (Alcamo et al., 2005). In the past (2000-2005) deforestation has occurred faster in countries with dry forests, such as miombo woodland (Rudel, 2013). This is likely to continue as the population grows and urban areas expand, resulting in subsistence agriculture increasing and further demand for fuelwood (Fisher, 2010). Demand for food will continue to be a major driver of land use change. Approximately 35% of the world's population is not food secure, and this rate has not fallen in four decades (Burke and Lobell, 2010). Africa is the only region in the world where per capita production of cereals has declined over the past 50 years, despite an 80% rise in the amount of cropped area on the continent (Burke and Lobell, 2010). This trend is likely to persist, as the population continues to increase and climate variability is expected to make it increasingly difficult to get good yields, as demonstrated by several climate models that show a projected decrease in yield in Africa, particularly sub-Saharan Africa (Porter et al., 2014, Schlenker and Lobell, 2010). Land use management that can provide for increases in crop yield, and also reduce the loss of forest and associated biodiversity and ecosystem loss (Perrings and Halkos, 2015) are urgently needed.

1.2.4 The study area - Tanzania

Rapid land use change through deforestation and forest degradation is occurring across Tanzania (Ahrends et al., 2010), leading to biodiversity declines and the loss of wildlife corridors (Jones et al., 2009, UNEP, 2013). The United Republic of Tanzania is comprised of mainland Tanzania and the Zanzibar Archipelagos. Tanzania has an area of 947,087 km^2 and a population of approximately 44,928,923 (National Bureau of Statistics, 2013). The country is ranked 159 out of 187 in the Human Development Index (HDI value for 2013 = 0.488), demonstrating low development (UNDP, 2014). Poverty remains significant, with 46.6% of the population being below the international poverty line of US$1.90 per day (PPP 2011).

Globally, billions of people are supported by forests for food, shelter and energy needs, and many more rely on forest products indirectly or rely on forest products for their income or employment (FAO, 2014). This is particularly the case for those living in poverty, and those in rural areas, which account for 70.4% of the population (National Bureau of Statistics, 2013). Forest covers approximately 35% (326,212km^2) of land area in Tanzania (2012 data, World Bank, 2015). Miombo woodlands are the largest wooded habitat in Tanzania, representing over 90% of forest cover (Shirima et al., 2011), demonstrating their importance to the livelihoods of local people, which are threatened by deforestation rates of 1.16% (FAO, 2010). To develop land management strategies to reduce such land use change in Tanzania requires understanding and analysis of the drivers of deforestation and degradation (Burgess et al., 2010). This thesis aims to address this gap by using case study information from the Kipembawe Division in the Mbeya Region, south-west Tanzania.

1.3 The need for an interdisciplinary approach

Land use change needs to be examined over social and ecological systems (Erb, 2012) by integrating research to understand the human and environment interactions that are involved (Cheong et al., 2012). To do so requires an interdisciplinary approach, drawing from the fields of both social and natural sciences (Mattison and Norris, 2005). Using an interdisciplinary approach also requires the use of mixed methods (Johnson et al., 2007), using qualitative and quantitative data collection. This research takes a case study approach, which focuses on understanding the dynamics within one particular setting (Eisenhardt, 2002). It is interdisciplinary, and uses mixed methods (Fisher and Christopher, 2007). It is also exploratory. The study area is in a remote, little studied area of Tanzania, from which there are few available reports or publications. This meant that prior to commencing research very little was known about the area, and therefore the research process was iterative, and developed as potential research questions were identified. Case study research using a mixed method, iterative process is suitable for areas and subjects where there little previous literature or empirical evidence on which to build a prior theory (Eisenhardt, 2002), and is therefore suitable for this research project.

1.4 Aims and objectives

The aim of this research is to investigate rapid land use change in miombo woodland, using holistic case study information from a multi-purpose miombo landscape in Kipembawe, south-west Tanzania. The status, trends and challenges of land use change, biodiversity and ecosystem service provision under varying levels of woodland utilisation are explored to guide future land use management strategies for miombo woodland.

To achieve this aim, the objectives of the research are:

1. To understand the history, social context, and contemporary background of the case study area.
2. To identify and assess the current drivers of land use change
3. To identify provisioning ecosystem services that are used by local communities, their perceived trends in availability and the impact this may have on livelihoods.
4. To identify and assess the current status of biodiversity focusing on trees and butterflies within sites with differing levels of woodland utilisation
5. To identify local challenges to the implementation of future land management strategies by assessing current projects, and determining opportunities and barriers to alternative income options.

1.5 Thesis contribution

This thesis highlights the value of interdisciplinary research which provides a holistic understanding of a landscape. This approach enables the provision of both empirical and applied contributions. It provides original data for a region that has been poorly sampled both ecologically and socially in the past, thereby advancing the understanding of this landscape.

The thesis analyses current deforestation by quantifying rates of woodland and carbon loss. This contributes to the growing literature on this subject, and also gives an indication of the future of the area if no mitigating action is taken. The use of ecosystem services within miombo woodlands has been explored before, but never in such a remote area, or within landscapes experiencing rapid change. This information contributes to the understanding of ecosystem service use within miombo woodland, and how households will be affected if rapid land use change continues.

Empirical data for tree and butterfly communities provides the first comprehensive species lists for this area, and reveals responses of these communities to land use change that have not been recorded elsewhere within miombo woodlands. Indicator species for disturbed woodland were identified, and carbon calculations add to the carbon literature, and may aid the development of carbon projects in other parts of the miombo ecoregion.

Analysis of current environmental and land planning schemes show the difficulties involved in implementing such strategies, and highlights conflicts of interest amongst farmers within the landscape, who struggle to balance the desire for profitable cash crops with the recognised need for ecosystem services. The benefits of tobacco cultivation for communities and households are described, of which there are limited accounts in the literature.

Finally, the holistic nature of this research gives a unique insight into the social and ecological miombo woodland landscape to identify cross-cutting challenges to the design and implementation of land management strategies. Policy suggestions for the development of land management strategies are given based on these challenges. Despite intentions to develop sustainable land management plans for miombo woodlands, few have been developed or successfully implemented (Dewees et al., 2011). This thesis provides the empirical data and interpretation which can now be taken into the development of a land management strategy. With site-specific alterations it can also be used to inform land management plans in miombo woodlands in other areas of sub-Saharan Africa.

1.6 Outline of thesis structure

This thesis is divided into 11 chapters. Following this introductory chapter, Chapter 2 discusses land use and land cover change and outlines the main drivers of such change. It then considers some strategies for land use management. It goes on to give a comprehensive description of miombo woodlands, the focus of the thesis. Chapter 3 presents the case study area, research design and methodology. Chapter 4 relates to objective 1, describing the case study area and the history that has shaped it, setting the context for the following chapters. Chapter 5 is linked to objective 2, and investigates the current drivers of land use change through the integration of ground cover and woodland utilisation surveys with results from social surveys. Chapter 6 fulfils objective 3, and investigates the relationship between local people and the provisioning ecosystem services the woodland provides, again through integrating ecological and social data. Chapters 7 and 8 address objective 4 by investigating the impact of woodland utilisation and land use change on tree and butterfly communities respectively. Empirical data for both taxa were collected from high, medium and low utilisation sites.

Chapter 9 links to objective 5 by assessing the effectiveness of several types of natural resource management efforts within the Kipembawe Division. Data from the social surveys are used to assess these projects. This chapter also examines possible alternative livelihoods in light of current benefits and costs that farmers experience as a result of tobacco cultivation. Chapter 10 integrates the findings from Chapters 4 – 9, and identifies five main challenges that emerge from these chapters to the design and implementation of land use management plans. These are discussed, and suggestions are made for policy makers. Finally the thesis concludes in Chapter 11 by suggesting next steps for both research and the design of sustainable land use management strategies that are needed to reduce the impacts of land use change within the Kipembawe Division.

Chapter 2

Literature review: Land use change, miombo woodlands and management options

Chapter summary

This chapter explores the subjects introduced in Chapter 1 in more depth. It considers land use change on a global scale, and discusses the drivers that lead to such changes, before looking at aspects of the ecological system that influence land management, and current theories of land management that are relevant to miombo woodlands. The chapter then discusses miombo woodlands, considering their ecology and social systems, and why management is required. This chapter considers literature that underpins the whole thesis. Literature relevant to individual chapters is presented within that particular chapter. Chapter 3 follows by describing the site selection process for the study area, and outlining the methods used throughout the research project.

Part 1: Land use change

2.1 Land cover and land use change

Land use and land cover change (LULCC) refers to the anthropogenic modification of the earth's surface (Ellis, 2013). Land cover change is an alteration to the biophysical attributes of the earth's surface, and land use change is the human purpose or intent that is applied to these attributes (Lambin et al., 2001). These changes are of such magnitude that they significantly affect key functioning of the earth's system, contributing to global climate change and influencing ecosystem service provision (Lambin et al., 2001). They also contribute to biodiversity loss and undermine the ability of ecosystems to support agricultural productivity (Foley et al., 2005).

One of the areas most affected by LULCC is the forest frontier. Initially swidden agriculture (or slash and burn, shifting cultivation) occurs within the forest at the frontier (van Vliet et al., 2012). This usually involves clearing land and farming it for several years, before leaving it fallow for long periods of time, when the fertility of the soil recovers and vegetation regrows (Dressler et al., 2015). This, contrary to previous assumptions, does not always result in permanent land use change (Ickowitz, 2006). However, as the fallow periods are shortened or lost altogether, and long-term cultivation takes place, permanent land use change does occur (Foley et al., 2005) and the forest frontier continues to be pushed back as agriculture expands. This transformation usually results in increased deforestation, and associated losses of biodiversity and other ecosystem services (van Vliet et al., 2012). Yet today the transformation from swidden agriculture to permanent cropping for subsistence needs is in many places no longer the dominant driver of deforestation (DeFries et al., 2010). Understanding what is driving deforestation is vital to developing land management plans, and this has profound implications for rural peoples (Harnish, 2014).

2.1.1 Drivers

The reasons for LULCC are often complicated (Lambin et al., 2001) and are related to several different drivers, acting at multiple scales (Meyfroidt et al., 2013). A driver of change is something that effects a change in the state of something else, for example land use, ecosystem processes or services, or the climate. A driver can be either natural (such as climate variability, extreme weather events, and seismic events) or anthropogenic (pollution, over-harvesting, clearing land) (MEA, 2005). They are either direct (physical or biological), where they unequivocally cause an influence, or indirect where they lead to or underlie the direct drivers (MEA, 2005). Direct drivers can be more easy to identify and understand than indirect drivers, and include agricultural extensification and intensification, logging, fire, urban development, and demand for biofuels (Lambin et al., 2003, Hertel, 2011). Indirect drivers are much less tangible, but are arguably more important (Rodríguez-Loinaz et al., 2015). Drivers operate in one of three ways: single factor causation - when one indirect driver influences one or more direct drivers; chain-logical causation where several interlinked drivers result in change; and concomitant occurrence, where drivers operate independently (Geist and Lambin, 2002). Changes can occur on local to global scales, and they interact across spatial, temporal and organisational scales (Carpenter et al., 2009).

There are five main categories of indirect drivers: demographic; economic; scientific and technological; cultural and religious; and socio-political (Nelson et al., 2006). Demographic drivers include a growing population, through increasing fertility, decreasing mortality and migration (Nelson et al., 2006). While the effects of an increasing population within the woodland area are clear, Rudel et al. (2009) also found, in a meta-analysis of the drivers of change in East African dry forests, that urban growth was one of the dominant indirect drivers of deforestation. This is due to three main reasons; the demand for fuel, export of timber, and changing consumption patterns (Ahrends et al., 2010, DeFries et al., 2010, Fisher, 2010). There can also be impacts of migration on labour availability, and effects of remittances from migrants to rural areas (Meyfroidt et al., 2013). Economic drivers include consumption, production and globalisation (Nelson et al., 2006). Poverty is often seen as one of the key indirect drivers of deforestation (Geist and Lambin, 2002, Lambin et al., 2001). Conversely, a country's economic growth and incorporation into the expanding world economy can also result in rapid land use change (Lambin et al., 2001). This occurs both in terms of the physical and institutional infrastructure which is required (Nelson et al., 2006), and also due to increasing export markets, which are often supported by trade in natural resources or agricultural products (Geist and Lambin, 2002). Land acquisition by foreign actors may also have an impact (Meyfroidt et al., 2013). Socio-political drivers are political or social decisions or actions that result in some kind of environmental consequence, including policies and guidelines, such as protected areas and the governance of the commons (Nelson et al., 2006). Technological and scientific drivers include the use of pesticides and fertilisers (Evenson and Gollin, 2003), genetically modified organisms and intensive farming methods (Geist and Lambin, 2002). Cultural and religious drivers are the influences of values, beliefs and norms that a group of people share which affect their decisions about the environment (Nelson et al., 2006). Agriculture is described in more detail below, as it considered to be one of the greatest drivers of LULCC.

2.1.2 Agriculture as a driver of land use change

Agriculture is implicitly recognised as a driver of deforestation (Beddington et al., 2012, Meridian Institute, 2011) and is the leading land use change associated with nearly all deforestation cases (Geist and Lambin, 2002). It is widely considered to be the biggest threat to biodiversity (Gonthier et al., 2014) and has been the main driver of past diversity loss and ecosystem degradation (Norris, 2008, Syampungani et al., 2010), threatening more species than any other anthropogenic activity, particularly in developing countries (Balmford et al., 2005). Agriculture includes permanent cropping, cattle ranching, shifting cultivation, and colonisation agriculture. Within permanent agriculture the expansion of food crop cultivation is three times more likely than the expansion of commercial farming (Geist and Lambin, 2002). The world's population is forecast to reach 9 billion by 2050 and to adequately feed this number of people 70-100% more food must be produced than the current output (Godfray et al., 2010), although it is argued that current worldwide production would be sufficient, but unequal distribution and unaffordable prices lead to hunger (Tscharntke et al., 2012).

In addition to the rise in population that causes an increasing demand for food is a change in food consumption (Smith et al., 2010). As the proportion of people who are in the middle classes increases (Godfray et al., 2010) with associated increases in per capita income, the share of additional income spent on food declines, as the amount is limited by the quantity of food one human can consume (Nelson et al., 2006). However, despite the amount people can eat being limited, as wealth increases this higher purchasing power tends to drive consumption away from the staple foods (rice, wheat, root crops) to more diverse and protein rich diets including meat and fish products and processed foods (Godfray et al., 2010, Smith et al., 2010, Smith et al., 2007). Livestock production requires more energy and land to produce per kilo than cereals and vegetables, so the demand for land for livestock increases, particularly when livestock is predominantly grain fed (Ewers et al., 2009, Rosegrant et al., 1999). Africa is the only region where trends in the growth of per capita income have not been seen (Nelson et al., 2006). However, the rural to urban migration has similar consequences with urban communities tending to eat more processed foods and meats, creating similar demand for land (DeFries et al., 2010). An additional problem resulting from rural to urban migration is an increase in the demand for bushmeat as migrants desire meat products as a cultural link to their homes (Bennett et al., 2007). This leads to biodiversity loss and ecosystem paucity. The significance of urban growth on deforestation rates implies that policies to reduce deforestation aimed at local rural populations will not address the main of deforestation in the future (DeFries et al., 2010). The study site in the Kipembawe Division is a remote rural area, and it is possible that it is affected by urban demand for meat and for fuel from the cities of Mbeya and Tabora.

2.2 Considerations for land management plans

Myriad considerations are necessary when land management options are being developed. These include understanding the drivers of land use change, but it is also necessary to understand what is required from the landscape in terms of both human needs and biodiversity conservation, and how this can be obtained, as this will affect the way that the landscape is managed (Haines-Young, 2009). The following sections discuss some key ecological considerations that underpin land use management in the context of land use change.

2.2.1 Ecosystem resilience

Ecosystem resilience is the ability of an ecosystem to maintain the general structure, functions, delivery of services, identity and feedbacks when undergoing disturbance (Holling, 1973, Petchey and Gaston, 2009) such as extinctions, invasions, habitat loss and reductions in the availability of nutrients and water. The level of resilience is the magnitude of such disturbance that a system can experience and yet remain in the same state (Holling, 1973). A system with high resilience is likely to persist, one with low resilience is likely to cease to exist (Holling, 1973). To describe this from the opposite point of view the term vulnerability is used as an antonym of resilience (Adger, 2000), therefore if a system has high resilience it has low vulnerability and vice versa. The simplistic nature of this antonym is debated (Gallopín, 2006, Miller et al., 2010) with an alternative definition suggesting that vulnerability refers to the ability of the system to remain as it is, whereas resilience is the ability of the system to recover from disturbance back to its original state. Vulnerability is not merely the exposure to disturbance, but also the sensitivity and resilience of the system experiencing these hazards (Turner et al., 2003).

Gradual or sudden changes to an ecosystem which erode resilience and increase vulnerability (Adger, 2000, Folke et al., 2004) may result in regime shifts which can be rapid and irreversible. These new systems can be highly resilient, as is particularly the case with degraded systems (Fischer et al., 2009), as ecosystems will shift to a state that is most resilient to disturbance (Cropp and Gabric, 2002) and this is often why the regime shift is irreversible, demonstrating that high resilience is not necessarily desirable (Walker et al., 2006, Walker et al., 2004).

A further aspect is that of stability. This is the manner in which the system returns to an equilibrium state after a temporary disturbance, and the more rapidly this occurs with the least fluctuation the more stable the system is (Holling, 1973). A system can be very resilient and still fluctuate greatly, demonstrating low stability (Holling, 1973). Such fluctuations can occur over very long time periods, and not follow linear patterns (Gil-Romera et al., 2010). This means that the system may fluctuate to a state where the ecosystem services that human systems rely upon are reduced, but the ecosystem itself has not undergone a regime shift. Unstable systems are unlikely in undisturbed systems (Cropp and Gabric, 2002).

Calculating the resilience and stability of a system can be achieved through modelling, where species or groups of species can be removed or added, and various environmental factors can be introduced or removed to determine the impact upon the system (Petchey and Gaston, 2009). Groups are usually determined by the functional role that the species plays within the system, and the groups may operate independently of one another or they may depend on the functioning of other groups (Petchey and Gaston, 2009). Functional diversity is when similar species perform different functional roles (Elmqvist et al., 2003), and this can mean that there are many species that perform the same ecological function, often at different temporal and spatial scales (Walker, 1995). This is a valuable asset as disturbance may only affect certain scales, and therefore if ecological functions are replicated across a range of scales the function can withstand a variety of disturbances (Elmqvist et al., 2003). Should there only be one species within a functional group the group is vulnerable, demonstrating low resilience. These species are often known as keystone species (Walker, 1995), and can be targeted for conservation priorities as they are often critical for the resilience of the ecosystem. The functional diversity of the system is important as it increases the performance of the system as a whole, and a second factor, response diversity, enables the functions to continue to occur when there are stresses and disturbances operating within the system (Elmqvist et al., 2003). Response diversity is the diversity of responses of the different species within the same functional group to disturbance (Elmqvist et al., 2003, Walker, 1995). High levels of response diversity mean that it is more likely that the functional group will persist, as the chances of a species being able to respond to a different set of conditions and maintain its ecological function is greater.

Understanding the resilience within the ecosystem can assist in the development of land use management strategies, particularly in areas where human utilisation of the ecosystem may take place. This is particularly the case within Kipembawe, where local communities rely on the woodland for provisioning ecosystem services. Understanding how resilient the ecosystem is to this utilisation will guide the management of these resources.

2.2.2 Adaptive capacity

Adaptive capacity is the ability of the system firstly to adapt to the changes caused through disturbance to sustain the appropriate ecological or sociological functions to maintain the social-ecological system in the same state, and secondly to improve its conditions in relation to its current circumstances, or to extend the range of environments to which it is adapted (Gallopín, 2006). The appropriateness of this term in relation to social-ecological systems is debated (Gallopín, 2006), particularly as it is widely used in relation specifically to the ability of communities to adapt to climate change (IPCC, 2007). However, it is used extensively throughout the wider livelihood literature both within and outside of social-ecological systems to describe the ability of populations to adapt to change that impacts their livelihoods (e.g.

Darnhofer et al., 2010) and is therefore a suitable term to describe the ability of both ecosystems and human livelihoods to adapt to disturbance.

2.2.3 Landscape heterogeneity

The modification of land for agriculture has led to a corresponding decline in biodiversity (Benton et al., 2003) resulting in a loss of native vegetation (Fischer and Lindenmayer, 2007) and a loss of ecological heterogeneity at multiple spatial and temporal scales. This means that global biodiversity protection is increasingly reliant on conserving biodiversity within human dominated landscapes (Fahrig et al., 2011). The majority of landscape heterogeneity studies have been in temperate settings within the western hemisphere (e.g. Atauri and De Lucio, 2001, Fahrig and Nuttle, 2005, Flick et al., 2012, Öckinger et al., 2011) and therefore the responses of tropical landscapes are less well known, although in a study in East Africa Epps et al. (2011) found that strong heterogeneity in both habitat and human activities enabled species to persist even outside protected reserves.

Heterogeneous landscapes within a human modified landscape contain many different land cover types, such as a variety of crops, arable and pastoral utilisation of land, and agroforestry, all of which are distributed in a complex pattern and interspersed with natural vegetation, such as woodlands and grasslands (Fahrig et al., 2011). There are two types of heterogeneous landscapes; compositional heterogeneity has a variety of different land cover types, and configurational heterogeneity has a complex spatial patterning to the various land cover types (Fahrig and Nuttle, 2005). Heterogeneity can also be temporal, in that species often require different habitat types at different times of year, and either move between them or rely on the provision of different habitats through seasonal changes (Benton et al., 2003). An additional consideration is that if a landscape is physically heterogeneous to the human eye it does not mean that it is heterogeneous to a species depending upon their functional use of the habitat (Fischer and Lindenmayer, 2007). Species richness differs between taxa in response to landscape heterogeneity (Atauri and De Lucio, 2001). This additionally highlights issues involved with either a species-oriented approach based on the functionality of the system, or a species assemblage/pattern-oriented approach, where the focus is on human-perceived landscape patterns and their correlation with species richness or other measures of species occurrence (Fischer and Lindenmayer, 2007). As these two approaches differ considerably it is necessary to consider the final aims of any management strategy before the design and implementation stages.

Habitat heterogeneity is associated with higher biodiversity at both small and large scales (Benton et al., 2003), and this has been demonstrated in several different taxa: e.g. birds (Atauri and De Lucio, 2001, Pickett and Siriwardena, 2011); butterflies (Flick et al., 2012, Öckinger et al., 2011); large mammals (Loarie et al., 2009); and pollinators (Sjödin et al., 2008). Diverse habitats have a greater potential to be exploited by a more diverse range of organisms (Benton et al., 2003). The advantages that a heterogeneous landscape has over a homogenous landscape for biodiversity need to be considered when identifying appropriate management strategies, however, trade-offs may exist when human systems and food security need to be taken into consideration. Understanding the current heterogeneity of the Kipembawe landscape, and how land use change affects this will aid the development of appropriate land use strategies.

2.2.4 Resilience in human systems

The term resilience is not restricted to ecology, and has been used throughout a range of domains, from ecology through to computer science, and throughout the social sciences (Folke, 2006, Gallopín, 2006). A relevant use of the term is in relation to livelihoods (Sallu et al., 2010). Livelihood resilience is the ability of people to change and adapt their livelihood strategies in response to shocks and changes in the environment, economic markets and governance (Adger, 2000, Eriksen and Watson, 2009). In social systems stability is important, particularly with regard to livelihoods (Adger, 2000) as the human dimensions operate on much shorter timescales than ecological systems so variability within the system can be catastrophic.

As ecosystems and livelihoods are inherently linked through the dependence upon ecosystems of communities and their economic activities (Adger, 2000) both systems are often considered together as social-ecological systems. These are complex, integrated systems in which humans are part of nature (Berkes and Folke, 1998) and equal weight is placed on the human and ecological elements of ecosystem function and maintenance (Webb, 2007). A social-ecological system can be specified from local to global scales (Gallopín, 2006). However, it is not always appropriate to use this system, as for much of the time over which ecosystems have developed the impact of humans has been relatively small (Webb, 2007), and therefore other causes of disturbance other than that of a human influence may be affecting the ecosystem. As ecosystem resilience declines, the resilience of the human system is tested, as livelihoods must adapt to losses or deficiencies in services to maintain their livelihoods (Walker et al., 2006, Sallu et al., 2010). Both the ecological and social systems must be assessed through quantitative and qualitative approaches (Dougill et al., 2010) when measuring resilience to inform land management policies.

2.2.5 Food security

Food security is linked to poverty, particularly when food prices rise. Poverty is seen as one of the key drivers of deforestation and degradation (Geist and Lambin, 2002, Lambin et al., 2001) as it drives resource extraction. Food security has risen to the forefront of international policy in recent years, due both to the Millennium Development Goal of halving the number of people suffering from hunger by 2015 (UN, 2000), and recent estimates of population rise and projections of the required agricultural yields for the 21st century (Foresight, 2011). There have been many definitions of food security; however the FAO (2003) definition below is the most widely accepted:

> *'Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life. Household food security is the application of this concept to the family level, with individuals within households as the focus of concern.'* (FAO, 2003, p.29)

Food security is inextricably linked to agriculture, one of the fundamental drivers of deforestation. In East Africa there has been substantial conversion of natural habitat to pasture, agriculture and urban areas, and land conversion to agriculture has outpaced the proportional human growth over the last few decades, yet food supply in calories per head has fallen (Maitima et al., 2009), demonstrating that merely increasing agricultural area may not be enough to provide food security. As a remote rural area in Tanzania, the Kipembawe Division is vulnerable to many of the issues that relate to food security. Land use management plans need to understand local challenges associated with food security, such as vulnerability of crops and past patterns of food insecurity.

2.2.6 Land use management strategies

The first stage of developing a land use management strategy is to identify the pathway of land use change which is currently occurring in a landscape, and the human and environmental interactions that are contributing to this (Lambin et al., 2001). This aids understanding of the causes and patterns of change (Ahrends et al., 2010), which can then be used to develop management scenarios. The greatest challenge is managing for multiple outcomes – conservation of biodiversity may require a suite of conservation management options that operate over different scales (Gonthier et al., 2014), and managing for multiple ecosystem services may require management over different landscapes (Raudsepp-Hearne et al., 2010). Meeting the needs of the local communities may require management on a different scale again, and it is inevitable that some trade-offs will occur.

The need to design spatial land management strategies to incorporate biodiversity conservation and agriculture is not new (e.g. Green et al., 2005, Lockwood, 1999). However, little research has been undertaken that examines the importance of local and landscape management for biodiversity and its relation to ecosystem services within agricultural landscapes (Tscharntke et al., 2005). This research project is spatially explicit, and therefore contributes to this debate. The majority of the land sharing and land sparing options discussed below have been developed within industrialised country systems in the western hemisphere where agriculture is already a dominant land use and new management policies are being developed to incorporate biodiversity almost retrospectively. This research project addresses the challenges for land management in a developing country context to incorporate both biodiversity conservation and ecosystem service provision from the outset.

There are two main methods proposed to increase agricultural productivity; land sparing, where production is intensified through increasing yield per hectare, and land sharing, where production is extended by converting more land is to cropland (Benton et al., 2011, Green et al., 2005, Paavola, 2008, Pretty et al., 2010). These are discussed below.

2.2.7 Land sparing

Land sparing (Green et al., 2005) or intensification (Paavola, 2008) is where an area is farmed intensively to produce high yields and utilised exclusively for cropping, and other areas are turned completely over to conservation/wild areas. These strategies aim to reduce the yield gap – the difference between potential yield that can be achieved using current genetic material and available technologies and the actual yield produced (Godfray et al., 2010). These systems aim to maximise the yield per area and require larger investments in terms of labour or capital than the land sharing alternatives (Benton et al., 2011).

In the last 50 years yields have increased through intensification; without these increases three times more land would have been required to produce enough crops to sustain the current population (Foresight, 2011, Smith et al., 2010). Intensification has been through technological improvements that have enabled productivity to increase, leading to an increase in per capita food availability (Smith et al., 2007). Rapid increases in yields in the western hemisphere were most evident during the Green Revolution of the 1950s – 1970s, where agricultural productivity doubled through the development of high yielding modern crop varieties, coupled with expansion in crop land and the use of pesticides and fertilisers (Evenson and Gollin, 2003). Future increases in agricultural yield will not be so straight forward, as competition for land increases, including protecting habitat for biodiversity conservation and ecosystem service provision, urbanisation and production of non-food products (Smith et al., 2010). Land sparing strategies have been successful in regard to both crop yield improvements and biodiversity conservation, particularly in countries with high food supply (Ewers et al., 2009).

One of the main issues with land sparing is what will happen to the land that is spared. With the competition for land (Smith et al., 2010) it is possible that land that is not used for agriculture will not necessarily be used for biodiversity, and may end up being used for practices that are not favourable to wildlife (Balmford et al., 2005). As the demand for more crop production increases those areas with higher yields are at risk from being converted to similar high yield systems (Balmford et al., 2005). This therefore requires strict enforcement and/or incentives to keep the land reserved for conservation purposes. In addition to the demand for land for crops, grain and grazing for livestock, the emergence of biofuels and urban expansion may also impact heavily on the potential gains that land sparing may have for conservation (Ewers et al., 2009) as the competition for land intensifies. The development of agricultural subsidies to incorporate biodiversity goals will ease the pressure on biodiversity areas (Ewers et al., 2009) but may not be sufficient.

2.2.8 Land sharing

Land management strategies that advocate farming and biodiversity conservation alongside each other are described similarly by several authors as land sharing (Benton et al., 2011), wildlife friendly (Green et al., 2005) and extensification (Paavola, 2008). These strategies retain habitat patches in the farmed area or have natural areas integrated within the cropland matrix, and advocate a reduction in the use of fertilisers and pesticides. The trade-off for higher biodiversity is a reduction in yields as they can be reduced by wild species either competing with or feeding on the domesticated species (Phalan et al., 2011a). Even moderately farmed land still sees a decrease in biodiversity, especially for those species considered to be of particular conservation concern (Green et al., 2005). Land that has regenerated following agriculture does not necessarily return to the same species assemblages that were in the area prior to cultivation, demonstrating that some land must be left undisturbed to maintain those species that are not resilient to land use change (Williams et al., 2008). Additionally, deterioration of vegetation structure and the area in general can still have a negative impact on many species, even if extensive areas of natural vegetation remain (Fischer and Lindenmayer, 2007). However, this may be the best option for conserving biodiversity within agricultural landscapes and also aid the production of foods, fibres and fuels (Perrings et al., 2006).

2.2.9 Integrated land sparing and sharing systems

As yields must increase overall, and not at the expense of biodiversity and ecosystem services, it will not be possible to have all agricultural systems operating solely on a land sharing system, as yields would not be high enough, or solely on a land sparing system, as biodiversity would be compromised (Benton et al., 2011). In order to determine the best practice for determining a management strategy for an area, it is necessary not to think on a field by field basis, but in terms of the field within a landscape, and in regard to the ecosystem services that the landscape provides (Benton et al., 2011). This must also cater for other land use activities such as the production of timber, fibre, energy and landscape amenities, and urbanisation and biomass (Smith et al., 2010). Therefore considering land management strategies that integrate land sparing and land sharing across the landscape, considering all stakeholders, would be optimal.

It is likely that cropland in the developed world will continue to decrease (Balmford et al., 2005) and although this has led to conservation projects being established in some regions, this decrease will lead to an increase in cropland elsewhere. This is leakage, where the need for higher yields is displaced, and another area must produce more (Benton et al., 2011). An issue with the strategy of using both sharing and sparing systems is that yield will not actually significantly increase if sparing is occurring at the same rate as sharing, as the intensified areas may merely make up for the decrease in yield seen in land sharing systems. Therefore it is necessary to develop a holistic strategy that increases overall yields whilst providing for biodiversity and ecosystem services (Norris, 2008).

The need to provide for biodiversity and for ecosystem services is of particular concern, as biodiversity losses continue and valuable ecosystem services are lost (Costanza et al., 1997). Such protection of natural habitats is unlikely to be successful if human requirements for agricultural products are not being met (Phalan et al., 2011a). Therefore a range of methods are required to increase agricultural productivity in light of these additional pressures on the land, to develop more equitable distribution of food, and to adapt farming methods for the predicted impacts of climate change, which are likely to seriously impact agricultural systems in the future.

In order to determine how land should be managed and identify areas where land sharing and land sparing could be feasible, it is necessary to develop a broad understanding of the processes taking place within a landscape. This thesis aims to do this within the miombo woodland in south-west Tanzania by using an interdisciplinary approach at a landscape scale.

2.3 Research approach

An exploratory approach was taken to this research project. The study area is remote, and there are few documented studies or reports from the Kipembawe Division. In the 1960s in-depth vegetation studies of the North Lupa Forest Reserve were conducted (Boaler, 1966a, Boaler and Sciwale, 1966, Jeffers and Boaler, 1966), and a wider study of plant communities in the Rukwa Basin took place in 2011 (Munishi et al., 2011), but there are no other taxonomic studies. There is a comprehensive ethnography of the Kimbu tribe (Shorter, 1972), but no recent documentation of the social landscape of the area, which has changed significantly since Tanzania gained independence in 1961.

This meant that before the start of the field research very little was known about the area. This guided the design of the research project (Chapter 3), which began with a range of biodiversity assessments to understand what changes were taking place in the area, followed by social surveys to understand why these changes were occurring, and determine what challenges exist to the development of sustainable land management strategies. This is an exploratory process, and this is demonstrated in Figure 2.1, which illustrates the process of this research project.

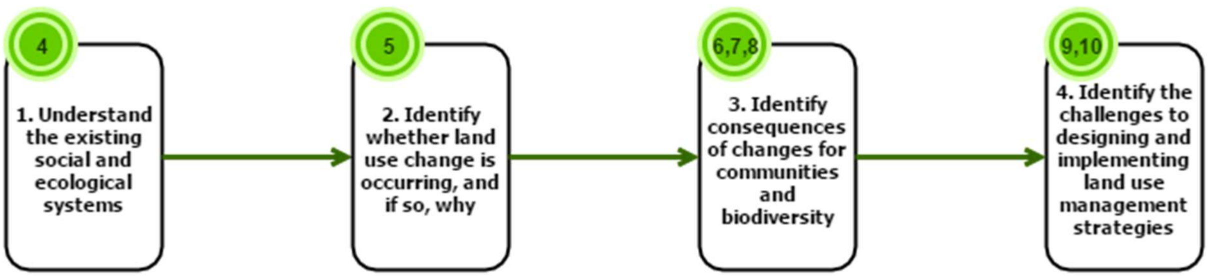

Figure 2.1: The research approach. Each stage of the project is represented in the boxes, and the chapters discussing each stage are represented within the green circles.

Due to the holistic, exploratory and empirical nature of this research project, it is not based on any one framework. Instead it draws upon several concepts to inform understanding of the empirical data produced. These concepts are outlined below.

LULCC is intricately linked to both the human and natural environment systems. Biodiversity conservation is increasingly dependent upon the maintenance of biodiversity within human dominated landscapes (Fahrig et al., 2011), and to implement effective conservation an understanding of human behaviours towards the environment is necessary (Byers, 2000) Ecosystem services are dependent upon the health of the ecosystem, agricultural productivity is linked to biodiversity, and land cover itself is affected by anthropogenic land use change. Despite these linkages, the trade-offs between food production, biodiversity conservation, ecosystem services and human well-being in agricultural landscapes have not yet been fully addressed (Perrings et al., 2006), yet understanding how altering the mix of ecological and social contributions to services affects long term sustainability is an important step in improving management of ecosystems and their services (Bennett et al., 2015).

The Socio-Ecological System (SES) framework was initially developed by Berkes and Folke (1998), and aimed to demonstrate that the social and ecological systems are linked, rather than separate, and rely upon one another, and that sustainability is therefore imperative. They defined sustainability as not challenging ecological thresholds on temporal and spatial scales that would have a negative impact on either the ecological or the social system. Social systems refer to property rights, land and resource tenure systems, and systems of knowledge pertinent to environment and resources, in addition to world views and ethics concerning the environment and resources. Ecological systems referred simply to the natural environment (Berkes and Folke, 1998; p4). While this definition of the social system incorporates land tenure issues that are pertinent in resource management (Robinson et al., 2014) and addresses the sustainability of resource use, it does not consider the fundamental requirements of a social system; access to food and to ecosystem services. The Ecosystem Service (ES) framework addresses this (Fisher et al., 2009), with the provision of ecosystem services as its main focus. The ES framework adopts an integrated view of the social and ecological factors related to human wellbeing and ecosystem services (Reyers et al., 2013). However, both of these frameworks are anthropocentric, and essentially utilise the ecological system for the provision of societal benefits. Therefore it is necessary to use these frameworks with caution, and to aid this consider biodiversity conservation approaches that have largely fallen out of favour – those that consider conservation for conservation's sake, rather than how it can provide some benefits to human systems (Doak et al., 2014). This enables land use management approaches to proceed with caution, and consider the sustainability of the ecological system not only for the provision of services but also for its intrinsic values. A further concept is that of integrative landscape management (also approaches or initiatives) which is a multi-objective, cross-sectional approach to the management of rural landscapes (Milder et al., 2014). This approach aims to integrate conservation and development at landscape rather than local scales, which have been the focus of past integrated management attempts (Milder et al., 2014). Integrated approaches have long been advocated (Luoga et al., 2005), and landscape scales, at over hundreds to thousands of kilometres (Forman, 1995) are more appropriate for land planning which incorporates biodiversity, ecosystem services and agricultural management (Atauri and De Lucio, 2001). Integrated landscape management aims to incorporate a wide range of stakeholders, and be highly participatory, explicitly seeking to improve food production, biodiversity or ecosystem conservation, and rural livelihoods (Milder et al., 2014) by achieving a multifunctional landscape (Estrada-Carmona et al., 2014). To do this requires the implementation of adaptive and integrative management systems (Reed et al., 2015) to manage strategies such as land sharing or land sparing (Estrada-Carmona et al., 2014). It addresses complex and widespread social and political challenges (Reed et al., 2015) through an approach that is neither strictly bottom up or top down, but is an interplay between both sets of stakeholders (Estrada-Carmona et al., 2014). To achieve this, a broad understanding of the processes and interactions across the social and ecological landscapes is required.

These frameworks were used to guide this research project to understand what knowledge is required to inform land management strategies, and to identify the challenges for successfully designing and implementing such a strategy.

Part 2: Miombo woodlands

This section gives a brief introduction to the miombo woodlands of sub-Saharan Africa to set the context for the rest of the thesis.

2.4 Miombo ecoregion

The miombo ecoregion (Figure 2.2) covers approximately 3.6 million km^2 of central and southern Africa, over parts of Angola, Botswana, the Democratic Republic of Congo, Zambia, Zimbabwe, Tanzania, Malawi, Mozambique, South Africa and Namibia (Byers, 2001). This ecoregion was defined by White (1983) as the Zambezian Regional Centre of Endemism, and has subsequently been defined further by the World Wild Fund for Nature (WWF) (Olson et al., 2001) and Conservation International (Frost et al., 2003). Miombo woodlands are contained within the ecoregion, and are the predominant of 11 habitat types, covering more than two thirds of the ecoregion (Frost et al., 2003). They are arguably the most extensive tropical woodlands in Africa, although the size of the region remains unclear and has been stated as 2.7 million km^2 after Frost (1996), 2.4 million km^2 (Dewees, 2008, Dewees et al., 2010, Dewees et al., 2011) and just under 2.5 million km^2 (Frost et al., 2003). No recent estimates of miombo woodland cover have been made, and given the rapid land use change that is occurring in the region (section 2.5.4) this is a signifincant gap in knowledge. Within this area remains arguably the largest single block of predominantly continuous tropical dry woodlands in the world, with approximately 1.2 million km^2 still intact (Byers, 2001, Frost et al., 2003). There are similar dryland woodland environments in both South America (the Chaco) and Australia (the Australian savannas), but these are not as extensive or as intact as those in Africa (Frost et al., 2003).

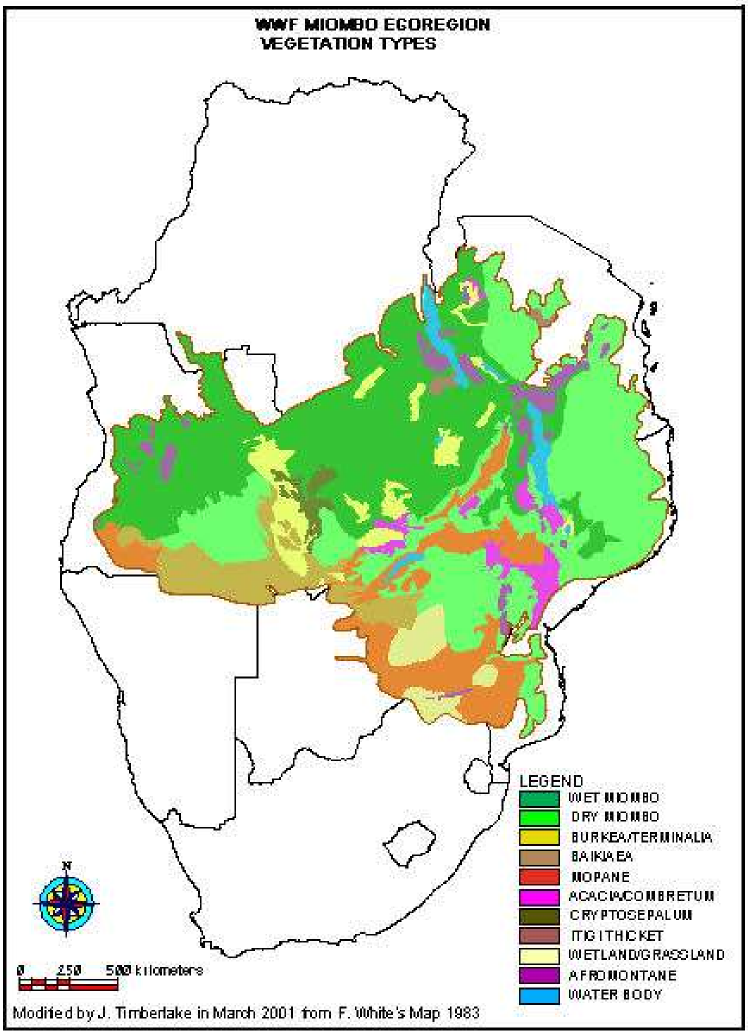

Figure 2.2: Miombo ecoregion (Source: Byers, 2001)

The miombo ecoregion has been receiving increased attention in recent years; in part due to being classified as of high conservation value by two of the largest international conservation Non-Government Organisations (NGOs), WWF and Conservation International. WWF assessed the region as part of their Global 200 Ecoregions classification scheme for conservation priority (Olson and Dinerstein, 1998) in 2001. The Global 200 Ecoregions were selected as priority conservation areas based on their levels of biodiversity, endemism, or uniqueness as an ecosystem (Olson and Dinerstein, 1998). WWF's Miombo Ecoregion is the largest of 21 Global 200 Ecoregions on mainland SSA (Byers, 2001). It is very similar to Conservation International's Miombo-Mopane Woodlands and Grasslands Wilderness Area, which covers 3.7 million km^2 (Frost et al., 2003), and contains 15 different habitat types (Table 2.1). Wilderness Areas are priority conservation areas, and to qualify as such the region must retain over 70% of its historical habitat area, have a minimum size of 10,000km^2, and a population density in rural areas of equal to or less than 5 people per km^2 (Mittermeier et al., 2003). Out of the 24 wilderness areas identified by Conservation International, the Miombo-Mopane Wilderness Area is one of five high biodiversity wilderness areas, with relatively high levels of biodiversity that also support indigenous communities, in addition to providing $US 2 trillion annually in terms of ecosystem services (Conservation International, 2012). Another large international conservation organisation, Birdlife International, has designated many Important Bird Areas and several Endemic Bird Areas within the region, also as a method of prioritising conservation (Birdlife International, 2012). There are several other classifications of the miombo ecoregion, outlined in Table 2.1. Approximately 21% (806,693 km^2) of the ecoregion is already under some form of conservation management (Frost et al., 2003) in the form of National Parks, Game Reserves, Game Controlled Areas, Forest Reserves, Wildlife Management Areas and conservancies. The value of the ecosystem as demonstrated above shows the need for management strategies which secure the sustainability of the woodland outside of these protected areas.

Table 2.1: Miombo ecoregion classifications

Size (million km²)	Countries	Name and Conservation status	Contains	Endemics	Threatened species	Organisation
3.8 and 3.6 quoted	Angola, Namibia, Zambia, Botswana South Africa, Malawi, Mozambique, Tanzania, Zimbabwe, DRC, Burundi	Miombo Ecoregion Global 200 Ecoregion	Miombo, Caesalpinoid woodlands, Acacia/Combretum woodland, Afromontane, Balkiaea woodland, Burkea/Terminalia/ Combretum woodland, Evergreen dry forest (Cryptosepalum), dry miombo, itigi thicket, mopane woodland, wet miombo, wetland/grassland	8500 plants of which 54% are endemic (cites White 1983)	Black rhino, African elephant, African hunting dog, cheetah, slender nose crocodile, 100 threatened plant species	WWF Byers, 2001 Miombo Ecoregion Report
3.7 (ecoregion) 2.5 (miombo)	Angola, Namibia, Zambia, Botswana, South Africa, Malawi, Mozambique, Tanzania, Zimbabwe, DRC	Miombo-Mopane Woodlands and Grasslands Wilderness Area Wilderness Area	Angolan Mopane Woodlands, Angolan Miombo Woodlands, Central Zambezian miombo woodlands, Eastern miombo woodlands, Southern miombo woodlands, Zambezian Baikiaea Woodlands, Cryptosepalum Dry Forests, Zambezian and Mopane Woodlands, Itigi-Sumbu Thicket, Zambezian Flooded Grasslands, Etosha Pan, Angolan Montane Forest-Grassland Mosaic, the Mountains of Eastern Zimbabwe, the Mountains of Southern Malawi, the Southern Rift	8500 plants, 4600 endemic. 938 birds, 54 endemic. 336 mammals, 14 endemic. 301 reptiles, 69 endemic. 138 amphibians, 33 endemic.	Black rhino, African elephant, Lichtenstein's hartebeest	Conservation International: Frost *et al.,* 2003 Miombo-Mopane Woodlands and Grasslands Wilderness Area

Size (million km^2)	Countries	Name and Conservation status	Contains	Endemics	Threatened species	Organisation
2.4	Angola, Malawi, Mozambique, Tanzania, Zimbabwe, Zambia	Miombo woodlands	miombo woodland only - *Brachystegia, Julbernardia, Isoberlinia*	8500 species of higher plants, of which 54% are endemic	None described	PROFOR - Program on forests World Bank Dewees *et al.,* 2011 Managing the miombo woodlands of Southern Africa
2.7 - 3.6	Angola, Namibia, Zambia, Botswana, South Africa, Malawi, Mozambique Tanzania. Zimbabwe DRC, Burundi	Miombo region	Miombo described as the dominant ecosystem, others not described	4590 plants, 35 mammals, 51 birds, 52 reptiles, 25 amphibians	None described	IIED (International Institute for Environment and Development UK) Bond *et al.,* 2010 REDD+ in dryland forest
2.7	Sub-humid tropical zone of Africa	miombo woodlands	Miombo woodland only	8500 species of higher plants, of which 54% are endemic, some birds	Sable, Lichtenstein's hartebeest mentioned	CIFOR Frost, 1996 In *The Miombo in Transition: Woodlands and Welfare in Africa*

2.4.1 Miombo woodlands

The majority of miombo woodland lies in the relatively flat Central African Plateau, at 1000-1600 metres above sea level, within the warm subhumid zone. Rainfall is highly seasonal, falling mainly through November to April, with the majority of the region receiving 600-1400mm/yr. Mean monthly temperatures range from 19-24°C (Frost et al., 2003). The dominance of the three characteristic genera (*Brachystegia*, *Julbernardia* and *Isoberlinia)* varies throughout the ecosystem (Banda et al., 2006) according to soil type and rainfall (Frost et al., 2003). The canopy ranges from 8-25m, and the trees are deciduous to semi-evergreen (Frost et al., 2003). Tree cover exceeds 40%, therefore distinguishing open savannas from closed woodlands (Kutsch et al., 2011). These species are unable to fix nitrogen, but are able to florish in the nutrient poor (predominantly weathered and leached) soils of the area. They have compound leaves which are efficient at dispersing heat, which distinguishes them from the similar ecosystems in Australia and South America (Frost et al., 2003). Trees from these genera are predominantly deciduous, and retain their leaves while they can still reach the dry season water table before dropping them, although some are able to retain them all the way through the dry season (Frost et al., 2003).

Two types of miombo have been broadly defined; wet and dry, although rainfall regimes tend to be variable. Dry miombo occurs in areas receiving less than 1000mm of rainfall a year, in the centre and south of the region (Frost et al., 2003). Canopy heights are lower (<15m) with impoverished vegetation, in comparison to the wet miombo that occurs in areas receiving over 1000mm of rainfall a year (Abdallah and Monela, 2007). In wet miombo there are approximately 70 tree species per hectare; in dry miombo this falls to 40 tree species per hectare (Frost et al., 2003). The difference between the two regions is important for management options, both in terms of their biodiversity value, but also as the soils in dry miombo tend to be relatively less fertile, and in some cases waterlog frequently (Frost et al., 2003) with implications for agricultural activities. Wet miombo therefore holds a greater potential for agricultural productivity, and this, combined with its higher biodiversity levels, demonstrates a need for management of wet miombo that enables the habitat to be both utilised and protected. This thesis examines an area of high rainfall miombo woodland which is understudied, and therefore the study will add to the literature that defines and describes miombo woodland.

2.4.2 Biodiversity in the miombo ecoregion

The miombo ecoregion is generally nutrient poor with a low carrying capacity through which herbivores move seasonally in order to make the best use of the available forage (Byers, 2001). This means that there are low levels of biodiversity in comparison to Conservation International's 'hotspots of biodiversity' (Conservation International, 2012). However, there are many endemic species within miombo woodlands (birds (54 endemic species); reptiles (68); mammals (14); amphibians (33) (Frost et al., 2003)). They are the centre of diversity for the tree genus *Brachystegia*, with 23 of the 32 known species found here (Frost et al., 2003), in addition to 8500 species of higher plants, of which 54% are endemic (White, 1983). Miombo additionally provides valuable habitat for more widespread species and is particularly important when utilised as wildlife corridors connecting protected areas. Many species that occur throughout miombo woodland are of conservation importance (Conservation International, 2012), such as the African wild dog (*Lycaon pictus*) and the African elephant (*Loxodonta africana*); about half of the remaining elephant and black rhinoceros (*Diceros bicornis*) populations in Africa are found within the miombo region (Byers, 2001).

Miombo woodlands have been seen to demonstrate high resilience and stability (Chinuwo et al., 2010, Chidumayo, 2004) due to a large regeneration bank of coppice shoots, root suckers, suppressed seedlings and saplings. The coppice shoots enable rapid regeneration regardless of the type of disturbance (Chinuwo et al., 2010). Seed longevity and dispersal rates are low (Desanker et al., 1997) and saplings grow very slowly (Chinuwo et al., 2010, Chidumayo, 2004). Rapid regeneration may create altered species dominance patterns, resulting in different population structures, and several studies have shown that areas that regenerate following clearing for farming do not reach the same climax vegetation that occurred in the region prior to degradation (Chinuwo et al., 2010, Williams et al., 2008). Regenerating farmland areas in Malawi took 10 years to establish tree diversities similar to that prior to clearing, but the defining miombo species did not regenerate within two to three decades after the area had been abandoned (Williams et al., 2008). Similarly in Zimbabwe stable sub-climax vegetation was observed after 20 years, but did not reach the basal area and coppice density in non-disturbed areas (Chinuwo et al., 2010).

2.4.3 Ecosystem services in miombo woodlands

Miombo woodlands provide a diverse range of ecosystem services to local and global popuations, from provisioning services through to hydrological control and carbon storage (Abdallah and Monela, 2007). It is estimated that 75 million people are directly dependent upon miombo woodlands, and a further 25 million rely indirectly upon energy sources produced from the woodland such as firewood and charcoal (Syampungani et al., 2009, Dewees et al., 2011). Miombo woodland resources support both rural and urban populations, and it has been suggested that they can provide a buffer to protect households from falling deeply into poverty as a result of environmental or economic stresses (Dewees et al., 2010). This can be through utilisation of products such as honey, mushrooms, edible caterpillars and termites, fruit (over 100 trees provide edible fruits), bushmeat and medicinal plants; or through energy resources, construction materials and dry season fodder for livestock (Jumbe et al., 2008, Dewees et al., 2010, Malambo and Syampungani, 2008). The use of medicinal plants and products can contribute up to 80% to rural health when they are used to cope with the effects of HIV/AIDS, malaria and other diseases (Syampungani et al., 2009). Areas with a high prevalence of HIV/AIDS experience a more rapid decline in woodland quality and availability than those with lower rates (Timko, 2011). Due to their extensive geographical cover miombo woodlands store globally significant amounts of carbon, despite per hectare storage rates being substantially lower than tropical forests (Shirima et al., 2015b). In addition to above-ground carbon stocks it is estimated that 50-80% of the total carbon stock within the miombo woodland system is found below ground (Walker and Desanker, 2004), and it is therefore possible that soils have a greater potential for storing carbon than above-ground stocks (Williams et al., 2008). Miombo woodlands are highlighted as suitable for Reducing Emissions from Deforestation and Forest Degradation (REDD+) projects (Bond et al., 2010), and Tanzania is a pilot country for REDD+ (UN REDD Programme, 2009). However, the study area within the Kipembawe Division is not currently part of any REDD+ project.

2.4.4 Land cover and land use change in miombo woodlands

Land use change within the miombo ecosystem occurs either through deforestation, where the woodland is cleared, or through woodland degradation, which is much harder to identify on both spatial and temporal scales. Estimating woodland cover change can be complicated within miombo woodland that is interspersed with savanna or grassland, or small scale shifting cultivation patterns, and low spatial resolution imagery of 1km may not be suitable to detect these changes (Cabral et al., 2011). Land degradation of between 61-91% has been seen in the miombo countries of Malawi, Tanzania, Zambia and Zimbabwe (Sileshi et al., 2007), In Zambia there are approximately 3.5 hectares of forested land available per capita (Jumbe et al., 2008) and yet annual rates of deforestation are ten times higher than in these other countries. There have been significant losses of miombo in Angola since the end of the civil war in 2009 (Cabral et al., 2011). Most forest loss occurs in villages and general land outside of protected areas, where the expanding human population lives (Tabor et al., 2010). The rate of deforestation in miombo woodlands is one of the highest in the world (Hyde and Seve, 1993). Degradation of miombo woodland affects small scale farmers dependent upon it through to the economic growth prospects of nations (Sileshi et al., 2007).

For over 55,000 years humans have lived within miombo woodlands, modifying them through a long history of cultivation, cutting and burning (Lawton, 1978, Timberlake and Chidumayo, 2011). Therefore the majority of miombo woodland has been disturbed to some extent, with very little primary woodland remaining throughout the ecoregion (Dewees et al., 2010). Fire is one of the most influential anthropogenic drivers, with fires in miombo affecting approximately 1 million km^2/year (Scholes et al., 1996 in Desanker et al., 1997), and it has become an important part of the miombo system. Much floristic diversity has been affected by anthropogenic fire (Timberlake and Chidumayo, 2011), and the fire regime is influential in determining species composition (Ryan and Williams, 2011). Today, burning is considered to exceed optimal levels, and therefore contributes to degradation of the system (Strömquist and Backéus, 2009).

Increasingly miombo woodland is coming under pressure from clearing for agriculture, overgrazing, commercial logging, unsustainable extraction of timber and non-timber forest products and urban expansion (Cabral et al., 2011, Dewees et al., 2010, Syampungani et al., 2009, Folke et al., 2004). Uncontrolled woodland utilisation has led to deforestation (Chirwa et al., 2008), and one of the most significant uses of miombo woodland is for fuelwood. Charcoal and firewood supply 70% of energy used in southern Africa (Syampungani et al., 2009). The greatest use of miombo woodland, and arguably the most degrading, is the consumption of charcoal, which is predicted to increase in line with urban demands and the lack of affordable alternatives (Ahrends et al., 2010). Without a corresponding growth in technological development there are few alternative energy sources (Abdallah and Monela, 2007), leading to increasing commercial production (Malambo and Syampungani, 2008; Cabral et al., 2011; Kutsch et al., 2011). Charcoal is produced in traditional kilns, which have an energy conversion rate of approximately 12% (Kutsch et al., 2011), rendering the process unsustainable (Luoga *et al*., 2002; Abdallah and Monela, 2007). Logging for charcoal is selective until preferred species become scarce, at which point less desirable woods are harvested (Malambo and Syampungani, 2008). In many cases the first areas to be deforested are those with lower wood densities, as these are easier to fell, and then the more dense species are felled, resulting in rapid clearing of the forest (Cabral et al., 2011). Extraction of valuable timber for sale does occur, usually through selective logging (Malambo and Syampungani, 2008) on a small scale or for construction purposes. High quality wood is exported, and poorer quality woods and poles are used in local construction (Ahrends et al., 2010). Much of the logging that is occurring for export is unsustainable, and sufficient revenue is not collected from its sale, either by local people or through the governments (Milledge et al., 2007). Additionally, should the demand for biofuels continue to increase it is likely that woodland may be converted to the production of crops for biofuels, thereby exacerbating deforestation (Kirilenko and Sedjo, 2007). Another cause of deforestation is a rapidly growing population and associated increases in the demand for agricultural land (Byers, 2001, Cabral et al., 2011, Dewees et al., 2010). Slash and burn is the most common agricultural practice within miombo due to low incomes and high population growth rates within the region (Williams et al., 2008). Shifting cultivation is often due to insecure ownership of the land (Geist and Lambin, 2002). Many of the soils within the miombo are poor (Frost, 1996), and land converted from miombo woodland to farmland often produces low yields, which decrease within a few years as the soil fertility decreases (Williams et al., 2008). Deforestation leads to a release of above-ground and below-ground carbon, immediately through fire used for clearing the forest and subsequently through a loss of soil organic matter (Hein et al., 2008) and a reduction in carbon storage it represents.

2.4.5 Management challenges for miombo woodland

Agricultural intensification and extensification is considered to be the main driver of deforestation and degradation within miombo woodlands (Grogan et al., 2013). Conservation of existing miombo woodland is necessary to maintain their defining species, and the fauna and flora that is associated with them (Williams et al., 2008). Additionally all of the countries within the miombo region demonstrate high levels of poverty (Campbell et al., 2007), and the extraction of resources from the miombo is often used as a safety buffer, preventing people from falling more deeply into poverty (Bond et al., 2010) and is of critical importance to livelihood resilience.

In resilient woodland where the area is utilised management strategies need to aim to maintain the woodlands' production capacity (Lund and Treue, 2008). However, biodiversity conservation goals are unlikely to be successful without integration of human livelihoods and well-being (Timberlake and Chidumayo, 2011). Determining the optimal mix of land use system and practices, which can include livestock ranching, safari hunting, timber production, small-holder agriculture, non-consumptive tourism and timber production, may be challenging (Campbell et al., 2000).

Dewees et al. (2011) described four main barriers to better management of miombo woodlands. These were biophysical barriers, including low inherent productivity and the difficulties associated with managing for multiple products; policy barriers, including disenabling forest policies and issues involved with devolution of rights of tenure, use and access, and the marginalisation of the forestry sector; economic barriers including cash constraints and preferences for rapid exploitation, low margins and poor markets; and organisational barriers, including weak local and national organisations, lack of clarity in regulations, and elite capture. This thesis will explore the degree to which the miombo woodlands of south-western Tanzania experiences similar challenges, and identify additional challenges that may be experienced in an area that has high rates of tobacco cultivation.

Chapter 3

Research design and methods

Chapter summary

This chapter describes the selection of the study area, biodiversity sites and study villages. It gives an introduction to Tanzania, the Region of Mbeya and the District of Chunya. It then explains research methods for the thesis that are applicable to multiple chapters. Those that are used in only one chapter are described in the relevant chapter. Chapter 4 follows by describing the Kipembawe Division in detail, using empirical data.

3.1 Introduction

This chapter describes the research design, site selection and methodology used to collect data using an interdisciplinary, multi-method approach. Part 1 describes the research design, and explains how the study area, biodiversity sites and study villages were selected, providing information about Tanzania and the relevant region and district to put the study area into context. Part 2 gives details about the study villages, and describes the social and ecological research methods used.

Part 1: Research design

3.2 Interdisciplinary, mixed methods approach

In order to understand the social and ecological complexities of this landscape an interdisciplinary, mixed-method approach was required (Fisher and Christopher, 2007). The research was conducted within a case study, and the process was exploratory and iterative

(Eisenhardt, 2002). An interdisciplinary approach brings research from different disciplines together (Hansson, 1999) to answer research questions that are beyond the expertise of a single discipline to address (Bracken and Oughton, 2006). Mixed methods is an approach which uses a combination of research methods and approaches, combining qualitative and quantitative viewpoints into one research project (Johnson et al., 2007). Combining qualitative and quantitative data can aid a research project in three ways: they can confirm or corroborate each other through triangulation; they can develop analysis to provide richer data; and they can be used to initiate new modes of thinking by producing new concepts (Rossman and Wilson, 1985). Interdisciplinary approaches are critical for successful conservation (Campbell, 2005). This research project draws from the ecological and social sciences, using a range of methods from both disciplines to generate both quantitative and qualitative data. Both ecological and social data contributed to the fulfilment of each of the research objectives.

3.3 Research design

Addressing the overall aim of the research project using an interdisciplinary approach required the division of the research into two stages. The first stage entailed a scoping study, which identified the research site, gathered basic information to aid the study formation and gave an overall understanding of the logistical situation. The scoping study was conducted in April 2012. The second stage was the full field survey, which took place between January and October 2013. This stage consisted of two Phases, Phase 1: Biodiversity survey (March – July 2013) and Phase 2: Social surveys (July – September 2013).

3.3.1 Stage 1: Scoping study

During the scoping study two areas of high rainfall miombo woodland were visited in the Iringa Region and in the Mbeya Region. These sites were identified through key informant interviews with researchers and managers from the Sokoine University of Agriculture (SUA), the Wildlife Conservation Society and WWF. Four villages were visited, and meetings were held with members of the village councils to ascertain current woodland management policies, prior research and the scope and priorities for future research.

Within Iringa, two villages (Kilwele and Kitapilimwa) and a forest reserve were visited. Both villages had forest reserves, there was a significant amount of overseas investment in the area

(DANIDA and EU) and there had also been recent research projects in the forest reserves. In Mbeya a further two villages (Godima and Mbanga) and a forest reserve were visited in the south of the Chunya District, and meetings were conducted with Council officers. Here there was no evidence of outside funding, little forest management and little prior research. This second area was more appropriate for this research, as according to the Chunya District Council miombo woodland covers 95% of the District, and there are few management plans. Additionally, the lack of prior research reduced the risk of research fatigue, and enabled a greater contribution to science through original empirical research.

The second site, in the Chunya District of Mbeya was provisionally selected for research. Following further discussions with key informants at SUA, the Kipembawe Division to the north of the Chunya District was finally selected, due to extensive miombo woodland and areas of agriculture and mixed agriculture and miombo. A key informant at SUA said that "*no-one knows anything about that area*", demonstrating that empirical data from this region would make a real contribution.

3.4 Stage 2: Data collection

3.4.1 Ethical considerations

All ethical considerations that were associated with data collection were approved by the University of Leeds Ethics Committee prior to the research being undertaken (Appendix A). However, further issues needed to be taken into consideration during research that is taking place in developing countries, and one is that of compensation. In most cases the researcher is extracting information from participants, for which they will see no personal gain, and may lose time from their daily activities in order to participate, and participants are therefore reimbursed for their time (Fry et al., 2005). However, giving individuals money or gifts in return for participation is problematic as it means that some people within an area benefit from the researchers' presence, while others do not, and this can lead to conflict between households and may also undermine voluntary consent (Head, 2009). When necessary it is better to give a gift to the community rather than individuals (Desai and Potter, 2006). On arrival in Lupatingatinga a meeting was held with representatives of the villages in surrounding areas. Lupatingatinga is the largest village within the Kipembawe Division, and would be the base village for the research team. At this meeting the research project was explained, including the activities that would be undertaken, the length of time that it was estimated it would take, and what could be expected. From the research team's perspective this could include walking across people's land and through their farms, and would also require participants for the social aspects of the research. It was explained the research team would like to do something for the community in return for their hospitality, and welcomed their suggestions for what was needed. The provision of wells for the two secondary schools in the Division, and text books for the five primary schools in the five surveyed villages was agreed. This meant that the majority of people would benefit indirectly from the research. This was explained at the beginning of all interviews and surveys.

3.4.2 Research assistants

Several research assistants were employed during the study to assist with data collection in the field. Due to the nature of the fieldwork it was necessary to employ people who were not from the area due to the skills that were required. The team consisted of the lead researcher and a British research assistant who assisted with the biodiversity surveys and logistics of establishing the project. Additionally a botanist from Dar es Salaam assisted with all vegetation surveys, and throughout the biodiversity surveys acted as a translator for non-research issues. Throughout the biodiversity survey two further research assistants and a cook were hired from Lupatingatinga. In accordance with the Acting Division Secretary's wishes these people were hired on recommendation from the Village Chairperson. Further, a Game Scout was hired for the duration of the biodiversity project in accordance with guidelines from the District Wildlife Officer to provide protection from wild animals and illegal poachers. The person hired for this position also came from the village. Additionally, while the research team were in the base village, guards were required to protect belongings during the day and night, and were recruited from the local security force. This was recommended due to the lack of formal security within the Division.

Throughout the period of social surveys two research assistants were employed, each with biology/conservation facing undergraduate degrees and hired through the Wildlife Conservation Society. In order to attempt to avoid any gender issues that may occur within the villages both genders were represented by the research assistants. Their role was to translate from English into Swahili and back, carry out the household surveys, and to act as interpreters for all interviews, livelihood matrices, and for any other situation where necessary. In very few cases only Sukuma was spoken in some households. In these cases a volunteer from the community who could speak both Sukuma and Swahili languages translated from Swahili to Sukuma and back. Where necessary a cook was hired from each village.

3.4.3 Pilot studies

Pilot studies were conducted prior to each phase of data collection. Pilot studies enable methods to be tested and practised, identify any practical problems and enable the research team to be trained (van Teijlingen and Hundley, 2001). The biodiversity pilot study was carried out near the Kalangali Forest Reserve, and lasted for five days. Each method was timed to determine what was feasible. During this period it was identified that using local ethnobotanists to conduct tree surveys using local names was not rigorous; this led to the recruitment of the qualified botanist.

The pilot study for the social surveys was carried out over a week in the village of Mtanila, where the household survey was shortened and refined until there were no ambiguities in translation and understanding, and it lasted for approximately 45 minutes per respondent. The lead researcher attended the household survey during the pilot study, but it was evident that this distracted the respondent. Therefore it was decided that during data collection one research assistant would be present only. Group interviews and livelihood matrices were also tested and refined, as were pertinent key informant interviews. The research assistants were trained; it was important to make sure that they knew enough about the project to understand why it was taking place and to understand why data were being collected on certain topics. In particular it was important for them to understand how to explain what something meant but not suggest answers or use leading questions. Throughout this period the research assistants gave valuable insights into the interview and survey design.

3.4.4 Phase 1: Biodiversity surveys

Biodiversity surveys were conducted at the end of the wet season and into the beginning of the dry season. This was necessary as most areas are inaccessible during the wet season due to seasonal floodplains and some small rivers. Timing was similar to other studies conducted within miombo woodlands in west Tanzania (Fitzherbert et al., 2006). Crops were in leaf and had not been harvested, so were easily identified. Miombo woodland trees tend to retain their leaves until the end of the dry season, and often change colour and bloom in late September, prior to the onset of the rainy season (Frost et al., 2003), and therefore were also identifiable. Surveys were conducted at nine sites (section 3.4.9). Land cover, trees, butterflies and disturbance was surveyed and quantified at each site.

3.4.5 Phase 2: Social surveys

Phase 2 took place during the dry season, after all harvesting had finished. During this period the tobacco markets are taking place, and it is too early to start preparing the fields for the new growing season. Therefore the majority of farmers were in the villages, and it was possible to reduce the impact of surveys on their livelihoods. Household surveys and livelihood matrices were conducted at the participants' home. Key informant interviews were usually conducted at the relevant offices. Group interviews were conducted at a central place, either the village offices or an outside area.

3.4.6 Study overviews

At the end of each day in the field for both Phase 1 and Phase 2 the research team discussed the day's work. This enabled all extra information to be recorded, such as opportunistic animal sightings, encounters with poachers and off-the-record conversations that gave useful insights into the village community. This is an important technique which records data that may not appear relevant at the time, but may be useful during analysis (Eisenhardt, 2002).

Part 2: Study area

3.4.7 Tanzania

Tanganyika gained independence from the United Kingdom on the 9th of December 1961, and became a Republic in 1962, shortly followed by Zanzibar (independence in 1963, Republic in 1964). Subsequently the two countries united to become the United Republic of Tanzania on the 26th of April 1964, and have since enjoyed a relatively peaceful union (National Bureau of Statistics, 2011). The country is democratically governed, under the framework of a unitary presidential democratic republic, with an economic growth rate of 7% per annum. The GDP per capita in 2012 was US$1,654, and total GDP was US$76.8 billion (2011 US$ PPP, UNDP, 2014). Average life expectancy is 61.5 years, literacy rates are 67.8% (2005-2012), and 21.5% of children aged 5-14 are in work (UNDP, 2014). Rural poverty in 2007 was 37.6% (National Poverty Line (National Bureau of Statistics, 2011)).

Agriculture, forestry and hunting contribute 28% of GDP to the economy (UNDP, 2014). Agriculture accounts for 80% of employment (70% of the total crop area is cultivated by handhoe), 66% of merchandise exports, and 55% of foreign exchange earnings (Chambwera and MacGregor, 2009). According to the World Bank, agricultural productivity is below its potential, mainly due to low adoption of new technologies, lack of market competition and high transport costs, in addition to poor policy interventions and trade barriers (World Bank, 2012). The Tanzanian Government is keen to support and develop the agricultural sector, and is in the process of doing so with several policies, including 'Kilimo Kwanza' (Agriculture First), and the Tanzania Agriculture and Food Security and Investment Plan, which has been developed with the Comprehensive Africa Agriculture Development Program (CAADP) for Tanzania (World Bank, 2012). This includes the development of the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) project. Both projects target the use of technologies and expanding agricultural areas to improve production.

Within Tanzania there are 16 National Parks (covering over 42,000km^2) and 17 Game Reserves, in addition to many Forest Reserves, Game Controlled Areas, Wildlife Management Areas, and other areas that are protected or have controlled access. There are currently 592 protected terrestrial areas covering 366,391km^2 (38.8%), and 27 marine areas covering 4,617 km^2; in total there are 619 protected areas (IUCN and UNEP, 2010), covering 37.8% of Tanzania's territorial area (National Bureau of Statistics, 2011). This means that there is an elevated conflict for land in the country, particularly in areas where conservation actions have resulted in evictions (Brockington, 2002), and around the edge of protected areas. The effectiveness of these protected areas is debatable – in a study of different types of protected areas within Tanzania Pelkey et al. (2000) found that Forest Reserves without active forest patrols did not demonstrate any benefits to conservation, Game Controlled Areas which allow settlement, grazing and hunting, saw more degradation than areas with no protection, and only National Parks and Game Reserves with restrictions on resource extraction and with onsite patrols were effective. This demonstrates that it is the effectiveness of protected areas that should be considered, rather than simply the number of designated areas. Shifting cultivation accounts for 50% of deforestation within Tanzania (Abdallah and Monela, 2007). Most miombo woodlands in Tanzania are not managed, and have no legal protection. For decades natural resources have been controlled by the state through centralised decision making processes, although there is now a move towards decentralisation and devolution to local communities (Luoga et al., 2005).

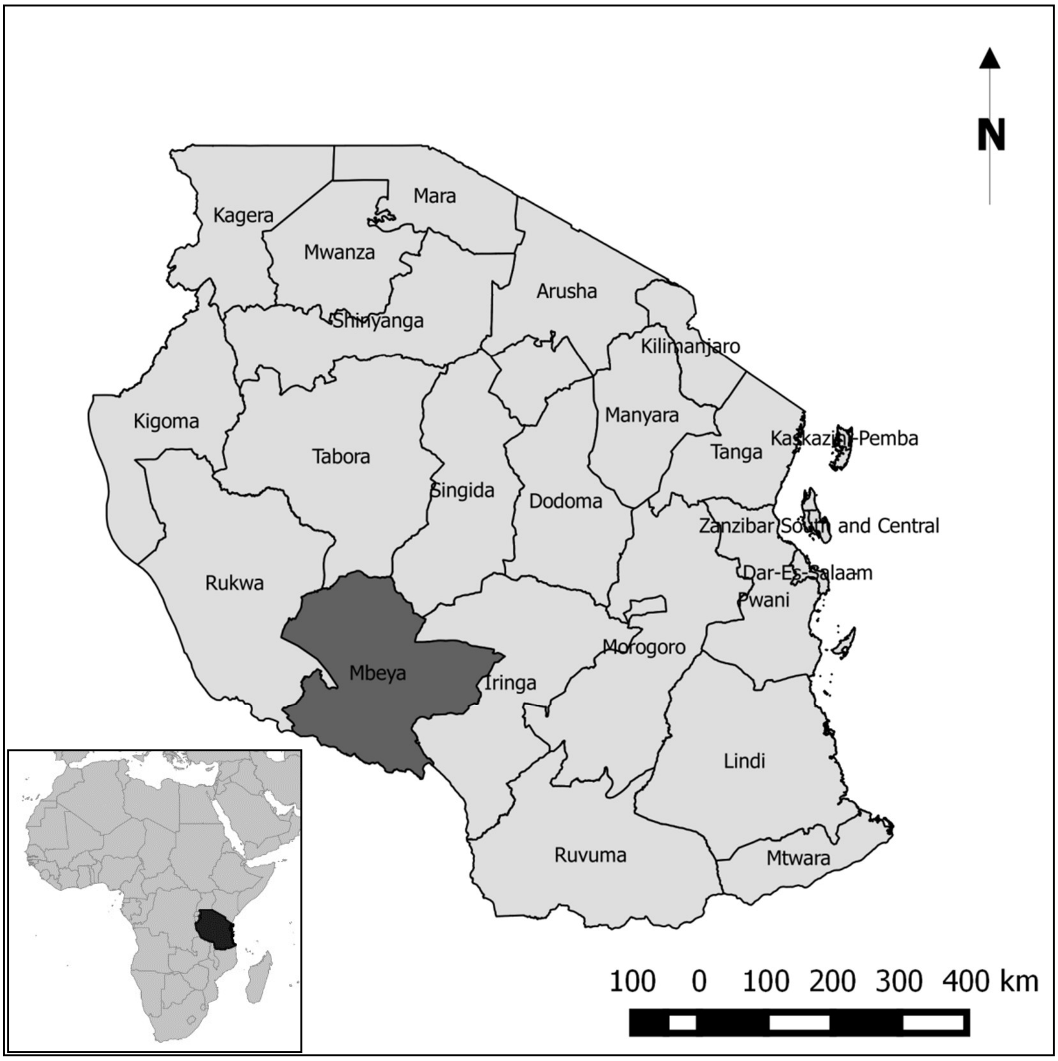

Figure 3.1: Mbeya Region in relation to other areas in Tanzania. Inset: Tanzania's location within Africa.

3.4.8 Mbeya and Chunya

Once Tanzania had been selected as an appropriate country for this research project it was necessary to select a region and study site. This took place during a scoping study in 2012 (Section 3.3.1). The selected region is Mbeya, and within this the Chunya District. Finally the research sites are situated within the Kipembawe Division. Mbeya and Chunya are described below, and the selection process for the research sites is explained. A detailed description of the Kipembawe Division is given in Chapter 4, using empirical evidence gathered during this research project.

Mbeya (Figure 3.1 and 3.2) lies within the Great Rift Valley, with altitudes ranging from 475masl at Lake Nyasa, and 2900masl at Rungwe Peak. Mbeya covers 63,617km^2, 6.4% of Tanzania, (61,783km^2 terrestrial and 1,834km^2 water) (National Bureau of Statistics et al., 2003). Within Mbeya the geology is predominantly crystalline and fersic gneiss and granite rocks, covered with thick layers of volcanic and alkali basalt (National Bureau of Statistics et al., 2003). The region borders Zambia and Malawi to the south, and is therefore an important international trade route. In Mbeya competition for land between agriculturalists and pastoralists is escalating, and deforestation continues (National Bureau of Statistics et al., 2003).

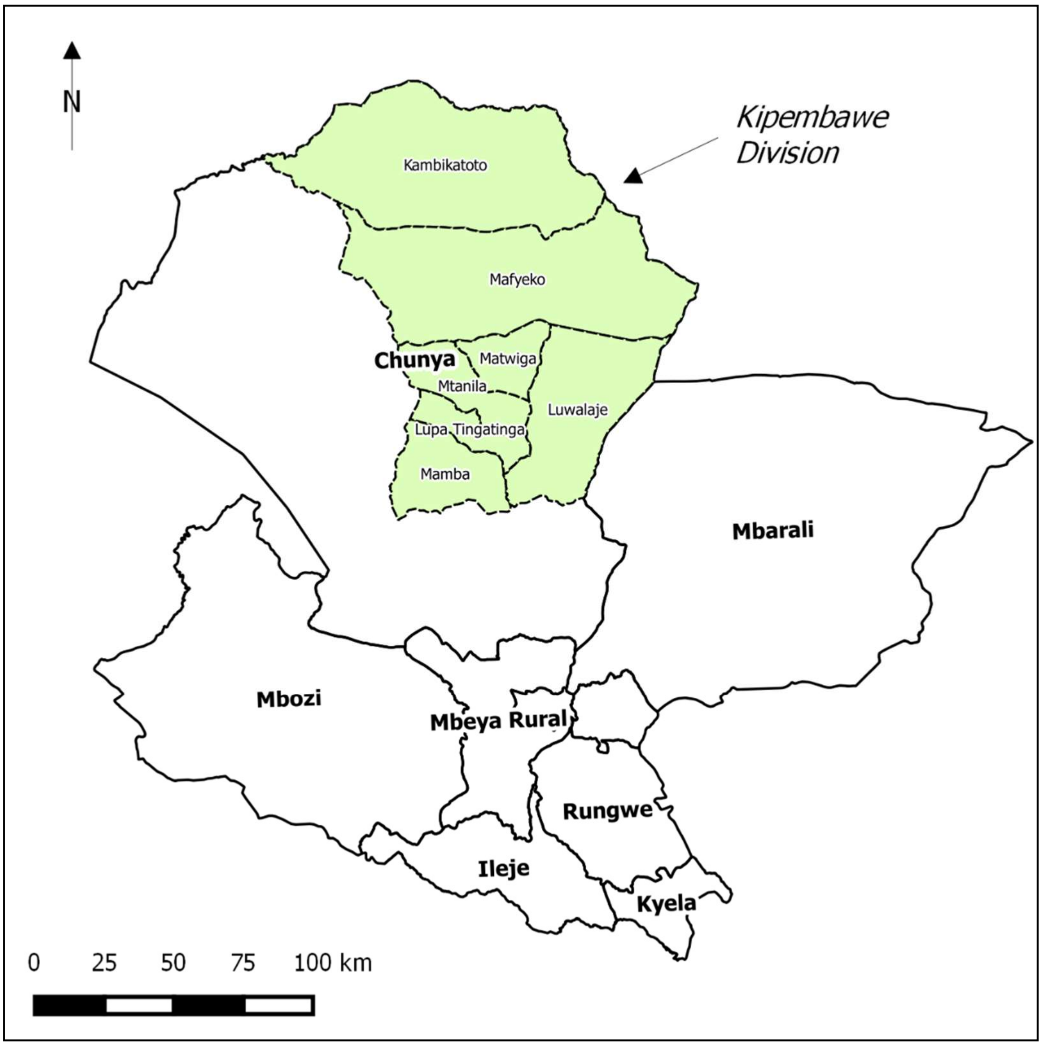

Figure 3.2: Mbeya Region and Districts. Highlighted area is the Kipembawe Division, illustrating Wards.

Chunya lies within the Rift Valley and the Southern Highlands, at an altitude of 800-1500masl. The average temperature is 21-23°C, and the average annual rainfall is 600-1000mm, with the heaviest rain falling from December to March (Chunya District Council, 2010). Chunya District

(Figure 3.2) is the largest of the eight districts in Mbeya, covering 46.9% of the region (29,219km^2) (Chunya District Council, 2010).

The dominant economy is agriculture, which contributes 69% to the income of the district and employs 85% of the district's working population. The Chunya District Council (2010) report on the District Investment Profile classify 79% of the area as arable land, with only 2% under cultivation (Table 3.1). Of the land available for agriculture 19 km^2 can be irrigated and 22,985km^2 is rainfed agriculture. There are 103,486 agricultural households in Chunya, 10 per km^2 (National Bureau of Statistics, 2007). The main crops grown are sunflower, sesame, tobacco, ground nuts, maize and millet (Chunya District Council, 2010). According to the latest Chunya Investment Profile (Chunya District Council, 2010) livestock farming contributes 17% to the district revenue, employing 2,357 people, with 135,000 ha of land suitable for livestock, of which 60,900 ha is used. This record suggested that within the district there are 286,500 cows, 36,600 goats, and 22,800 sheep, with a capacity for carrying 450,000 livestock units per year. This is over double the estimates from 1999, when there were thought to be 125,830 cows, 35,043 goats, and 11,380 sheep.

Table 3.1: Classification of land in Chunya

Classification	**Area km^2**	**Area share %**
Arable land	23,006	79
Game reserve	2,000	7
Forest reserves	413	1
Water bodies	1,105	4
Other	2,694	9
Total	29,219	100

Adapted from Chunya District Council (2010) (source: Land Planning Office 2009).

Other economic activities include forestry throughout the district, and fishing in Lake Rukwa, in the west of the District. Beekeeping is encouraged in miombo woodland areas, particularly in Kiwanga and Kipembawe (Chunya District Council Officers, pers. Comm., 2012). There are some limited opportunities for game viewing and trophy hunting in the north of the district, and mining for gold, coal, and green tourmaline in the south (Chunya District Council, 2010).

Much of the land that is classified as 'arable' is miombo woodland, as 95% of land cover in Chunya is miombo. Three of the divisions (Kiwanga, Kipembawe, and Kwimba) have significant areas of miombo; land cover in Songwe is half miombo and half the Rukwa basin, and is where most of the agriculture occurs (Chunya District Council Officers, pers. Comm., 2012).

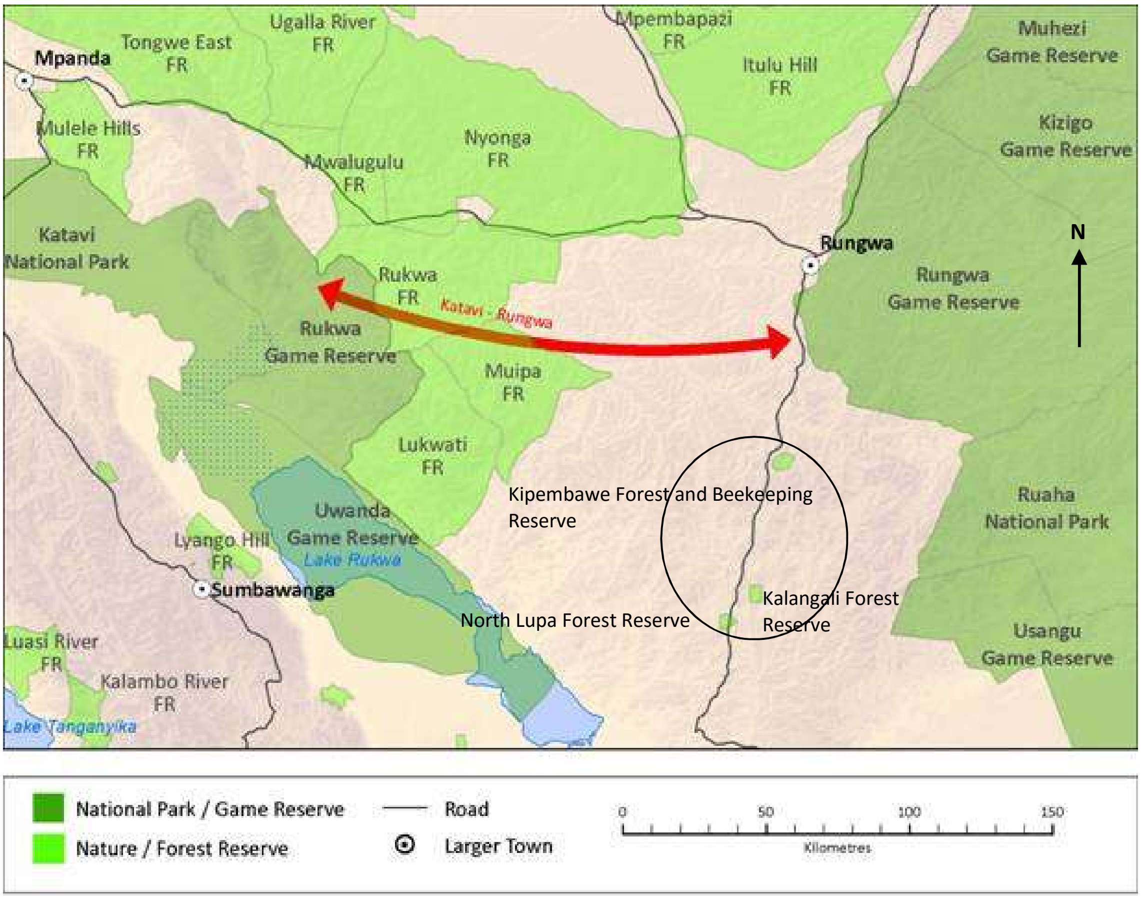

Figure 3.3: Protected areas within Chunya. Wildlife corridor represented by red arrow (source: Jones et al., 2009). Study area marked by circle.

Within Chunya District there are 26 protected areas, nine of which are central government controlled Forest Reserves. In the Kipembawe Division these are the North Lupa Forest Reserve to the south of the main village of Lupatingatinga, the Kalangali Forest Reserve to the north of Lupatingatinga and the newly gazetted Kipembawe Forest and Beekeeping Reserve which is near the old village of Kipembawe (Figure 3.3). There are two District managed Forest Reserves in Chunya, neither of which are in Kipembawe. There are also 15 village Participatory Forest Management Reserves, five of which are in Kipembawe, and two are within the study villages of

Nkung'ungu and Matwiga. Non-reserved areas of forest are general lands (District Forestry Officer, 2013). The Chunya District Council (2010) stated that not enough research has been conducted to know all the species within the district, however there are believed to be many large mammals in the area, including lions (*Panthera leo*), leopards (*Panthera pardus*), elephants (*Loxodonta africana*) and a range of antelope.

There are hunting concessions in the north of the Division around Kambikatoto and Mafeyko in the Rungwa Game Reserve which is connected to the Ruaha National Park (District Wildlife Officer, 2013). These areas to the far north of Kipembawe are considered to be part of the Katavi/Rukwa/Lukawati-Rungwa/Kisigo/Muhesi wildlife corridor (Jones et al., 2009) (Figure 3.3). Piti Game Reserve was gazetted in 2013 (District Wildlife Officer, 2013), formed from the Chunya West, Chunya East and Piti West Open Areas in the north-west (TAWIRI, 2014).

3.4.9 Site selection: Kipembawe Division

In the north of Chunya District, the Kipembawe and Kiwanga Divisions have substantial areas of miombo woodland and agricultural areas, so these areas were examined in further detail. Settlement and access to villages in Kiwanga are largely restricted to the shores of Lake Rukwa, and a road leading to a commercial gold mine. Therefore it was considered unsuitable, and the Kipembawe Division (8,766km^2) was used for further assessment.

3.4.10 Biodiversity site selection

Images obtained through Google Earth (Google Earth, 2012) demonstrated that there were broadly three categories of land cover (Figure 3.4) that could be identified through remote sensing images (Figure 3.5). These three categories are miombo woodland, agriculture and mixed agriculture/miombo woodland, and formed suitable levels of habitat change for sampling because each represented a different land use type and were likely to have experienced different levels of human disturbance. Landsat TM images (2009) were classified using programme ERDAS Imagine 2011 (ERDAS, 2011). A training model was produced through the identification of pixels representing vegetation in each category. Mining concessions and protected areas were removed from the study area, as these areas are already under management.

Once this classification process was complete it was then possible to randomly select GPS points within each land use type for potential biodiversity survey sites. On arrival at the site each point was checked for suitability, and to ground truth the accuracy of the image classification. Site selection was constrained by vehicle access and water availability. Local knowledge from village elders and Chairpersons was used to determine the history of the site. The study area was located at 7°54’58.44” S, 33°19’22.84”E. All biodiversity sites were a minimum of 10 km apart, and each site covered 200 ha.

Figure 3.4: Different land cover in Kipembawe Left: Agriculture (high utilisation); Middle: Mixed agriculture and miombo woodland (medium utilisation); Right: Miombo woodland (low utilisation). Source: Google Earth (2012).

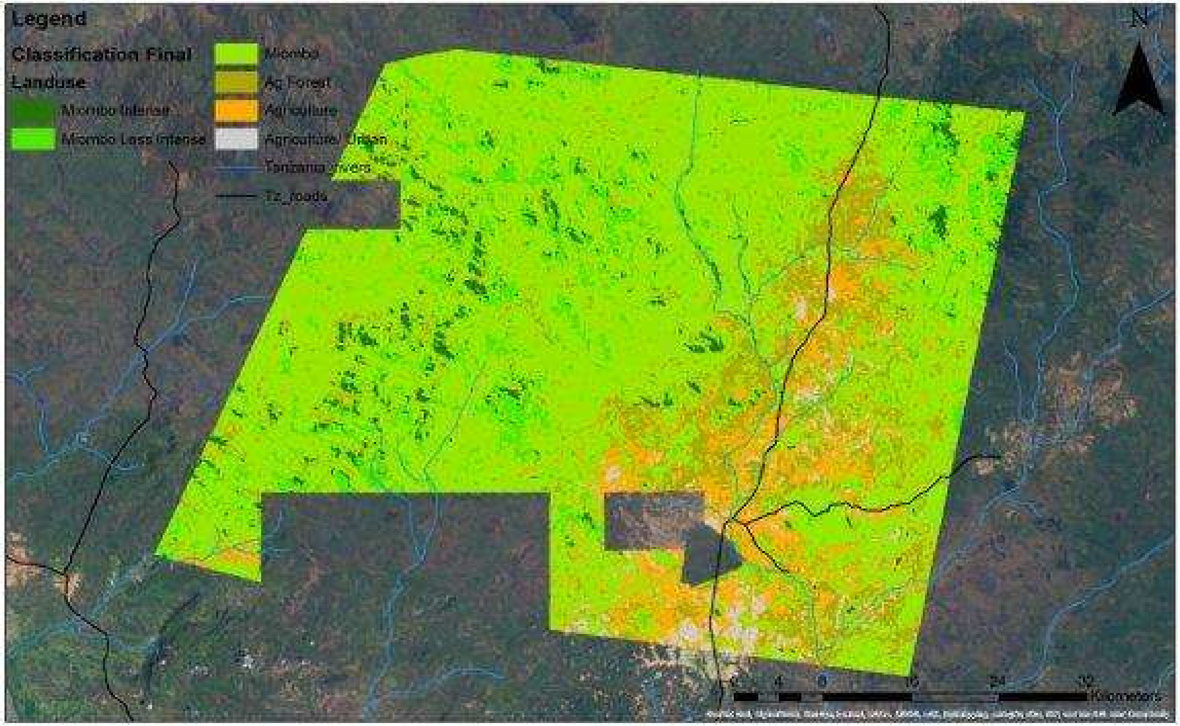

Figure 3.5: Remote sensing classification with mining areas and protected areas excluded. The Kalangali Forest Reserve (rectangular block) is incorrectly placed in this map, however the co-ordinates are known and it was excluded from the generation of GPS points.

Following ground truthing nine sites were selected for field surveys. Two agricultural sites represent high utilisation; four mixed agriculture/miombo sites represent medium utilisation, and three miombo sites represent low utilisation (Figure 3.6). Full site descriptions are given in Table 3.2.

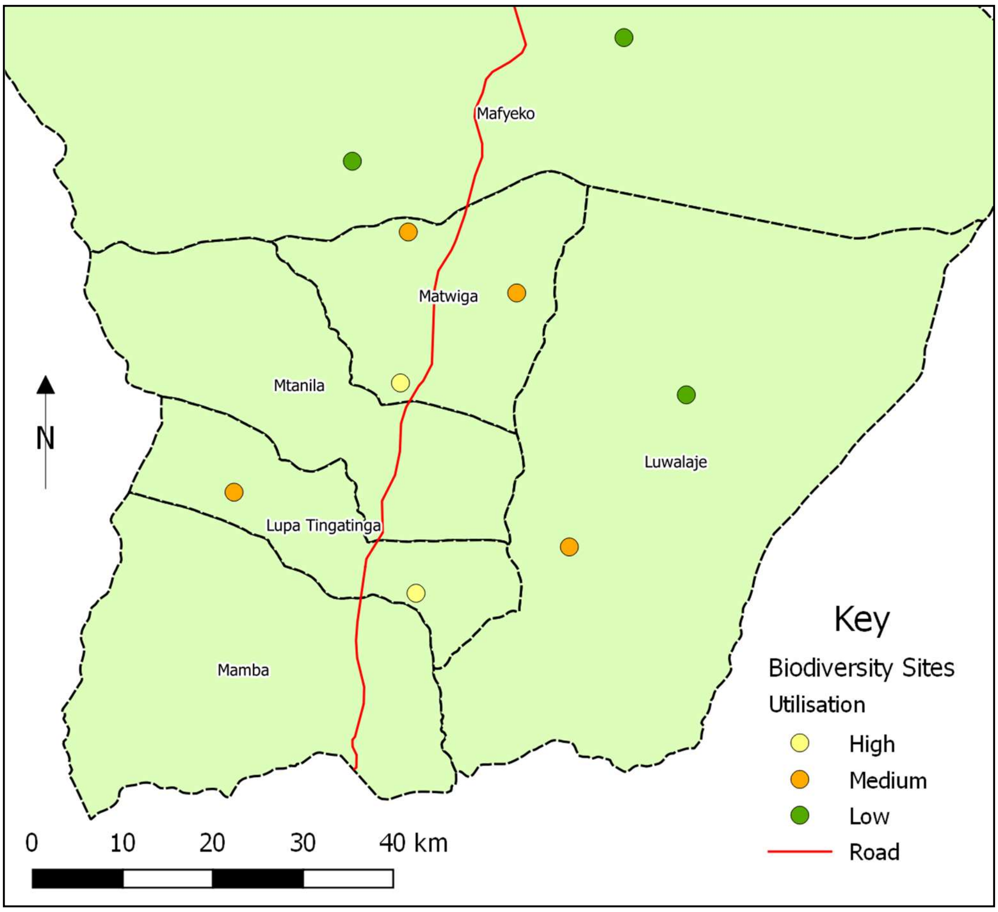

Figure 3.6: Final biodiversity sites. Dotted lines represent Ward divisions, as named.

Table 3.2: Biodiversity site descriptions

Site	Main land use	Age of agriculture (years)	Type of woodland	Approximate distance from road (km)	Approximate distance from settlement (km)	Cattle tracks present on transects (%)	Additional information
1	Agriculture	20	Regenerating (5-10 years old)	0.6	1.7	25	Very small patches of woodland adjacent to crops. Timber extracted for construction.
2	Agriculture	13	Mature	3.2	5.9	0	Areas of seasonal floodplain, very small patches of woodland.
3	Mixed	9	Mature	1	1	3	Village established seven years ago
4	Mixed	2	Mature	7.3	8.7	27	Some areas chopped down but not cleared or farmed. Other farms established two years ago
5	Mixed	20+	Mature	3.2	7.4	2	People moved off and onto the land, since 1974 (villagisation). Forest connected to protected area.
6	Mixed	20+	Mature	3.5	3.9	93	Very heavily grazed by livestock
7	Miombo	n/a	Mature	9.8	9.8	0.3	Open Area - restricted access for beekeeping, tourist hunting and timber extraction. Managed by hunting company. Permits issued by District.
8	Miombo	n/a	Mature	14.6	17.5	9	Unprotected miombo area on the edge of a recently gazetted (2012) Woodland and Beekeeping Reserve, which is not yet established on the ground. No officially known settlements or established agriculture in the area although some clearing occurring during research - 1 week old, none other found.
9	Miombo	2	Mature	6.6	6.6	0	Mature forest adjacent to farmland showing no signs of use but not protected. Farms expected to expand into the woodland in next 2-3 years. Areas of seasonal floodplain and rocky outcrops. Transects running north were all in woodland, butterfly/bee/vegetation plots were in farmland. Adjacent to protected areas

3.4.11 Village selection

Five villages were selected for participation in the social survey from three wards. The villages were selected due to their proximity to the five biodiversity sites which were initially classified as mixed miombo woodland/agriculture (medium utilisation). They were selected like this because the people within these villages were most likely to use the adjacent woodland and the results from the survey could then be aligned with the biodiversity survey data. Villages selected were: Mazimbo, Matwiga (Matwiga Ward), Lualaje, Mwiji (Lualaje Ward), and Nkung'ungu (Lupatingatinga Ward) (Figure 3.7). Biodiversity sites and villages are shown in Figure 3.8.

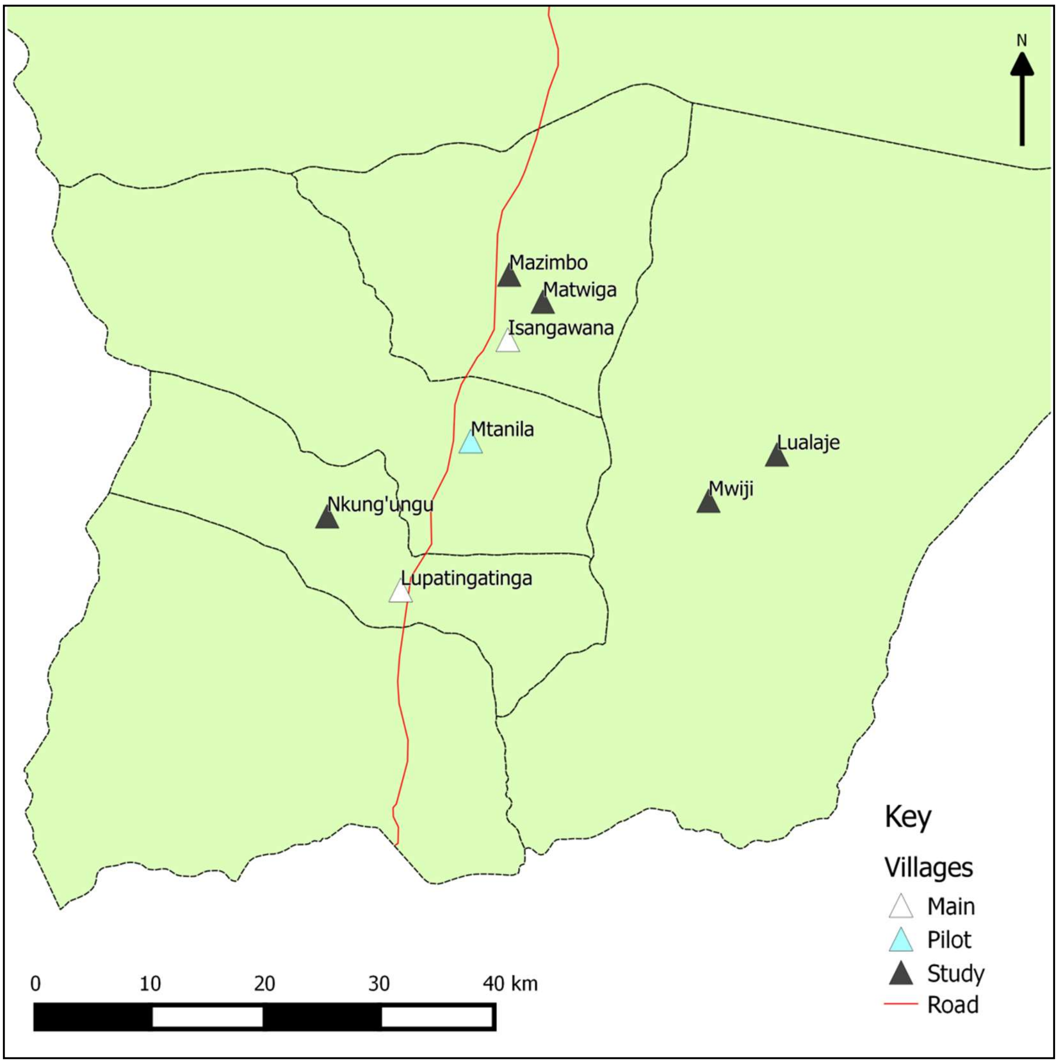

Figure 3.7: Location of survey villages, main supply villages and the pilot study village

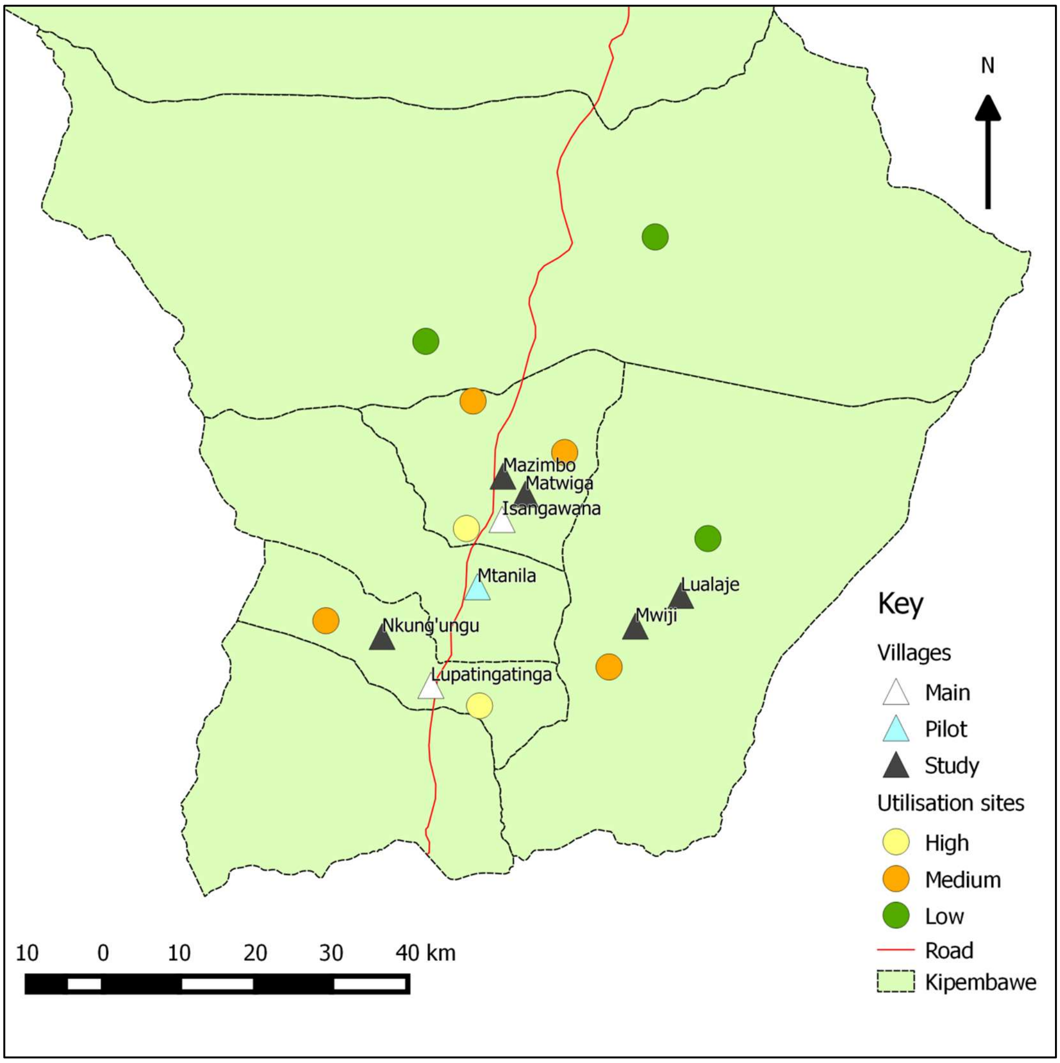

Figure 3.8: Location of all study sites and villages within the study area

Methods

This section provides details of methods that are used in multiple empirical chapters. Methods that are only used in one chapter are described within the relevant chapter.

3.5 Biodiversity surveys

3.5.1 Land cover and utilisation

In each site, land cover type and the utilisation intensity (human use of the woodland, e.g. agriculture, extraction of timber, use of non-timber forest products) were surveyed along five 1.5 km transects. Transects were 10 m wide and divided into 20 m sections (Doggart, 2006), and ran south-north, sampling 75,000m^2 at each site. The dominant land cover type for each section was recorded, and within each section all live and dead poles and timbers, and cut poles and timbers, were recorded. Poles were defined as having 2 m straight stem and being between 5-15 cm diameter at breast height (DBH) which is standardised at 1.3 m. Timbers were >15 cm DBH, with a 3 m straight stem (Blomley et al., 2008, Frontier-Tanzania, 1997). Cut timbers and poles were recorded as old or new. New cuts were identified by the cutting surface being a fresh cream/pink or green colour, with no blackening or other signs of decomposition, indicating that the cut was 0-6 months old (Blomley et al., 2008). Prior to the survey, woodland walks were conducted with local people to establish what they would use for poles and timber to assist the researchers with later data collection. All other signs of human utilisation (e.g. beehives, burned trees, tobacco burners, paths) on the transects were recorded.

3.6 Social surveys

Social surveys were conducted to gather information about the area, including topics such as governance, land use, ecosystem service use and livelihood perspectives. The wide range of subjects was necessary because of the exploratory nature of the research. While research focused at village and household levels, interviews were also conducted at Division, Ward, District and Regional level. A mixed methods approach was used, which included household surveys, focus group, key informant interviews and participatory livelihood matrices. This enabled a range of data to be gathered and triangulated (Fielding, 2012). Throughout the results chapters individuals are anonymised to prevent their identification. However, due to the contextual nature of the results, village names are retained where appropriate.

3.6.1 Household surveys

Household surveys (HHS) were conducted to generate quantitative, semi-quantitative and qualitative data regarding the household (demographic), farming practices (e.g. crops grown, size of cultivated land, land preparation methods) and woodland resource use (building materials, non-timber forest products etc.). The survey is available in Appendix C.

At each village 10% of households (n=196, Table 3.3) were selected randomly to participate in the HHS (Meshack et al., 2006). Surveys were conducted with the head of the household, where households were defined as people who sleep under the same roof and eat from the same pot (Antwi-Agyei et al., 2014, Knueppel et al., 2010), and the head of the household was defined as the primary decision maker within the household (Collins, 2004). Sampling household heads resulted in a skewed male to female ratio, with males representing 80% of those surveyed. Villages are generally divided into sub-villages. The sub-village chairperson was approached in each village and asked to provide a list of all household heads within the sub-village. This is normally a document that is already prepared, although in most cases this had to be updated. Once this list was complete each household was then given a number. Random numbers were then generated using Microsoft Excel, and the households were selected on this basis (Davis et al., 2012). This was in order to avoid biases that could have occurred by asking for volunteers, or the village/sub-village chairpersons supplying respondents, and it was a transparent process that removed any possible jealousy between households. 'Spare' numbers were also generated, and if any households on the original list were unable to participate these households were approached. Once the household had been selected the sub-village chairperson then introduced the research assistant to the head of household, the project was explained and the option to participate was given.

Table 3.3: Villages and sub-villages surveyed. Numbers of households and number of surveys conducted in each sub-village.

Village	Sub-village	Total number of households	Number of surveys
Mwiji	Mwiji A	28	3
	Mwiji B	27	4
	Mwiji C	27	4
	Mwiji D	115	13
	Isote	122	8
Matwiga	Tankini	110	11
	Maendeleo	171	17
	Milimani	46	5
	Moyo	65	7
Nkung'ungu	Nkung'ungu	186	19
	Lukalya	100	10
	Kinyampuma	89	9
Mazimbo	Mazimbo	138	14
	Ilindi	222	22
	Kiyombo	65	7
Lualaje	Kabuta	84	8
	Kitakwa	64	6
	Itete	40	4
	Sumbwe	28	3
	Ikingo	44	4
	Kiseru	140	14
	Muungano	43	4
Total		1954	196

3.6.2 Focus groups

Focus group discussions (Morgan, 1997) were conducted within each village with specified groups of people (e.g. pastoralists, agriculturalists, villagers), and additionally representatives of village committees (e.g. social welfare committee, Participatory Forest Management committee). In total 28 focus groups were conducted (Table 3.4). Groups consisted of 2-8 people, depending upon availability, and lasted for approximately one hour. Where possible an even number of men and women attended, although in most cases more men were present than women. Participants for focus groups were volunteers, usually facilitated by the village or sub-village chairperson, who was provided with the types of groups that had been selected for participation. At the beginning of each focus group the researchers were introduced, the aim of the research as a whole was given, and the community gift was explained. It was reiterated that the process was voluntary and anonymous, and participants were given the option to leave at any time, and to ask any questions. The aim of the focus group was to gather further detailed information on a range of topics relevant to the group. For example, the social welfare committee is usually involved with land use planning and the environment. Pastoralists were able to give deeper insights into the livestock issues. Questions that had arisen from HHS data could be explored within these groups in more detail. A series of questions were asked, and answers considered among the whole group, which often required facilitating (Ritchie et al., 2013). Themes that arose were explored further where relevant. All sessions were recorded, and notes taken through translation by the lead researcher.

3.6.3 Key informant interviews

Key informants are individuals with an in-depth knowledge about a specific topic, or involvement with a certain project or programme within the community (O'Leary, 2013, Tremblay, 1957). Interviews were conducted with key informants at Village, Ward, Division, District and Regional levels, and included representatives from the government, private companies and non-governmental organisations. Interviewees were identified throughout the study period. Interviews were conducted as semi-structured interviews that explored the topic relevant to each person, and aimed to gain a broader insight into subjects that were pertinent at local level, or that influenced local level activities. Interviews were either conducted by the lead researcher in English, or in Kiswahili through a translator. Interviews lasted approximately one hour, and were arranged previously. Paper consent forms were signed by all participants. Interviews were recorded and notes were taken. Forest walks were undertaken with forest dealers and traditional healers to talk about plants and their uses, and enabled identification of the plant. In total 41 key informant interviews were conducted (Table 3.4).

Table 3.4: Interviews and focus groups conducted. Further details cannot be given due to anonymity guarantees.

Level	Number
Key informant interview	
Regional government	4
District government	8
Division government	4
Ward government	5
Within villages	16
Private companies and other organisations	4
Focus groups	
Village elders	5
Villagers	5
Agriculturists	5
Pastoralists	4
Social welfare	5
Participatory Forest Management (PFM)	2
Land Use Planning Committee	2

3.6.4 Participatory livelihood matrix

Participatory livelihood matrices (Sallu et al., 2009) were conducted with five people in each village (n=25) to gain an understanding of income streams into the household. These were conducted with volunteers, and conducted by the lead researcher and a research assistant. For this research technique participants were asked to describe their livelihoods for any year that they could remember, and describe why they had changed their activities for those years. This was facilitated by drawing a grid on the ground, and writing on the y axis the activity or crop that they grew, and the year on the x axis (Figure 3.9). Then for each year they would place a pile of beans to represent how large or small a contribution that activity made to their livelihood. Most people remembered either good or bad years, and were able to describe why that was the case. This gave valuable insights into crop vulnerabilities and coping strategies.

Figure 3.9: Participatory livelihood matrix (source: E Jew, 2013)

3.7 Conclusion

This chapter has outlined the site selection process, and defined the study area. It has described the methods that are used throughout the thesis. The following chapter describes the Kipembawe Division using empirical data.

Chapter 4

The Kipembawe Division

Chapter summary

This chapter contributes to Objective 1 by exploring the history of Kipembawe in relation to Government policies of the last 60 years, and identifying how this history influences the area today. It also provides further descriptive detail regarding the ecological and social status of the area today. Such detail aids understanding of the complexities within the area and provides a platform for future chapters. This chapter builds upon Chapter 3, where Kipembawe was selected as the study area, and its geographical position was demonstrated. Aspects about Kipembawe highlighted here are then selected and considered in greater depth in the following chapters.

4.1 Abstract

The Kipembawe Division has been shaped by government policies of the past, most notably those aimed at resettlement. Each of the villages studied were formed in response to one of three settlement programmes during the 1960s and 70s. Notably within this area all the settlements were formed around tobacco cultivation, and today tobacco remains the main commercial crop. It continues to drive immigration; 75% of households surveyed migrated to the area, and the majority did so in order to cultivate tobacco. Although formal processes of obtaining land are in place, these are not followed, and as a result there is almost no tenure security. Village Land Use Management Plans are being developed as part of a Government policy to address this. There are comprehensive governance structures in place at district to village levels, but they suffer from lack of funding and accessibility. This means that governance is weak, particularly in remote parts. The Kipembawe Division is remote, with poor road networks, communications and access to services. The landscape is dominated by miombo woodland, in a high rainfall regime.

4.2 Introduction

Landscapes emerge as a product of social and ecological history (Leach et al., 1999). Within Tanzania the resettlement schemes implemented during the early years of Independence had huge consequences for land use and environmental health (Kikula, 1997). The legacy of resettlement schemes in the Kipembawe Division (hereafter referred to as Kipembawe) is key to understanding current land use and land use change for future planning. One dominant land use is tobacco cultivation, which has been particularly influential in south-west Tanzania, and remains so today. Land tenure and governance structures dictate how the land should be divided, allocated and managed, and influence how this occurs in practice. This chapter examines these three critical elements (tobacco, land tenure and governance structures) and the relations between them through a combination of literature review and empirical evidence from Kipembawe. It finishes by providing background information about the division today, setting the context for the following empirical chapters.

4.2.1 Village Settlement Schemes, *Ujamaa* and Villagisation

Following Independence in 1961, three successive governmental strategies were developed that aimed to influence the distribution of populations in rural Tanzania through various settlement schemes. The first of these were 'Village Settlement Schemes' which had previously been attempted by the British Colonial Government between 1922 and 1956 to mechanise farming and increase production in three districts (Coulson, 2013, Kauzeni et al., 1993). One such successful scheme was the introduction of tobacco farming in Tabora, a region to the north of Mbeya (Boesen and Mohele, 1979). The World Bank advocated the development of new technical, social and legal systems through comprehensive Village Settlement Schemes (Kulaba, 1982, World Bank, 1961), and these were incorporated into Tanzania's First Five-Year Plan (1964-1969). Sixty pilot schemes were proposed in the Plan to be enacted by 1970, with an aim to increase this number to 200 schemes by 1980. The aim was that within each settlement there would be approximately 250 individual farms which would be encouraged to work on a co-operative basis, yielding economic and social benefits that would justify the financial investment in the project (Coulson, 2013). Farmers were supplied with food rations, transport costs were covered, and credit given for the purchase of farming implements (Kulaba, 1982). However, by 1966 the extreme costs of the project (in the region of £150,000 per settlement) rendered the programme infeasible, and it was announced that no more would be developed. In 1967 it was evident that the cost of running those still in existence was uneconomic and a burden to the nation (Kulaba, 1982).

Village Settlement Schemes were replaced by '*Ujamaa*' ('Familyhood') villages in 1967. These were villages where people lived and cultivated communally, a concept developed by Tanzania's first president, Julius Nyerere, who was influenced by ideas of African socialism (Coulson, 2013). Division of labour was encouraged, and savings could then be used to purchase equipment that would benefit the whole group. Nyerere's plan was idealistic and general, there were no real guidelines to deal with the consequences of setting up such a village, and there was no long term plan in place to guide agricultural development (Raikes, 1975). People were reluctant to move into *Ujamaa* villages, and although Nyerere stated in 1967 and 1968 that *ujamaa* must be voluntary, by 1973 he was quoted as saying that 'to live in villages is an order' (Coulson, 2013). At this point the principle of *ujamaa* was effectively dropped, and people were moved to villages in 'villagisation' schemes. Villagisation compelled all farmers in a selected area to live in villages. It was done quickly at village level, with little time for planning and discussion, and in some cases by Presidential Planning Teams (Kauzeni et al., 1993) who had no knowledge of the area. It was also a top-down approach, involving the recently appointed local government staff. A large proportion of rural populations were moved into villages of 250-300 households and in 1977 Nyerere reported that 13,065,000 people were living in 7,684 villages (Coulson, 2013).

Once the villages had been established, their aims became somewhat blurred (Raikes, 1975), and focus moved to the provision of seeds and fertiliser, but the intensification of farming around the villages led to rapid decreases in soil fertility. The lack of people in the bush led to increases in game populations and which resulted in higher tsetse flies numbers and increased crop damage in areas that were far from the village and unprotected at night (Coulson, 2013). However, villagisation did lead to significant improvements in social services at local levels, particularly education and health (Ibhawoh and Dibua, 2003).

There was a marked decrease in agricultural productivity between 1974 and 1977, causing exports to fall and imports to rise. This seriously depleted the Bank of Tanzania's foreign currency and by 1980 villagisation was seen to have failed (Ergas, 1980). Nyerere stepped down as President, and his successor rapidly undid many of the hard-won gains towards a socialist state (Coulson, 2013) by embarking on a path to a free market economy (Pallotti, 2008). Devaluing the currency and cutting government spending improved the economic position of Tanzania at national level, but led to a reversal in local education, health service provisions and water supplies (Coulson, 2013).

4.2.2 Land tenure in Tanzania today

One of the reasons for the development of villagisation schemes was the need to address land tenure (Shao, 1986). As early as 1958 land tenure reform was discussed in Tanzania, and there were two schools of thought, one encouraged individuals to have land to cultivate and prosper, at the risk of an unequal society, and a second that would result in everyone working together and either all prospering, or no-one (Shao, 1986). This second option aligned with Nyerere's vision of African Socialism and led to villagisation, and although this ultimately failed, land reform was not addressed again until 1997 with the release of the National Land Policy. This was designed to consolidate land policies which had not been significantly addressed since the 1960s, and in doing so did not redistribute land or introduce new categories, but instead devolved responsibilities for the administration of rural land to local government (Pedersen, 2012). The National Land Policy had an overall aim to '*promote and ensure a secure land tenure system, to encourage the optimal use of land resources and to facilitate broad-based social and economic development without upsetting or endangering the ecological balance of the environment'* (National Land Policy, 1997, p5). The Land Policy reinforced the notion that land cannot be privately owned: *'all land in Tanzania is public land vested in the President as trustee on behalf of all citizens';* meaning that the government will always be able to remove people from the land, should it be required for a different purpose. Land can be leased from the government, or a right of occupancy can be granted (Sundet, 2004).

There have been various amendments and updates to the National Land Policy, including the 1999 Land Act, the 1999 Village Land Act, the Land (Amendment) Act of 2004, and the National Land Use Planning Commission Act, 2007. The Village Land Act of 1999 states that the village council is responsible for the management of all village land. This Act also enabled individuals to obtain formal recognition of occupancy of land. There are two types of occupancy: the Statutory Right of Occupancy, which has a term of tenure of 99 years; and the Customary Right of Occupancy, which is unlimited. In order for someone to apply for these the village whose land they occupy they must have a Village Land Use Management Plan. The person must obtain approval from the Village Council for an application of Right of Occupancy, and then the application goes to the District to be approved by the District Land Officer. The success of this policy depends upon local and village level governance. Land tenure is often influential in regard to land use (Robinson et al., 2014) because it affects the way people regard the land, and therefore it is necessary to determine the status of land tenure and access to formal rights of land within the case study villages.

4.2.3 Governance in Tanzania

Governance in Tanzania has been through a series of 'pendulum' swings (Mollel and Tollenaar, 2013); from centralised governance, to decentralisation and back again, with both deconcentration of power and attempts at devolution of power. During British governance District Councils were created, through which central government policies were enacted (Picard, 1980). During *ujamaa* the District Councils were abolished in favour of a decentralised system of administration through Regional Development Committees who would represent *Ujamaa* villages (Kessy and McCourt, 2010). However, greater local participation was not achieved, and administrators ended up becoming agents of central governments (Kessy and McCourt, 2010). District Councils were reintroduced in 1982 (Pedersen, 2012) and power was devolved to them with the intention of enhancing community participation (Mollel and Tollenaar, 2013). However, this failed to happen, and led to the latest attempt at local governance reform – the Local Government Reform Programme, developed in 1998 and implemented from 2000 (Kessy and McCourt, 2010). This aimed to decentralise authority from central to local government in a process of 'decentralisation by devolution' (Mollel and Tollenaar, 2013). Today local governments receive authority and resources from central government, and operate within a national legal framework which gives them autonomy (Kessy and McCourt, 2010) and increased community participation is encouraged (Mollel and Tollenaar, 2013). Local governance remains based on the concept of villages as the basic units of the local government system as introduced during villagisation, with elected councils who represent the village. The governance structures within Kipembawe are presented here; and the strengths and weaknesses of this governance structure are discussed further in Chapter 9.

4.2.4 Tobacco cultivation and governance

Tobacco cultivation underpinned some of the early Village Settlement Schemes, particularly those in the south-west of the country (Boesen and Mohele, 1979). These were some of the most successful Settlement Schemes (Davis, 1971), and tobacco continues to support livelihoods in these areas today (Sauer and Abdallah, 2007). Tobacco is cultivated throughout the world (Goodman, 1993, Knapp et al., 2004), and is the world's most widely grown non-food crop (Geist, 2009). The Tanzanian government has made tobacco cultivation one of the centre-pieces of its new strategic economic plan (Maegga, 2011) due to its importance as a source of revenue, both on domestic and international markets. In terms of tonnage it is the fourth largest Tanzanian export, behind wheat, cashew nuts and sesame, but in terms of income it is the second largest earner after coffee, with an export value of US$106,585,000 (2011 data, FAOSTAT, 2014). Most tobacco cultivation is undertaken by subsistence farmers (Geist, 2009), who do not have the capital to purchase seeds, fertilisers or pesticides, and therefore rely on co-operative societies.

Co-operative Unions were encouraged by the colonial government and initially started in Tanzania in 1932 (Coulson, 1977), partly to compete with Asian traders through the provision of alternative produce buyers during the colonial period. Unions were established for several export crops, including tobacco (Mitchell and Baregu, 2012). These co-operatives were deregistered in 1976, and villages told to act as multipurpose co-operative societies by buying crops from the residents and selling them to registered parastatals (organisations with some political authority serving the state indirectly) (Putterman, 1995). In the case of tobacco the parastatal was the Tobacco Authority of Tanzania (TAT) which was formed in 1972 (Mitchell and Baregu, 2012). The TAT was responsible for all aspects of the tobacco industry, providing the co-operative societies (villages) with the inputs required to cultivate; and then transporting, storing, processing and exporting the product (Putterman, 1995). Throughout the 1980s there were further reforms, including the re-introduction of the co-operative unions in 1984; allowing the private sector to become involved with buying, processing and exporting the crop in 1995; and various amendments to TAT, the most recent in 2001, when the Tanzanian Tobacco Board was formed (Mitchell and Baregu, 2012), which does not have authority to engage in the marketing or processing of tobacco. Today three private tobacco merchants together form the Association of Tanzania Tobacco Traders (ATTT), which deals with input supply and green tobacco procurement. This organisation buys and distributes inputs to the Primary Co-operative Societies (PCS) (formed in each village) in the tobacco growing regions who then supply farmers with the necessary equipment to produce the tobacco (Maegga, 2011). The village-level PCS are affiliated into Co-operative Unions, and these Unions are under the umbrella of the Tanzania Tobacco Co-operative Apex (TTB, 2013). Farmers then buy the fertilisers and pesticides from the PCS against credit, which is taken from the sales of the tobacco at the end of the harvest. Seeds are provided for free, and the tobacco merchants also provide extension services for the farmers. The process that takes place in Kipembawe is described below in section 4.4.2.

4.2.5 Contemporary ecological and social landscape

This chapter provides the historical context and land and governance policies that shape many of the decisions that take place within Kipembawe. However, the influences of the environment and human infrastructure also need to be taken into consideration. Therefore these aspects of the Division are described to provide the complete context for the setting of this thesis.

4.3 Methodology

Study area selection is detailed in Chapter 3. The empirical data used within this chapter comes from household surveys, livelihood matrices, focus groups and key informant interviews as described in Chapter 3, section 3.6. In particular focus groups with village elders were used to gather oral histories about the area. Oral histories are personal testimonies that are delivered in oral form (Yow, 2014). By conducting these as a group, all members were able to contribute to the process and helped to cross-check the timings of events. Conducting similar focus groups in each of the five villages enabled cross-referencing of the data. Secondary data from Tanzania Government departments are also used, and credited as such. These are supplemented through personal observations by the research team and additionally relevant literature is drawn upon where appropriate. Themes were identified and cross-referenced across the multiple methods. Household survey data were collated across the five villages and descriptive statistics calculated where necessary.

4.4 Results

4.4.1 Historical and social policies

Villages within Kipembawe were affected by all three government settlement programmes. Accounts from the village elders in Matwiga and Lualaje are given in Boxes 4.1 and 4.2.

Box 4.1: Village Elders focus group, Matwiga 2013

The river between Matwiga and Mazimbo is where many giraffes used to go to drink. A long time ago, in the 1960s, the Wakimbu (who were scattered hunter gatherers) found a giraffe stuck in the mud and they killed it. It is because of the giraffes that the village is called Matwiga. Before 1964 there wasn't a village here, just the Wakimbu lived here. There were some people in Mazimbo, where they farmed maize and finger millet. Then in 1964 people were moved to the area as part of the 'settlement scheme', and then tobacco cultivation was introduced. At this point there were 51 people in Matwiga.

Tobacco came from Urambo in Tabora, first to Lupa in 1958 where it was farmed by a Dutch South African called Joffery. He had been employed by the government and was the manager who controlled the Turkish tobacco. In 1964 it was introduced to Matwiga, which became the headquarters, run by a man called Harrier. Then it spread to other villages. The Turkish tobacco was bad though, because it had to be dried in the sun and there were no benefits to farming it. It was farmed for two years until 1965. During the Turkish tobacco period researchers and surveyors saw the importance of sandy soil - it is good for tobacco. The Turkish tobacco didn't use fertiliser but wasn't good quality. In 1965 the government Minister for Agriculture introduced fire-cured tobacco. They started using fertiliser for this tobacco right from the very start – CAN (calcium, ammonium, and nitrate) and NPK (nitrogen, phosphorus and potassium) and have been using the same fertilisers since then.

After the introduction of tobacco everyone spread out and moved to the farms, and then between 1971 and 1972 the area was run as a communal socialist village called Ujamaa where everyone had to farm together and then split the profits equally. After 1975 they realised that the socialist system didn't work, so they farmed their own land, and this has been practised up to the present.

In 1966 there was one primary school which was used by everyone. All four sub-villages here were all created at once in 1988. Up until this point the population in Matwiga had been very low, now there are 430 tobacco farmers. To become a sub-village 50 households are needed. From 1964 to 1990 all the tobacco was sold to TAT, which was run by the government. Then from 1990-1998 STANCOM traded tobacco. In 1998 one of the companies operating today took over, and in 2004 the other one started operating here.

In the future we think that there will be drought because the population is increasing but there will be limited land for agriculture. Trees should be planted to avoid desertification. The number of livestock affects water sources – the immigrants come with a lot of cows – so there should be restrictions on the numbers of cows that are kept.

Box 4.2: Village Elders focus group, Lualaje (2013)

In the 1960s there were four groups of people living in the Lualaje area. They were Kimbu people. There were probably about 40 people in total, and they were hunter-gathers, and harvested honey, and also cultivated a little maize and millet. There were no cars, and the forest was very thick. There were no medical facilities and no connection with the outside world. People used to run away from the sound of aeroplanes. In 1966 the Minister of Agriculture came to see if the area was suitable for any agriculture. In 1968 he sent a research team to see if the land would be suitable for growing tobacco, and due to the abundance of trees and water they concluded that it was. At this time there was thick forest and lots of animals, including elephants and lions. In 1967/68 people were bought here to construct a road. When this was completed in 1969 people were bought into the area on trucks by the government as part of a resettlement programme to take people to the area so they could grow tobacco. They were provided with maize flour, clothes and cooking oil by the government. At this point the Lualaje village area was divided into plots, which are still used as boundaries for the sub-villages today. Once people were given the plots they had to clear the land, and cultivate tobacco and maize. From this point onwards people have cultivated tobacco and maize in this area.

The first co-operative society (the Tanzania Authority of Tobacco) was established in 1979 to provide a link between the villages and the government who supplied the seeds. They ran a socialist system, where everyone pooled all their crops and shared all the profits. Eventually this system failed, so the government handed authority to the villages to find a market. This also failed, and eventually in 1991 they used a free market and companies started to come to the area to compete to provide the tobacco. This system has continued until now.

The Wakimbu lifestyle prior to 1964 was described by the Mazimbo Elders focus group (2013):

> *"The village of Mazimbo is named after a mountain of the same name nearby. Prior to 1962 Mazimbo was a small settlement on the other side of the river to the West where the Wakimbu lived. Before independence there was a traditional leader called Mtemimlewa (Mtemi means leader). He was the person they would go to farm for first, and then they would go to their farms. All the land was under his supervision, and you had to do what he said. There was only one such leader in Kipembawe, everyone had to follow his rules and any indescrepencies were punished. All workers were centralised around him, he would give allowances. Some people hunted, some farmed, and some kept bees. There was no tobacco. After Independence these leaders were removed from their posts and the village government was started."*

By the end of 1963 four Pilot Village Settlement Schemes had been started across the country, and another three were planned. One of them was in Lupatingatinga (Kulaba, 1982). Village settlement schemes were then introduced in Matwiga in 1964, and Lualaje in 1969. All three villages were encouraged to cultivate tobacco, and by 1969 these three villages, along with another Tobacco Settlement in Tunduru, produced 1 million tonnes of flue-cured tobacco (Davis, 1971). Mazimbo was formed in the early 1960s by people eager to farm tobacco. Nkung'ungu was created in 1971 as a Village Settlement Scheme, when 26 villagers were moved from Lupatingatinga and Oysterbay to create a new village. They had to be given new land, because they were too far away from their own farms (Nkung'ungu Village Elders, 2013).

In 1973 Villagisation started in the area, and Ilindi, Isangawana and Igomaa were formed. In 1975 Mwiji was established. The village of Kipembawe was dissolved during villagisation, because it was considered too remote, despite being a large village established in the colonial period with a mission hospital, school, a road train and brick buildings. There is no longer a village called Kipembawe, only the walls of old colonial buildings remain. However, with the gazetting of the Kipembawe Forest and Beekeeping Reserve in 2012 there is a plan to renovate the buildings and make this a headquarters for Forestry personnel, where they can be more accessible to monitor the activities within the woodland (District Officer 1, 2013). Kipembawe remains on all maps reproduced of the area.

4.4.2 Tobacco cultivation in Tanzania and Kipembawe

From 2010 to 2011 production more than doubled (Figure 4.1), enabling Tanzania to leapfrog Zambia and Zimbabwe to move from fourth to second largest producer in Africa (FAO, 2015a). Figure 4.1 demonstrates a sharp increase in the cultivated area and production of tobacco, but does not demonstrate any increase in yield, which is contrary to global trends (FAOSTAT, 2014).

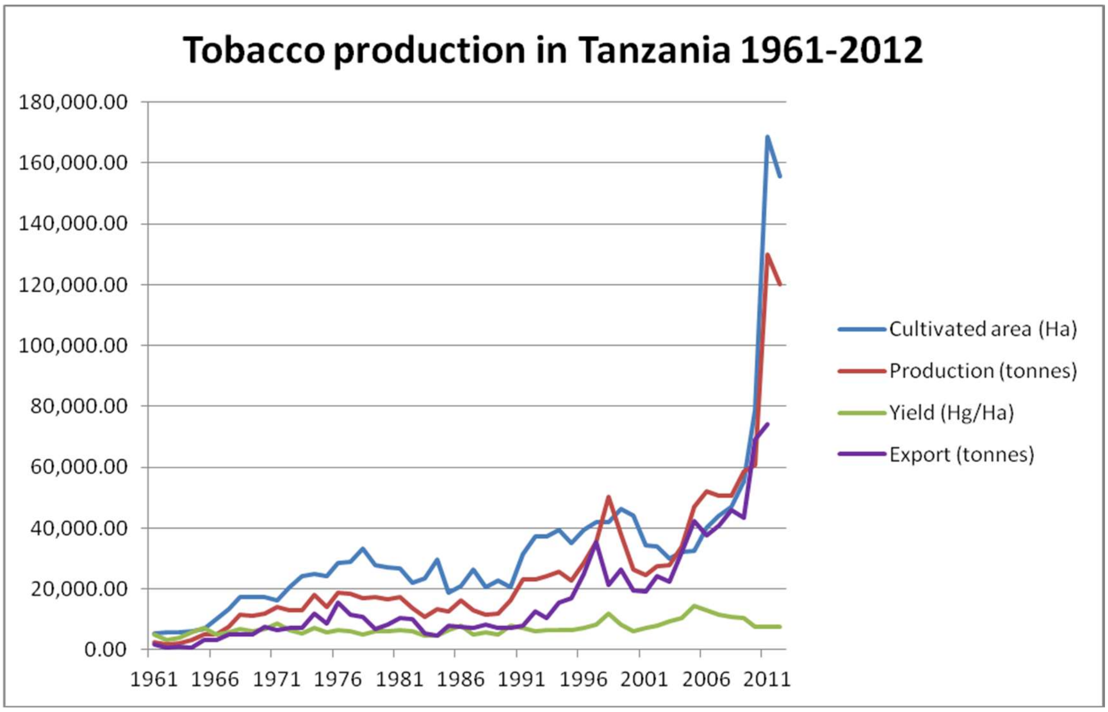

Figure 4.1: Tanzania tobacco trends (FAO, 2015a)

Virginia Flue Cured (VFC) tobacco is gown in Kipembawe, in a labour intensive process from seed to harvest (Goodman, 1993). Harvested leaves are cured to preserve them through heating in barns, a process that takes approximately one week (BAT, 2014a, ITGA, 2014). Cured tobacco is graded according to quality and sold at market. Primary Co-operatives called AMCOS (Agricultural Marketing Co-operative Societies) act as the middle man between the farmers and the tobacco companies. The Cooperative Union that supports AMCOS is in Chunya, called the Chunya Tobacco Growers Co-operative Union (CHUTCO). CHUTCO was established in 2003 to help tobacco farmers, representing all the co-operative societies. Representatives from CHUTCO explained the role of AMCOS, which is synthesised below:

Assistance with the cultivation of tobacco, maize, and some other crops is provided, and in 2013 approximately 8000 farmers in Kipembawe were supported. The tobacco companies supply AMCOS with the tobacco seeds and also tree seedlings to distribute to the farmers. These are supplied at no cost to the farmers. AMCOS then sources appropriate fertiliser and pesticides for tobacco and maize, and supplies these to the farmers against a loan, which is recorded and then paid back when the harvested product is sold. All prices are arranged in US dollars, as this is the pricing system used globally, and inputs are usually bought in dollars. Prior to each season AMCOS will inform each village of the price that a kilogram of tobacco at each grade will expect to fetch for the coming season. Then each tobacco farmer will register with AMCOS and tell them how many acres of tobacco they wish to farm that season. AMCOS will then order sufficient fertiliser and pesticide to supply each farmer. The registration process with AMCOS is complicated, and not all farmers are registered. This means that they won't be able to get the fertiliser and pesticide from AMCOS, and will have to buy it from another farmer. Registration can only happen once you have farmed tobacco for one year, and have become part of a group of farmers, with whom you register. This group is then responsible for covering the debts incurred by other farmers within their group. Once the seeds and inputs have been distributed to the farmers they can then go and grow the tobacco. Throughout the year the tobacco company will organise seminars, workshops and farm visits that farmers are able to attend at no cost to learn how to improve their production. Attendance is voluntary.

There are no other suppliers of fertiliser or pesticides for any crops within the Division.

4.4.3 Land use planning in Kipembawe

In all the villages that were surveyed, the formal method for obtaining land is to approach the village council with a request for land. The council would then find and allocate land, and mark out the boundaries. They do not have to pay for use of the land (Village C Social Welfare Committee, 2013). However, this happened in very few cases; "*most people just go to the village and find a piece of land they like, and settle there*" (Village E Land Use Committee, 2013). Several focus groups reported that they were "*running out of land for farming"* (Village D Agriculture focus group, 2013) and said that they needed to use forest reserves for agriculture.

In the Mbeya Region 60 of 1,926 villages have Land Use Management Plans, of the rural Districts Mbarali has the most, and then Chunya. There are few because the land use plan concentrated on urban-led development, and because it costs TSH 6 million per plan (Regional Officer 1, 2013), although District Officer 8 (2013) estimated the cost to be approximately TSH 11 million. Within the study villages plans have been developed for Matwiga, Mazimbo, Lualaje, and Mwiji. Their development and implementation is discussed in Chapter 9. In villages with Land Use Plans people can apply for a formal 'right of occupancy'. In this case the process for obtaining land is the same as above, and Village Council approval must be gained; then the District Land Planning Officers would go to the land and measure it, and if it is approved at all levels the right of occupancy can be awarded (District Officer 8, 2013).

At the time of research only one 'right of occupancy' had been issued. Regional Officer 1 explained that it is more likely to happen in the future: *"From this year [2013] the government is starting to put more emphasis on village land. Now going to issue traditional rights of occupation – a title deed for rural land, and to do this they must have a land use plan. So now people will share the cost to get the land plan and therefore the traditional right of occupation…There is a programme to train Land Use Planning Committees so that they can apply the rules".*

During the Household Survey respondents were asked what sort of land they used, and what the ownership status of that land was; 99% of respondents said that they owned at least one type of the land they used; 4.6% of respondents said that some of the land they used was village land. Figure 4.2 demonstrates the amount and type of land used by each household.

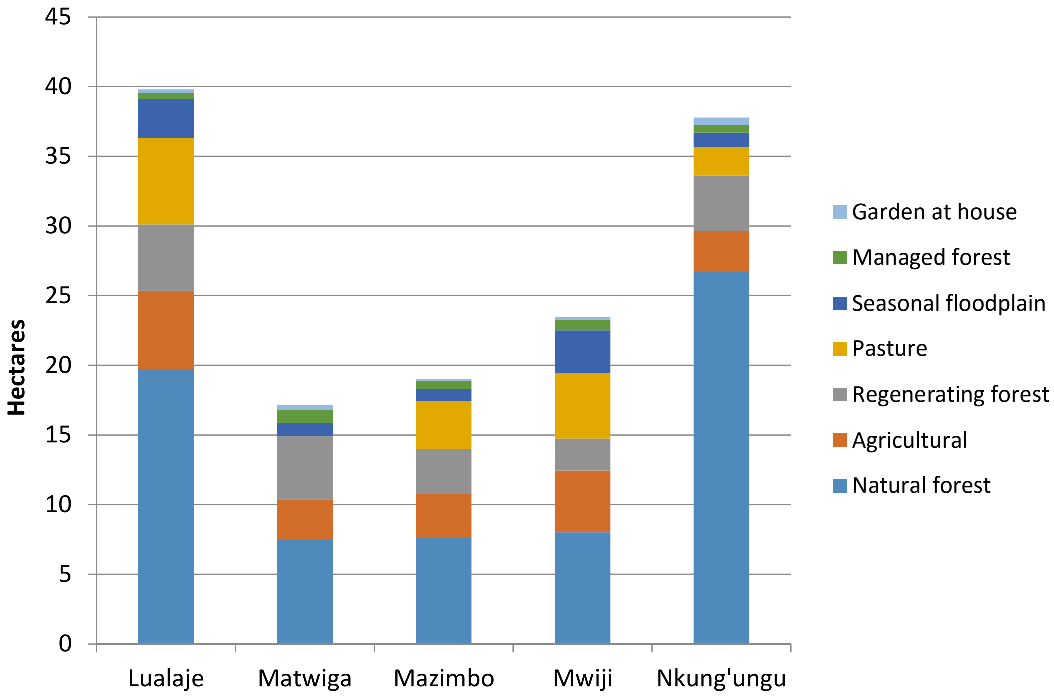

Figure 4.2: Average amount of land held per person in each village (Source: Household surveys, 2013)

4.4.4 Administrative, governance and institutional structures

Mbeya Region is divided into nine District administrative units, including Chunya District. Chunya is further subdivided into four Divisions, which are then divided into Wards containing villages and sub-villages (Figure 4.3). The numbers of Wards and villages can change; in 2002 there were 23 Wards within Chunya (Central Census Office, 2004) which has now increased to 30 (National Bureau of Statistics, 2013). Villages with more than 50 households are divided into sub-villages, and when a sub-village reaches 250 households it can apply to the District Council to become a village. Within the Division of Kipembawe there are seven Wards and 16 villages.

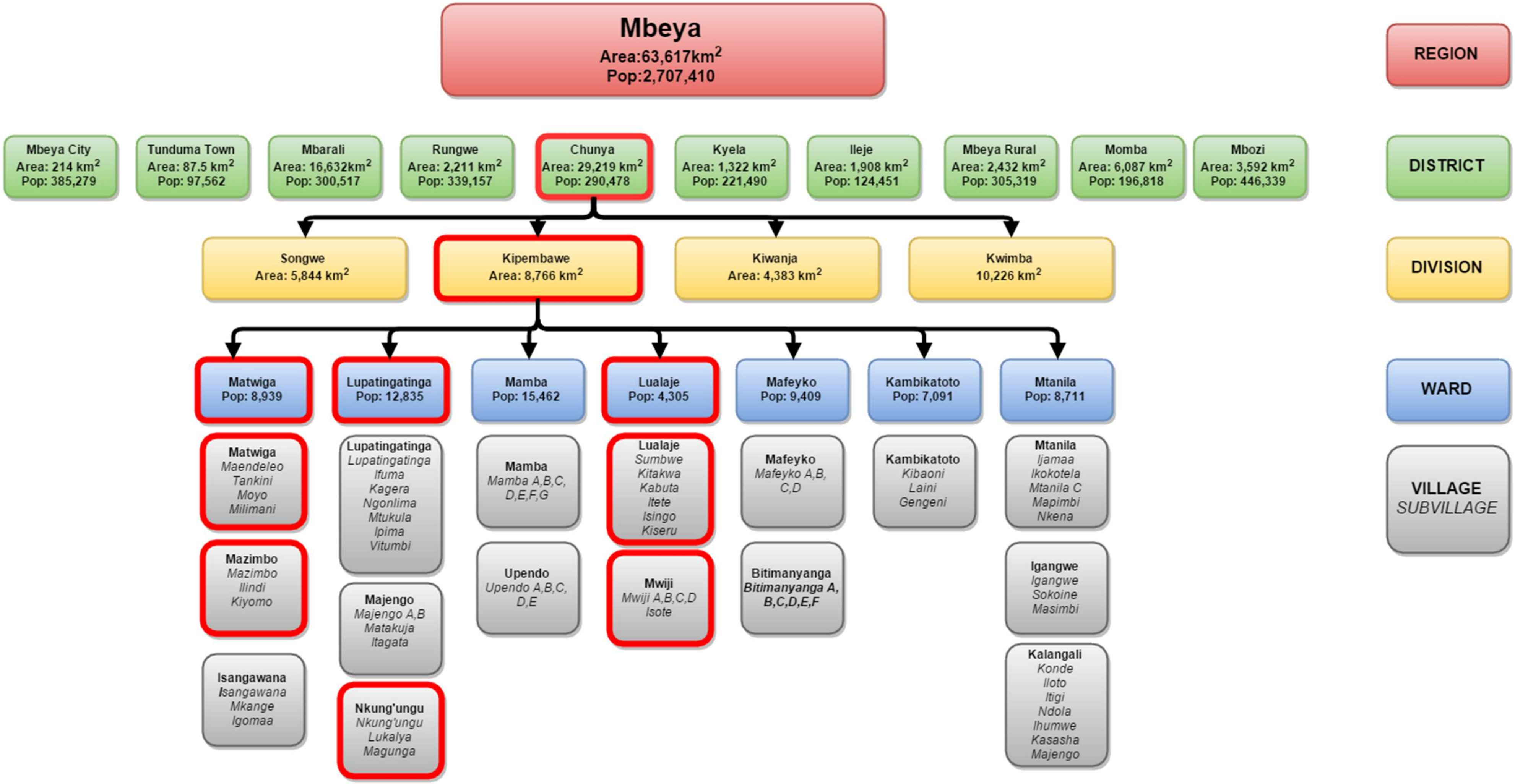

Figure 4.3: Administrative structure of Mbeya Region. Size of area and population are provided where reliable figures exist. Names in red indicate locations where social surveys were conducted (sources include: National Bureau of Statistics, 2013, The Planning Commission DSM and Chunya District Council, 1997).

There are different governance structures at each administrative level: Regional, District, Division, Ward and Village, and each has varying influence upon governance. At the regional level there are Regional Officers whose responsibility is to the National Government. They receive new policies and instructions from the National Government, and disseminate these to the District Headquarters (Regional Officer 2, 2013). The District Officers are responsible for implementing the policies and providing training and information to the extension officers at Division, Ward and Village levels.

At District level there is usually one senior Officer and several junior Officers. This varies considerably from role to role, and is dependent upon central government funding. For example, at the Chunya District Council Natural Resources Division there is a Natural Resources Officer who is the senior Officer, and there are four Wildlife Officers (District Officer 2, 2013). Within the Forest and Beekeeping Division there is a senior District Forestry Officer, four Forest Officers, and three Beekeeping Officers (District Officer 3, 2013). There are then extension officers at Division and Ward level, who visit their allocated villages and liaise with village officers. Neither Natural Resource nor Forestry Officers have access to vehicles, which seriously impedes their ability to conduct anti-poaching patrols (District Officers, 2013). The Chunya District has been referred to as the *"Wild West"* (District Officer, 2013) due to poor governance, exacerbated by the size of the area – the representatives above oversee an area covering over 29,000km^2. In order to address this there are plans to divide Chunya into two Districts, creating the Songwe District to the south-east (Regional Officer 1, 2013).

At Division level there are two Division Officers, although their positions have not yet been formalised: one is the 'Acting' Division Secretary and the other the 'Acting' Natural Resources Officer. At Ward level there are Ward Executive Officers, who are government employees, who must attend regular meetings at the District Headquarters, and may also be required to attend meetings at the Regional Headquarters (Division Officer 1, 2013). Due to a lack of funding one person may take on several roles, and this limits their ability to fulfil their duties (Ward Officer 2, 2013). For example the Lualaje Ward Agricultural Officer was also the Lualaje Ward Livestock Officer, and he was also the village representative for both of the villages within the Ward for both positions. There can be other roles at ward level, such as Beekeeping Officer and Development Officer; these vary from ward to ward. There are also committees at ward level, for example Matwiga Ward had a Safety and Peace Committee, an AIDS Committee, and a Development Committee (Ward B Officer 1, 2013). The next levels are village (Figure 4.4), and sub-village. At village level there can also be extension officers for livestock and agriculture, and sometimes a Village Game Scout. These are government employees. At sub-village level there is an elected Sub-Village Chairperson, who is a member of the Village Council. They then select approximately 5 members of the sub-village to sit on the sub-village committee.

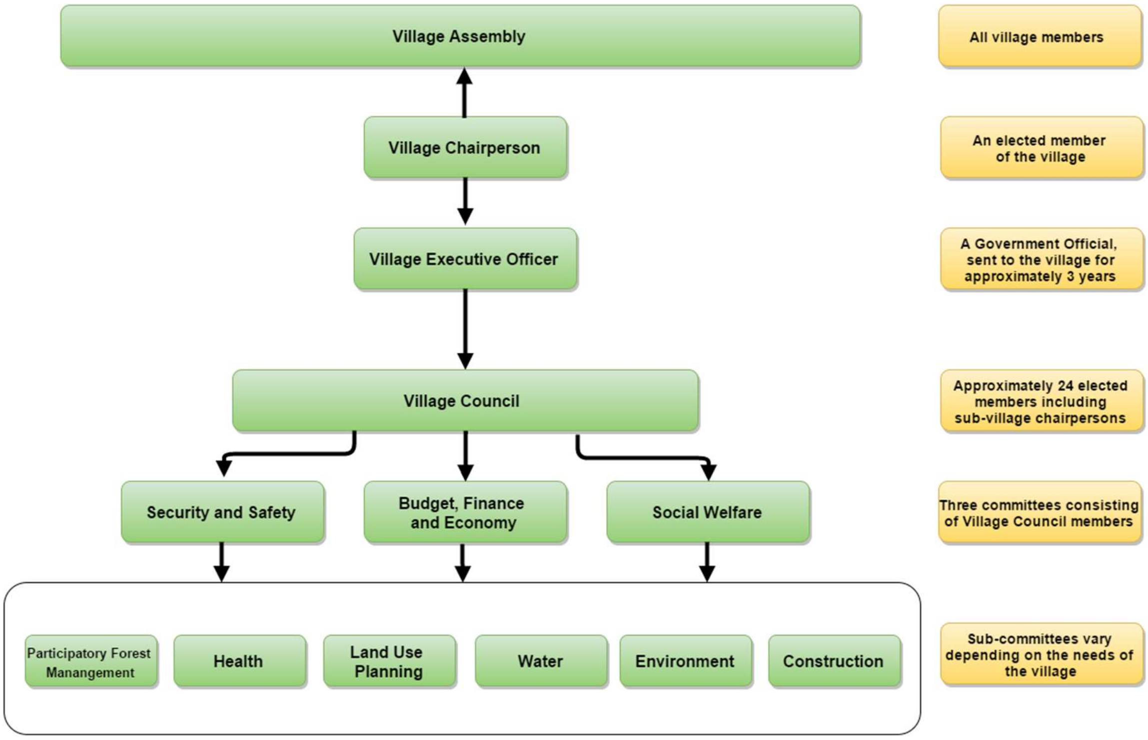

Figure 4.4: Village governance structure (source: Key informant interviews (2013))

Institutional administration in the Division is poor, and vigilante behaviour was observed. At the time of the research there was no official police force in the area due to a serious incident two years previously. The closest was in Mkongolosi, approximately 3 hour's drive south. During this period criminal matters were dealt with at village level, by villagers. In December 2013 a police force was re-established at Lupatingatinga, however in April 2014 local punishments were still being issued, demonstrating that it will take time for a measure of trust in the police to be re-developed. At the time of research there was no access to any physical form of banking system, except in Chunya (Mpesa – a system of storing and transferring money by mobile phone – is possible in areas with mobile phone signal). This was due to the lack of security (Division Officer 1, 2013).

4.4.5 The ecological landscape

The Kipembawe Division lies within the southern highlands of Tanzania, at an altitude of 1000-1400masl. The landscape is flat, with some scattered single hills. To the south and west it borders the Kiwanja Division, to the south and east it borders the Tabora, Singida and Iringa Regions (Figure 3.1). Within the Division there are many areas of seasonally inundated floodplains, and three main rivers; the Lupa, Lualaje and Piti Rivers. The soils are shallow and stony with low fertility. They are sandy, of a red or pale colour, containing albic arenosols, orthic ferralsols, ferralic arenosols and ferralic cambisols (The Planning Commission DSM and Chunya District Council, 1997). The dominant ecotype is miombo woodland, covering about 85% of the Division (District Officer 4, 2013) characterised by trees from the genera *Brachystegia*, *Julbernardia*, and *Burkea*, which is typical of miombo woodland throughout the ecotype. Lupatingatinga Weather Station data (available from 1976 (Lake Rukwa Water Basin River Board, 2014)) confirms that the climate is seasonal with a bimodal rainy season typically lasting from October to May, characterised by short rains in November and December and long rains from February until May. The dry season, a period of minimal rainfall, typically occurs between June and September. Average annual precipitation (mean ± standard error) is 933.4 ± 36.5mm (min 602.8mm, max 1466.0 mm, n=28 years). Temperature records from the same weather station for the period 1996-2013 illustrate average temperatures of 22.16 ± 2.74°C (min 16.29°C, max 27.77°C), with the highest and lowest temperatures in November and July respectively. These data are typical of the miombo woodland ecoregion (Frost et al., 2003). Miombo woodland is often categorised as 'wet' (>1000mm p.a) or 'dry' (<1000mm p.a) (Frost et al., 2003). Therefore Kipembawe would lie just under the 'wet' classification, and this, together with vegetation data, suggests that there is a gradient between the two categories. Tree data from this study (Chapter 7) estimates that there are approximately 60 tree species per hectare (which is between the 40/ha for dry and 70/ha for wet (Frost et al., 2003)), and canopy height frequently exceeds 15m, which is the maximum for dry miombo (Abdallah and Monela, 2007).

There are few, if any, accurate accounts of wildlife assemblages and populations in the area. District Officer 2 explained that wildlife censuses are supposed to be conducted every 10 years by plane and one is due, but there are no plans for it to be conducted. Instead, the trophy hunting companies submit their records to government, and it is on these records that quotas are calculated. According to Division Officer 2 many changes in animal populations have occurred within the last five to ten years due to increasing human population, expanding agriculture and increases in cattle numbers and poaching, with 19 of the 24 listed species that were present over five years ago decreasing in number (Table 4.1).

District Officer 1 broadly agreed with this: *"In the past there were many animals, apart from rhino. Now as the [human] population has increased, there is more agriculture, more cattle and less water, [so] they have moved to reserves. Only small animals that can hide in the bushes remain. In the future there won't be any animals here, only in reserves*". These points were also highlighted by District Officer 2, who said in addition to poaching the destruction of habitat by pastoralists and agriculturalists contributes to decreasing wildlife numbers. Historical accounts of wildlife populations from the Village Elders demonstrated that there were high animal densities in the past, but few are seen now: "*From 1977 to 2003 there were buffalo, bushpig, lion, warthog, sable, hartebeest, kudu, reedbuck here. Then the Sukuma came and the lions went. There are no animals here now apart from kudu after the Sukuma arrived*." Village B Elders focus group (2013). An increase in human population, expanding agriculture and a lack of water were also given as reasons for decreasing animal numbers. Bushpigs, baboons and monkeys are still present (Village D Elders focus group, 2013).

Table 4.1: Presence of animals in the past and present (source: Division Officer 2 (2013))

Common name	**Species**	**In the area 5+ years ago**			**In the area now**				
		Yes	**No**	**Don't know**	**More**	**The same**	**Fewer**	**None**	**Don't know**
Elephant	*Loxondonta africana*	✓					✓		
Greater kudu	*Tragelaphus strepsiceros*	✓					✓		
Lesser kudu	*Tragelaphus imberbis*		✓					✓	
Sable antelope	*Hippotragus niger*	✓			✓				
Roan antelope	*Hippotragus equinus*	✓			✓				
Common Warthog	*Phacochoerus africanus*	✓			✓				
Bushpig	*Potamochoerus larvatus*	✓				✓			
Zebra	*Equus quagga*	✓					✓		
Common Eland	*Taurotragus oryx*	✓					✓		
African Buffalo	*Syncerus caffer*	✓					✓		
Giraffe	*Giraffa Camelopardalis*	✓					✓		
Common Duiker	*Sylvicapra grimmia*	✓					✓		
Impala	*Aepyceros melampus*		✓					✓	
Bushbuck	*Tragelaphus scriptus*	✓					✓		
Kirk's Dikdik	*Madoqua kirkii*	✓					✓		
Hartebeest	*Alcelaphus buselaphus*	✓			✓				
Waterbuck	*Kobus ellipsiprymnus*	✓					✓		
Lion	*Panthera leo*	✓					✓		
Leopard	*Panthera pardus*	✓					✓		
Cheetah	*Acinonyx jubatus*		✓					✓	
Hippopotamus	*Hippopotamus amphibious*	✓					✓		
Yellow baboon	*Papio cynocephalus*	✓			✓				
Vervet monkey	*Chlorocebus pygerythrus*	✓					✓		
Jackal sp.	*Canis sp.*	✓					✓		
Wild dog	*Lycaon pictus*	✓					✓		
Black Rhinoceros	*Diceros bicornis*		✓					✓	
Black & white colobus monkey	*Colobus angolensis*		✓					✓	
Blue monkey	*Cerocopithecus albogularis*	✓					✓		
Spotted Hyena	*Crocuta crocuta*	✓					✓		
Blue Wildebeest	*Connochaetes*		✓					✓	
Aardvark	*Orycteropus afer*	✓					✓		
African Civet	*Civettictis civetta*	✓					✓		

4.4.6 The social landscape

The Division is very remote; approximately 3 hours north from the nearest town, Mkongolosi. The District capital Chunya is a further 1.5 hours south of Mkongolosi. The nearest cities are Mbeya to the south, and Singida and Tabora to the north, all in excess of 7 hours away in the dry season. There are two roads that lead from Mkongolosi to Mbeya, one passes through Chunya and the other takes a longer route around the Southern Highlands. Both are currently dirt roads, and can be impassable in the wet season, however In April 2014 the road from Mbeya to Chunya was being sealed, and some parts were completed. All other roads are single track and dirt, and in the wet season they become impassable, and trips to the cities can take days. The road that runs from Mkongolosi into Kipembawe continues north through the villages of Lupatingatinga and Isangawana to Rungwe and Singida, and is the main road within the District. There are also three smaller roads leading off this road to Lualaje, Nkung'ungu and Mtanila. These roads are poorly maintained and often impassable in the wet season. Public transport comprises of buses that run daily between Singida and Mbeya, there are no regular public transport services between villages. The cost of hiring local transport (motorbikes or 4x4 vehicles that operate when full) to make the trip between villages is prohibitive to most people, and availability is very low. The closest fuel station was in Mkongolosi, although a new petrol station was being built in Lupatingatinga in 2014. Limited petrol and diesel was available in Isangawana from Jerry cans and plastic bottles.

Within Kipembawe there are six wards comprising 16 villages (Figure 4.3), with an estimated population of 66,752 (National Bureau of Statistics, 2013). Household survey respondents (n=196) from five villages represented 23 ethnic groups, the most common were the Nyakyusa (23%), Malila (13%) and Sukuma (11%). The Kimbu, identified in focus groups as originating in this area, comprised 7% of the sample. Within this sample 75% of respondents had immigrated to the area, 40% within the last 10 years, and 62% percent moved in order to cultivate tobacco. The average age of respondents (household heads) was 40.7 years, of whom 91% married. Nationally 74.3% of people are married at this age (National Bureau of Statistics, 2013). Average household size was 5.9 people. This is slightly higher than the average household size in Mbeya (4.2), and nationally (4.7) (National Bureau of Statistics, 2013).

There are primary schools in each village in the Division, and secondary schools at Lupatingatinga and Isangawana which take students until age 16. Education for 16-18 year olds is available in

Mkongolosi and Chunya. The school at Lupatingatinga is building dormitories to enable the provision of education to 16-18 year olds. Respondents to the household survey demonstrated that 91% of those questioned had not attained a pass at Standard 7 (which indicates finishing primary school and enables progression to secondary school). No formal education had been received by 26% of respondents.

There is a Mission hospital and a Government medical centre in Lupatingatinga, the only ones in the Division. Both have beds and consulting rooms and can treat minor injuries and illnesses. For more serious medical issues patients must travel to Chunya or Mbeya. The NGO 'Restless Development' runs HIV/AIDS awareness campaigns, and there are government-run education campaigns for HIV/AIDS and water use. HIV/AIDs rates in Mbeya are 9%, the third highest in the country by region (Tanzania Commission for AIDS, 2012). A Restless Development representative estimated that 2 in every 5 people in Kipembawe are HIV positive. Division representatives suggested that rates are high because the tobacco income is distributed at the end of the season and women come to the area to take advantage of this, leading to high infection rates. It was not within the scope of this study to corroborate these reports. The effect of HIV/AIDS on a household can be profound, as it reduces the workforce, resulting in poor agricultural yields, possible food shortages and children help on farms rather than going to school (Drimie, 2002).

The two main villages in the Division are Lupatingatinga and Isangawana. At these villages there are markets and a range of shops, services and a guest house. In other villages there are few shops. Electricity was installed in Mamba and Lupatingatinga in February 2013, but it has not been installed further north. Likewise masts for mobile phone reception were installed in Lupatingatinga in 2008; reception in Isangawana is patchy, and further north unconnected.

Within the Division the main income generating activity is agriculture – cash crops are tobacco, sunflower and sesame; 86% of households surveyed cultivated tobacco, and 98% said that farming was their main occupation (n=196). Food crops include maize, rice and beans. Livestock keeping, beekeeping and logging are also practised (Acting Division Secretary, 2013). Chickens are kept by 90% of surveyed households, and free-grazing cattle by 16% (n=196). Food shortages are experienced annually by 23% of households (n=196), most frequently during the planting season between November and March. Reasons given for this included poor weather conditions and inadequate supplies of fertiliser.

Commercially there are three industries, timber, trophy hunting and mining. There are few legal, commercial timber companies operating within the Division. Logging of hard wood, such as *Pterocarpus angolensis* and *Periscopis angolensis* is usually carried out by individuals. Timber can only be removed if a permit has been issued. There is only one company that has a permit to log, near Nkung'ungu, and it was only for a short time (District Officer 3, 2013). District Officer 3 explained the process of acquiring a permit: *"In order to get a permit the person must first go to the District headquarters for the permit to sell and to transport timber from general land. They must first have a Tax File Number, and then their application must be passed by a committee. Then they can log and take the timber to market".* A permit to log costs TSH 200,000, and the transport on a lorry is TSH 150,000/lorry. In Kipembawe five people have about 30 licences a year (licences only last one month). District Officer 3 explained that there are many illegal harvesters because the forests are big, and they have no transport to find them. The impact of the illegal harvest of *Pterocarpus angolensis* is discussed in Chapter 7.

There are six hunting outfits operating in the north of the Division near the villages of Kambikatoto, Mafeyko and Bitimanyanga which contribute revenue to the District. They manage the land within the Game Reserves and run anti-poaching patrols, and contribute to the villages by providing school buildings, wells and infrastructure, and provide limited opportunities for employment (District Officer 2, 2013).

Mining for gold occurs mainly in the Kiwange and Songwe Divisions, carried out on commercial scales and by small scale 'artisan' miners (District Officer 5, 2013). Within Kipembawe there is very little mining activity, however mining in the other Divisions is used as a 'fall-back' option if crops fail, or if there are younger men in the family and insufficient land to farm. This was raised through the livelihood matrices activity:

> "*In 2008-09 I went to mine near Saza because it was really hard to farm - I was only making enough to pay the debts from AMCOS. I made a lot of money because I found a lot of gold, but I came back because there were no more minerals to find*".

Village E Livelihood Matrix 3 (2013).

Mining is important in terms of land planning and the environment, as it effectively supersedes all other land uses. Minerals are owned by the government, and if there is any conflict over using land for mining the government makes the final decision. Mining can also happen in Forest

Reserves, if the exploration phase demonstrates that there is sufficient benefit, and the feasibility report demonstrates how impacts will be minimised and rehabilitation will take place (District Officer 5, 2013). Compensation is paid to the relevant people who hold the surface rights, whether this be individuals or the Forest Services, based on the Land Act 1999. However, this is not required on land where no formal tenancy agreements have been issued.

4.5 Discussion

The Kipembawe Division is a remote area of Tanzania, and its history is little known, particularly prior to the 1960s. The village elders identified the Kimbu as the ethnic group originating from this area. The Kimbu cultivated, and set their homesteads within their fields. A settlement would comprise of a maximum of four male headed households, and they would move their households when necessary (Shorter, 1972). This was usually every 6-7 years, which corresponded with estimated soil fertility. Areas were abandoned for twenty to thirty years, indicating that they practiced shifting (swidden) cultivation (Shorter, 1972). The establishment of the various Settlement Schemes in the area resulted in huge changes for the way the land was managed. Throughout Tanzania the establishment of permanent settlements failed to take the ecology and soil types of different areas into account resulting in dwindling productivity and food shortages (Shao, 1986). Siting the villages away from the cultivating fields led to increases in crop damage from wildlife populations that were at greater densities than they are now. The promotion of tobacco cultivation within south-west Tanzania included a World Bank International Development Association loan of US$9 million to improve tobacco production (World Bank, 1970), for a scheme that was be operated, and additionally financed, by the Tanganyika Tobacco Board and the Tanzanian Government. This distributed loans to farmers for the purchase of inputs through the National Development Credit Agency. The aim of the project was to establish 15,000 new growers in 150 village communities, arranged in complexes of 10 villages each, cultivating 30,000 acres of tobacco. Additionally, infrastructure was improved, 15 co-operative societies established, credit provided for inputs, staff and extension officers trained, and tobacco auctions introduced (World Bank, 1970). Such schemes led to a population increase in the area, and even after they had finished the population continued to grow. Between 1978 and 1988 the population of Chunya grew by over 65%, probably driven by both tobacco cultivation and possibly the attraction of the Lupa Goldfields (Barke and Sowden, 1992), although mining was not part of Independent Tanzania’s plans, and ceased in 1967 (Voight, 1995), not starting again until 1994. The data presented in this chapter demonstrates that the population today is still growing through immigration and the main driver remains tobacco cultivation. The impacts of tobacco cultivation on the environment are discussed in Chapter 5, and the impacts of high immigration for land use management are discussed in Chapter 10.

High immigration has led to people settling on the land without formal permission from the village council, and there are no written agreements of occupancy. Although the majority of people believe that they own the land that they are using, in reality they do not have secure tenure. As land scarcity increases, land tenure is necessary to assure efficient allocation of land, and is necessary for sustainable land use management (Holden and Otsuka, 2014). Additionally secure land tenure results in less deforestation and degradation (Robinson et al., 2014). This may be because the lack of secure tenure means that the land is perceived as being vulnerable to expropriation (Holden and Otsuka, 2014), and this leads to short term use strategies, which may not be sustainable.

The governance structures within Kipembawe is established in accordance with government guidelines. While there is a lack of funding from the Government at District levels to comprehensively provide guidance to farmers and livestock keepers within the villages, and to protect wildlife and forestry resources, at local level governance structures are in place to serve the villages. However, there do appear to be problems within these structures to deliver, particularly in terms of land use planning and tenure. The ability of government officials and elected members at village level to govern effectively is severely limited by poor access and communications. The large distances within the Division and the lack of public transport limits the ability of officials to visit residents, and vice versa. Poor communications mean that village councils cannot effectively communicate issues that they may be having, and equally villagers may not be aware of programmes or policies that may affect them.

4.6 Conclusion

Kipembawe is in a remote area of south-west Tanzania with a rich history shaped by government policies and a heavy reliance on the tobacco industry, which continues today. This chapter has described these polices and shown how the tobacco industry works within the area today. The lack of recognised land tenure has been highlighted, and the governance and structures of the area defined. Finally the ecological and social landscapes have been described. In doing so this chapter provides background context in which to set the rest of the thesis.

Chapter 5

Drivers of land use change in the miombo woodlands of south-western Tanzania

Chapter summary

This chapter fulfils Objective 2 by identifying and assessing the drivers of land use change within the miombo woodlands of Kipembawe. Chapter 4 described the history of the area, explained governance structures and highlighted the main income generating activities. This chapter builds upon this by identifying the activities taking place that contribute to land use change. Chapter 6 goes on to identify the role the woodlands play in supporting local livelihoods through provisioning ecosystem services, and how the land use changes identified in this chapter affect the availability of these services.

5.1 Abstract

Miombo woodland is one of the most extensive ecosystems in sub-Saharan Africa, and provides a vital role in supporting agriculture, biodiversity and ecosystem services. Due to its large extent, miombo is frequently over-utilised and under-managed, leading to land use change which can result in degradation and deforestation. Understanding the drivers of land use change is fundamental to developing more sustainable land management options. Within a remote miombo woodland area of south-west Tanzania the indirect and direct drivers of land use change were identified and examined through the integrated analysis of ecological and social survey data. Research in the Kipembawe Division (8,766km^2), Mbeya Region, showed that the cultivation of the cash crop tobacco (*Nicotiana tabacum*) has led to rapid expansion of agriculture, with an estimated 7,260 ha of natural woodland cleared annually by tobacco farmers (with clearing repetition from annual to every five years) of which approximately 1,353 ha is used to cure the tobacco leaves. This results in the immediate loss of approximately 38,500 tonnes of carbon to the atmosphere in the curing process. The loss of the remaining 5,907 ha

results in the loss of 168,350 tonnes of stored carbon, which may be released to the atmosphere immediately through burning or gradually through decomposition. Miombo woodland covers roughly 745,110 ha; at this deforestation rate all miombo woodland in this Division would be lost in 103 years. The high price received for the sale of tobacco has encouraged migration into the area, which in turn increases demand for food crops and woodland products such as firewood and timber for the construction of houses, tobacco burners and stores. A secondary driver of land use change is an increase in livestock numbers, leading to overgrazing and deforestation. Continued deforestation will lead to tobacco cultivation in the area becoming unviable within 10-15 years, due to a reduction in available, accessible fuel wood to cure the crop. Sustainable land management strategies are urgently needed if tobacco is to continue to support thousands of livelihoods in this area.

5.2 Introduction

Miombo woodland is the largest woodland type in Tanzania (UN REDD Programme, 2009) covering 95% of the forested area (MNRT, 2006). An estimated 13% of miombo forest cover in Tanzania was lost between 1990 and 2000, with a further 10% loss of other forest types in the country (UN REDD Programme, 2009). This loss is approximately at a rate of 403,000ha per year, representing an annual change between 2005 and 2010 of -1.16% (FAO, 2010). However, the same deforestation figure of 403,000ha per year has been used since 1990, and therefore it is unlikely that these figures are accurate. The Tanzanian final report to the REDD+ programme outlines the main causes of deforestation as "*related to the needs of an expanding human population that remains poor and dependent upon natural resources, and the national need to earn foreign exchange to fund national development and debt repayments*" (UN REDD Programme, 2009 p25). This report identified four main categories of drivers: smallholder agricultural expansion; energy needs; plantation development and building materials. It also identified weak and corrupt governance, complex and insecure land tenure systems, poorly developed costs and benefit sharing mechanisms, deeply rooted poverty with a lack of opportunities outside of poverty and the reliance on exploiting natural resources to survive.

These are similar to drivers identified for miombo woodlands regionally; the expansion of subsistence agriculture, overgrazing, the extraction of fuelwood, timber and charcoal, uncontrolled burning and the overexploitation of important tree and animal species (Fisher, 2010, Rudel et al., 2009, Cabral et al., 2011, Dewees et al., 2010, Kowero, 2003, Vinya et al., 2011). Drivers of deforestation are described in Chapter 2, sections 2.1.1 and 2.1.2. While broad descriptions of drivers provide background that may inform the development of in-depth research projects, they do not capture the local-scale nuances that may be critical to mitigation. Understanding both direct and indirect drivers (Nelson et al., 2006) is the key to providing effective long-term management solutions for miombo woodlands, particularly as drivers vary widely between regions (Bond et al., 2010, Vinya et al., 2011). However, there is a paucity of detailed case studies at local scales (Kowero, 2003). This chapter aims to address this gap using a case study from the Kipembawe Division in south-west Tanzania to identify the direct and indirect drivers of land use change within miombo woodlands.

5.3 Methodology

A mixed methods approach was used to identify the main drivers of miombo woodland degradation and deforestation. This approach combines ecological and social surveys, drawing upon a wide range of complementary data to provide an in-depth analysis of the drivers of land use change.

The study area is described in Chapter 3, with the selection of biodiversity sites and villages described in sections 3.4.9 and 3.4.10 respectively. The Kipembawe Division is described in Chapter 4. Methods to determine land cover type, and utilisation of poles, timber and non-timber forest products are described in Chapter 3, section 3.5.1. Social survey methods (household surveys, focus groups and key informant interviews) are described in Chapter 3, section 3.6. Results are supplemented by secondary data and personal observations.

5.3.1 Analysis

Land use and cover were documented along transects and through social surveys. The dominant land cover for each 20m section on the transect was recorded, and percentage cover of each type was recorded across all 30 transects. Each household was asked how much of each crop they cultivate, and these answers were summed across the 196 surveys, and descriptive statistics calculated. Due to the large range of sizes of cultivated area, the mode was deemed more appropriate than presenting the mean with standard deviation. Each household was asked to estimate how much natural vegetation they cleared, how often, and why. Clearance estimations were transformed to represent annual clearance per household, and these data were then amalgamated to enable calculation of land cleared per person per year. During key informant interviews the two tobacco companies provided the numbers of registered tobacco farmers throughout the Division in 2013 (7,800 farmers), and the total amount of land under tobacco: Tobacco Company 1: 6,088ha (based on annual crop surveys); Tobacco Company 2: 2,281ha (estimated based on total harvest and average yield per hectare) giving a total of 8,639ha. Total land clearance was calculated using the average deforestation per household from the HHS and the number of farmers in the Division. The amount of carbon this represented was calculated using the estimation of above-ground carbon contained within low utilisation woodland, 28.5 t ha^{-1}, as calculated in Chapter 7. An estimation of the length of time it would take to clear all the remaining woodland in Kipembawe at the rate calculated in this chapter was made as follows: Total land area in Kipembawe is 876,600ha. Approximately 85% (745,110 ha) of the land cover is miombo (District Officer 4, 2013). Therefore this final area was divided by the amount of land cleared annually, and does not take into account expected increases (Tobacco Company 2) in the number of tobacco farmers.

The reason for clearance were coded into categories, and summed per category. Through this process, focus groups and observations the curing of tobacco leaves was identified as one of the key drivers of land clearance. Therefore this was investigated in more depth. During the HHS households were asked to estimate how many trees they thought they used to dry tobacco. However, these results were not deemed reliable given large variations. Therefore the amount of wood used was calculated as follows. According to Tobacco Company 1's Corporate Social Responsibility Programme, 18m^3 of wood is required to cure 1 tonne of tobacco. Using the estimations of Shirima et al. (2011) that the density of wood in miombo woodlands is, on average, 0.39g/cm^3, it is possible to convert the amount of wood used from m^3 to tonnes. In 2013, Tobacco Company 1 expected a harvest of 8 million kg. Tobacco Company 2 had a harvest of 3 million kg, giving a total harvest of 11 million kg (11,000 tonnes) in 2013. This gave an estimate of the number of tonnes of wood required to cure this harvest. Wood biomass is estimated to be 50% carbon (IPCC/OECD/IEA, 1997), and this was used to calculate the amount of carbon released through the curing process in 2013. Using the low utilisation woodland above-ground carbon estimation of 28.5t ha^{-1} the area of woodland used for curing was calculated. This was subtracted from the total amount of land cleared per year to estimate remaining carbon released.

Utilisation of poles and timbers was calculated as the percentage of poles and timbers that were cut from all available poles and timbers (dead and alive) across all sample sites. Further utilisation information was extracted from the household surveys, focus groups and key informant interviews. Livestock density was calculated as a percentage of the number of 20 m sections along the 1.5 km transects that livestock tracks were present.

Key informant and focus group data were coded according to emerging themes and pooled across the survey.

5.4 Results

5.4.1 Direct drivers

Agriculture

The transect data showed that 38% of ground cover was agricultural, and 62% was natural vegetation. Household data demonstrated that the two dominant crops cultivated are maize as a food crop, and tobacco as a cash crop (Table 5.1). It was estimated that in 2013 8,639 ha of tobacco was cultivated in the Kipembawe Division. Households were most likely to cultivate 1.2 ha of maize (mode, median =1.2 ha, average = 1.7 ha, n=194) and 0.8 ha of tobacco (mode, median =1.2 ha, average = 1.5 ha, n=167) (Figure 5.1, Table 5.1). Other crops such as beans were often intercropped with the maize, grown in gardens at home, or occupied small areas; households were most likely to cultivate 0.2 ha of groundnuts, which was the fourth largest crop type grown.

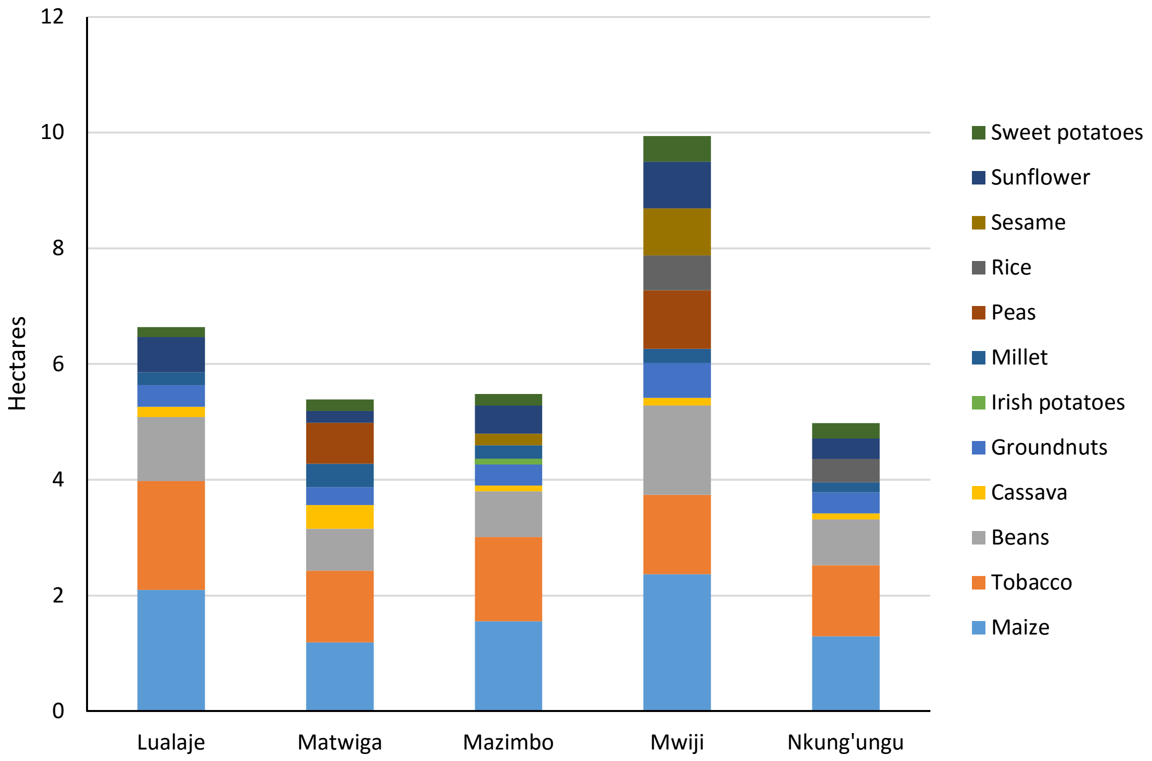

Figure 5.1: Average crop grown per household in each village (Source: household survey, n = 196)

Table 5.1: Land use and cover from ground cover surveys and household surveys. Farmers were asked how many acres of each crop they grew during the previous season. This demonstrates the correlation between ecological and household surveys with regard to land cover and use. Note, maize and beans are normally intercropped. (Source: ecological surveys and household surveys, 2013).

Land cover type	Land use	% cover from transects	Hectares of crop grown
Under cultivation	Agriculture (maize)	12.10	327
	Agriculture (tobacco)	4.42	245
	Agriculture (beans)	0.31	65
	Agriculture (groundnuts)	0.76	46
	Agriculture (other)*	1.21	16
	Agriculture (sweet potato)	1.43	16
	Agriculture (sunflower)	0.71	7
Prepared for cultivation	Agriculture (fallow)	6.21	
	Agriculture (under preparation)	0.40	
	Cleared woodland	1.88	
Cultivated in past	Agriculture (abandoned)	1.16	
	Regenerating miombo woodland	7.23	
Natural habitat	Open miombo woodland	55.80	
	Riverine forest	0.76	
	Seasonal watercourse	0.22	
	Seasonal floodplain	5.18	
	Tall grasses	0.22	

*Other crops grown: Cassava (5 hectares); Millet (4); Peas (4); Rice (2); Sesame (1)

Land clearance

Surveyed tobacco farmers clear an average of 0.9 ha of natural vegetation annually (Tables 5.2 and 5.3); the annual total clearance by all tobacco farmers within the Division is approximately 7,260ha p.a, equivalent to a loss of carbon storage of 206,910 t/year. At this rate of deforestation, the woodland in this area will be entirely depleted in 103 years.

The main reasons for clearing land for tobacco are to expand the farm, find fertile land for the tobacco, and to cure the tobacco leaves to preserve them for sale and use. According to Tobacco Company 1, the normal pattern with land clearance is that tobacco is planted and harvested, and to dry that tobacco another area of land is cleared. The following year the tobacco will be planted on that cleared land, and another crop such as maize is planted on the old land. Then more trees must be harvested to cure that harvest. The year after that the farmer will grow tobacco on the first field. However, the farmer will still need more wood to cure the tobacco, so each year they must remove some trees, even if it is not always a larger block. If they wish to expand their farm they must clear land. Rotation is necessary due to the low fertility of miombo woodland soils (Frost et al., 2003), and the nutrient-hungry nature of tobacco (Baris et al., 2000).

An estimated 7.02 tonnes of wood are required to dry 1 tonne of tobacco. Therefore it is estimated that to dry the 2013 tobacco harvest approximately 77,000 tonnes of wood was burned, releasing 38,500 tonnes of carbon. This is equivalent to 1,352.78 ha of miombo woodland. Therefore, in 2013 approximately 38,500 tonnes of carbon was released to the atmosphere through the curing process, and a further 168,356 tonnes of carbon was lost through woodland clearance not used for curing, but may be released through burning to clear the land, or gradually through decomposition.

The tobacco industry is aware of this demand on the wood, and is encouraging the planting of eucalyptus trees (Chapter 9):

> *"We need a lot of firewood for tobacco. If they cut the trees it means that trees will be finished and tobacco production will not be there anymore because we need a lot of wood to cure the tobacco. If we don't have wood we don't have tobacco. Kipembawe used to be a very big forest. So it will be in 10 -15 years there will be very big problems here, the tobacco production will diminish."*
>
> Tobacco Company 1, 2013

To mitigate the demand for wood the tobacco companies are encouraging the use of fuel-efficient 'modern' tobacco burners ('rocket burners') over traditional burners (Figure 5.2) to reduce wood consumption. Throughout the research season only two of these were observed (Figure 5.3).

Figure 5.2: Traditional tobacco burner (source: E Jew, 2013)

Figure 5.3: Modern 'rocket burner' (source: E Jew, 2014)

Table 5.2: Natural vegetation clearance by each household (Source: HHS, July – September 2013, n= 194)

	Hectares																
How often	**0**	**0.1**	**0.2**	**0.4**	**0.6**	**0.8**	**1**	**1.2**	**1.6**	**2**	**2.4**	**3.2**	**4**	**6**	**6.4**	**8**	**don't know**
every year		1	1	19	2	16	2	7	3		1		1				1
every 2 years			1	11	3	20	2	6	4							1	1
Every 3 years				3	1	12		1	3	2	1		1	1			1
every 4 years						3		1	2								
every 5 years				1	1	3		1									
Never	24																
no natural vegetation	7					1		1	1								
Only once	3			3	1	1		1	3	1	1	1	2		1		1

Table 5.3: Reasons for clearing natural vegetation given by household survey respondents (multiple reasons accepted) (source: HHS, July- September 2013; n=196).

Reason for clearing	No. respondents	% (n=161)
Agricultural expansion	75	46.58
Fertile land	64	39.75
To increase tobacco production	27	16.77
Firewood to dry tobacco	16	9.94
To start farming	8	4.97
Other	7	4.35

Reason for not clearing	No. respondents	% (n=35)
Don't cultivate tobacco	13	37.14
No natural forest	12	34.29
For new trees to regenerate	2	5.71
I have enough	2	5.71
No reason given	6	17.14

Wood extraction

In addition to the extraction of wood for curing tobacco, wood is also extracted for domestic use, for the construction of houses, tobacco stores and tobacco burners. Throughout the biodiversity sites, pole utilisation was 27.26%, timber utilisation 29.41% and total utilisation 28.96%. Of the 196 households sampled, 174 collected building poles from the forest, and all used them for domestic use only. Thirty-one households used timber for building, of which nine households collect it themselves for domestic use, one collects for both sale and domestic use, and 21 buy timber. One household buys timber from Mbeya.

There is very little commercial extraction. All timber must be extracted under licence, which must be approved at District level. At the time of research there was one logging company that operated for a short time near Nkung'ungu, and 5 people in Kipembawe had about 30 licences between them (District Officer 3, 2013). Each licence costs approximately TSH 1.6 million and lasts for 30 days, within which time 20m^3 of timber may be harvested (Division Officer 2, 2013). Village Chairperson 1 (2013) explained that "*There are few lumberers because the permits are so expensive*", and this leads to high amounts of illegal lumbering. The research team witnessed two illegal operations while conducting the biodiversity surveys where timber was removed by truck, and came across many small-scale pit-saw sites.

All households surveyed used firewood as their heating source for cooking. Ten households also used charcoal. Few people use charcoal in the area, but according to District Officer 3 (2013) 90% of households within Mbeya town are dependent upon charcoal, and villagers in Mamba in the south of Kipembawe are now allowed to sell charcoal, and are finding it very profitable.

Livestock grazing

Livestock grazing was frequently cited as a reason for deforestation in key informant interviews and focus groups. Livestock tracks were present in 10.71% of transects within the biodiversity sites. However, it was much more difficult to determine deforestation and degradation caused as a result of pastoralism in comparison to cultivation, and therefore most of the evidence of cattle in the area is based on secondary data and data collected during the social survey.

Table 5.4: Livestock numbers for Chunya and Kipembawe. Matwiga village not available.

Animal	*Chunya District (2003)	^Chunya District (2013)	~Nkung'ungu Ward (2013)	**Lualaje Ward (2009)	^^Mazimbo village (2012-2013)
Cow	173,800	186,800	15,300	44,450	782
Goat	36,000	46,624		17,900	124
Sheep	22,800	22,820		8697	5

*District Officer 4, 2013 ^District Officer 6, 2013 ~Village E Officer 2, 2013** Ward A Officer 2, 2013^^ Ward B Officer 2, 2013.

The livestock numbers (Table 5.4) are those that are officially registered with the Livestock Officers, and all Officers stated that many livestock are brought into the area and are not registered, so the total number of livestock is likely to be far higher. District Officer 6 explained that overcrowding of cattle causes environmental destruction, as they damage the land, pasture doesn't regrow, and trees don't regenerate. Therefore they are regulating the numbers of cattle by restricting numbers to 70 per keeper. This policy is widely known, as demonstrated in pastoralist focus groups, although it is also widely recognised that these restrictions are largely ignored. District Officer 6 also outlined a programme to encourage each livestock keeper to plant 400 trees a year in their area, and to have a rain-water harvesting technique for the household. However, he thought that most people are not interested. In addition to the damage caused directly by the cattle, trees are also believed to be cut down by pastoralists:

> *"Livestock keepers clear the natural vegetation which leads to environmental degradation because they think that no trees equals no tsetse. It works, but the environment is very degraded because of this. In the north it is now desert because of this, so they have moved here and are doing the same. If there are more tsetse traps there would be no flies [and they would not need to cut the trees down]."*
>
> District Officer 4, 2013

Cattle were cited as a cause of damage to the environment among all respondents. One of the greatest problems associated with cattle was water sources, where there was increased competition for water access, and damage to the water sources.

5.4.2 Indirect drivers

Economic drivers

Economic and demographic drivers are related in this area. In terms of wealth/financial assets, Ward C Officer 1 (2013) believes that people in this area are better off than in other areas of Tanzania. Village A Officer 1 said that the problem is not the amount of money that people have, but the way they use it. Data from the household surveys classify 50.5% of households as better off or very well off - characterised by tin roofs, solar panels, transport, and general appearance of the property and the household members. Tobacco prices are set by the Tobacco Council of Tanzania at the beginning of the year, based on the global market. There are 72 grades of tobacco, although only 62 are generally used. For the 2012/2013 season the top grade was priced at US$1.939/kg, and the lowest at US$0.396/kg (CHUTCO, 2013). If these prices are high, more people move to the area to farm; the price was set to be higher for the 2013/2014 season, and therefore Tobacco Company 1 expected that tobacco would be cultivated on 10% more land than in 2012/2013.

Migration

In 1988 the population of Chunya District was 164,493, rising with an average annual growth rate of 1.6% to 205,915 in 2002, and with an average annual growth rate of 3.5% to 290,478 in 2012 (2002, 2012 Census Reports). The total population of Kipembawe in 2012 was 66,752 (2012 Census). Demographic data from the HHS demonstrate that there is high immigration into the area, with 75% of respondents migrating to the area. The most common reason for moving to the area was to cultivate (62%), and of these 74% (67 households) said they moved to the area with the purpose of farming tobacco. Ward B Officer 1 (2013) explained:

> *"The population growth is very high; the monthly birth rate is very high. Most of the women giving birth are under 18. There is also a lot of immigration for tobacco cultivation, when the price is high. When it is low they leave, and go to the mining area."*

A rising population contributes to demand for food and water, and puts additional pressure on infrastructure. Here the increase in population due to a motivation to cultivate tobacco has a direct influence on the expansion of agriculture.

5.5 Discussion

Agriculture is implicitly recognised as a driver of deforestation globally and is the leading land use change associated with nearly all deforestation cases (Geist and Lambin, 2002, Beddington et al., 2012). This study shows that tobacco cultivation is the main driver of deforestation and degradation within the miombo woodlands in the Kipembawe Division, Tanzania. Tobacco influences land use change both as an indirect and a direct driver, with lucrative prices encouraging migration to the area to start new farms in addition to incentivising others to expand their farms. Tobacco depletes soil nutrients faster than almost any other crop, leading to rapid clearance of vegetation in a search for fertile soils and heavy use of fertiliser and pesticides (Baris et al., 2000). Further, the preparation of the tobacco leaves for storage requires large quantities of wood for curing. Additionally, the rising population requires food crops, infrastructure and firewood, which are extracted from the remaining woodland.

5.5.1 Wood used for tobacco curing

In addition to the clearance for the production of tobacco, curing the green leaves uses 200,000 ha of woodland a year (Geist 1999), which amounts to 1.7% of global net forest cover loss. The figure estimated in this chapter of 7.02 kg firewood per 1kg of tobacco is low in comparison to that found in other studies, although estimations vary widely: 1kg of cured tobacco requires 100-130kg of firewood (Muwanga-Bayego, 1994); 1kg of cured tobacco requires 20kg of firewood (Otanez, 2008); 1kg of cured tobacco requires 14kg of firewood (Siddiqui and Rajabu, 1996); 16.1m^3 (23 stacked m^3)[2] of firewood is needed to produce 1400kg of cured tobacco (Mangora, 2005); 13.93m^3 (19.9 stacked m^3) of firewood is needed per tonne of tobacco (Geist, 1999). However, this estimate is similar to that produced by Fraser (1986), who estimated that 7.8kg of firewood is needed to cure 1kg of tobacco. Similarly, the base figure used in the estimation in this chapter that 18m^3 of wood is needed to cure 1 tonne of tobacco is provided by the tobacco industry. The final figure of 7.02kg firewood/kg tobacco takes into account the

[2] Stacked wood is harvested timber which is stacked, and measured according to the volume it occupies. To convert from stacked volume to solid volume a conversion rate of 70% was used (FONSECA, M. A. 2005. *The Measurement of Roundwood: Methodologies and Conversion Ratios*, CABI.).

density of wood, which is not always considered. Therefore, in the absence of empirical data from curing barns (where further research is needed) this is an adequate estimate for the amount of firewood required to cure tobacco in miombo woodlands in Kipembawe. Traditional curing barns lose 98.5% of the energy supplied; modern (or 'rocket') curing barns are 43.6% more thermally efficient; losing 55.6% of the energy supplied (Musoni et al., 2013).

5.5.2 Expanding cultivation

In other areas of miombo, slash and burn is the most common agricultural practice, due to low incomes and high population growth rates (Williams et al., 2008). Shifting cultivation is often due to insecure ownership of the land (Geist and Lambin, 2002) and accounts for 50% of deforestation within Tanzania (Abdallah and Monela, 2007). Many of the soils within the miombo are poor (Frost, 1996), leading to farmland being abandoned, and more woodland cleared elsewhere. Within Kipembawe land is cleared to expand the farmland, and fertiliser used on poorer soils; therefore there is little incentive to allow the land to regenerate, particularly not for the 25 years that enable miombo to return close to its former composition (Kalaba et al., 2013b). Rapid land use change as a result of tobacco cultivation has precedence in Tanzania, where areas in Tabora have experienced drought, irregular rains, whirlwinds and a scarcity of wood (Maegga, 2011). The prices of tobacco grades for the following year's harvest is set prior to cultivation and are determined in a consultative process by the Tobacco Council of Tanzania, which is comprised of representatives of key actors in the system – i.e. co-operative unions, merchants, processors and the Tanzania Tobacco Board (Maegga, 2011). This price is then released, and farmers can decide how much tobacco they wish to cultivate based on this. If the price is high, it encourages migration to the area to cultivate tobacco, thereby accelerating the amount of tobacco that is grown.

A second driver of land use change in this study site is pastoralism. In this case, the agro-pastoralist Sukuma tribe have been displaced from their traditional lands in the north of Tanzania by the spread of cash crops and population growth and have moved to other areas in search of grazing and water (Charnley, 1997). They have been further displaced from the adjacent Mbarali District in Mbeya due to the expansion of the Ruaha National Park (Sirima and Backman, 2013). Throughout the social survey, it was evident that many of the farmers thought that most of the changes within the woodland were associated with the grazing of livestock, rather than the cultivation of tobacco. Woodland clearance to eradicate tsetse fly occurs throughout the miombo region and has an impact on land cover and land use across large areas (Desanker et al., 1997). While livestock keepers do cause damage to the woodland in Kipembawe, it would appear that tobacco cultivation is the greatest driver of land cover change. It is however important to note that, if the agriculturalists do believe that the cattle cause the most change, then the implementation of policies to reduce the impact of tobacco farming on the environment such as the tree planting programme, or any other land use management strategy may have lower participation rates.

5.5.3 Harvesting for household fuelwood

The harvesting of wood for fuel and poles by individuals for domestic use is the dominant form of deforestation by wood extraction (Geist and Lambin, 2002). Charcoal or fuelwood supplies 70% of energy used in southern Africa (Syampungani et al., 2009). The greatest use of miombo woodland is the production of charcoal, which is expected to rise as it is increasingly produced commercially (Malambo and Syampungani, 2008; Cabral et al., 2011; Kutsch et al., 2011) due to increasing demands for energy from a growing population. Without a corresponding growth in technological development there are few alternative energy sources (Abdallah and Monela, 2007). Charcoal is produced in traditional kilns, which have an energy conversion rate of approximately 12% (Kutsch et al., 2011), rendering the process unsustainable (Abdallah and Monela, 2007, Luoga et al., 2002). Logging for charcoal is selective until preferred species become scarce, at which point less desirable woods are harvested (Malambo and Syampungani, 2008). In many cases the first areas to be deforested are those with lower wood densities, as these are easier to fell, and then the more dense species are felled, resulting in rapid clearing of the forest (Cabral et al., 2011). Charcoal consumption is predicted to increase in line with urban demands and the lack of affordable alternatives (Ahrends et al., 2010). In other areas of Chunya, 88.3% of timber harvesting was thought to be for the purposes of charcoal (Sawe et al., 2014). This demonstrates how unusual this study site is in comparison with other areas of miombo in that very few people used or produced charcoal. This is probably due to the wide availability of firewood, the remoteness of the area and low accessibility due to the poor road network. It is likely that this will change in the future as the road network is improved and charcoal can be transported to Mbeya to meet growing urban demand. Within miombo woodlands, extraction of valuable timber for sale occurs through selective logging (Malambo and Syampungani, 2008). High quality wood is exported, and poorer quality woods and poles are used in local construction

(Ahrends et al., 2010). Similarly to charcoal, commercial extraction of timber is not a significant factor within Kipembawe, due to the remoteness of the area and lack of accessibility.

5.5.4 Other drivers

Two other drivers that are highlighted throughout the literature as significant in miombo woodlands were the over-exploitation of species, and fire (Vinya et al., 2011). The over-exploitation of some wood species as identified by Kowero (2003), is discussed in Chapter 7, and illustrates that the over-harvesting of *Pterocarpus angolensis*, an important timber tree, is likely to lead to its local extinction. Chapters 6 and 9 discuss the level of poaching, and found that local poaching for bushmeat in the area is not excessive, but that poaching for ivory is becoming a big problem. The research team were aware of several fires that occurred in the area during the biodiversity surveys, and they were mentioned as a growing problem by Division Officer 2, but fire did not appear to be a main contributor to land use change within the area.

5.6 Conclusion

The drivers of change in the Kipembawe Division are broadly similar to those in other areas of miombo woodland. Agriculture is the greatest driver of change, particularly the cultivation of tobacco, through both clearing for planting and extracting wood to cure the crop. Indirectly tobacco cultivation leads to immigration into the area, and some of the consequences of this on ecosystem service provision are discussed in the following chapter. Given the Tanzanian government’s position on tobacco, it is likely that tobacco cultivation in Tanzania will continue to expand, driving further woodland deforestation and degradation. This demonstrates that urgent action is required to mitigate these impacts, through land management strategies that regulate utilisation, and through the development of alternative methods for drying the crop. Achieving sustainable use of the miombo woodlands will secure the livelihoods of communities that are dependent upon agriculture.

Chapter 6

Provisioning ecosystem services and rapid land use change in miombo woodlands

Chapter summary

This chapter addresses Objective 3 by identifying provisioning ecosystem services that are used within the study landscape and investigating the impact that rapid land use change identified in Chapter 5 has on the availability of these services, and what this may mean for their users. Chapters 7 and 8 then go on to identify the impacts of this rapid land use change on biodiversity by examining tree and butterfly communities respectively.

6.1 Abstract

Provisioning ecosystem services (ES) are essential for rural communities in sub-Saharan Africa to support their livelihoods, but the impact of land use change can affect households' ability to fully utilise these services. Within a rural miombo woodland landscape undergoing rapid land use change in south-western Tanzania the relationship between household use of provisioning ES, land use change and the availability of provisioning ES was explored. Social and ecological surveys were conducted to determine provisioning ES use through household surveys, focus groups, key informant interviews and woodland transects. This approach enabled the integration of qualitative social data and quantitative ecological data. These data showed that communities within the five sampled villages rely exclusively on locally sourced firewood for cooking, and that almost all building materials are procured from the woodlands, in addition to fruits, mushrooms and medicines. Provisioning ES are used by all households, regardless of their economic status. Use is determined by access to alternative products, with households in areas further away from shops and services utilising more provisioning ES. In areas with higher woodland utilisation fewer provisioning ES were used. Households perceived declines in firewood, water and honey availability during the time that they had been resident in the villages. This has implications for the food security of the area, in addition to the sustainability

of apiculture, which is being promoted as an alternative livelihood to tobacco cultivation, the main driver of deforestation. Water levels in the River Lupa have decreased by between 14-90% per month from 1975-1993 to 2005-2014, indicating depleting groundwater sources. Farmers and pastoralists also suffer from the impacts of ecosystem disservices, through pest damage to crops and livestock disease. To maintain the provision of these services sustainable land management strategies are required that retain miombo woodland in areas that are accessible and prevent over-utilisation.

6.2 Introduction

Ecosystem services are the direct and indirect contributions of ecosystems to human well-being (de Groot et al., 2010). The Millennium Ecosystem Assessment framework divided ecosystem services into four categories: provisioning services are the products obtained from the ecosystem, such as food, fibre, fuel and fresh water; regulating services are the benefits obtained from the regulation of ecosystem processes such as water purification and pollination; cultural services are the non-material benefits obtained from cultural heritage, recreation and tourism; and supporting services are necessary for the production of other services, such as soil formation, photosynthesis and nutrient cycling (MEA, 2005). Globally, human activities have already resulted in a 60% decrease in the services provided by biotic systems (MEA, 2005); two major causes are the over-exploitation of resources and agricultural expansion (Egoh et al., 2012).

While all these services are important to human well-being, basic provisioning services are widely recognised as essential for meeting human needs (Daniel et al., 2012) and these are more tangible to the rural poor, who disproportionately rely on such services (Chirwa et al., 2008, Shackleton et al., 2008). The livelihoods of approximately 100 million people within sub-Saharan Africa are dependent to some extent on miombo woodlands (Syampungani et al., 2009, Dewees et al., 2011). Miombo woodlands have been described as *"...a pharmacy, a supermarket, a building supply store, and a grazing resource*" (Dewees et al., 2010: p61), due to the range of goods and services that they supply to local communities. Additionally, they are of global importance, due to the amount of carbon they store (Dewees et al., 2010 and Chapter 7). However, they are becoming rapidly degraded in their extent, and this may reduce the ecosystem services that they provide, with potentially devastating consequences for the livelihoods that they support. Several studies on ecosystem service provision and use within miombo woodlands have found that the use of provisioning ES is extensive, and that they are disproportionately used by the rural poor (Dewees et al., 2011, Njana et al., 2013, Syampungani et al., 2009). However, the degree to which the remoteness of a community to alternative products influences the use of woodland provisioning ES has not been analysed. Additionally the impact that the reduction or loss of provisioning services within miombo woodlands has on local communities has not been defined (Chirwa et al., 2008).

Ecosystems can also provide disservices which cause harm, either directly or indirectly, of which there are many forms (McCauley, 2006). Although diseases of crops and livestock may be a prominent disservice (Dunn, 2010), others such as pest and wild animal damage to crops, competition for water, pollination, nutrients and sunlight (Zhang et al., 2007) can also be detrimental for communities that rely on agricultural production. Ecosystem disservices can be critical to the relationship between the local communities and the ecosystem by creating negative perceptions of the environment and thereby presenting challenges for land management strategies, regardless of the potential benefits.

This study seeks to address these gaps (remoteness, impact of rapid land use change and ecosystem disservices) by exploring the provisioning ecosystem services and disservices used and experienced by local communities within Kipembawe, the relationship between the use of provisioning ES and the location of the community relative to alternative products, and the extent to which these issues cross income levels. It assesses the impact of rapid land use change on the availability of these services, and how this may affect local livelihoods. Finally it turns to land use management, and discusses how the identified ecosystem disservices may present challenges to sustainable land management.

6.3 Methods and analysis

The study area is detailed in Chapter 3, Part 2. Biodiversity site selection is described in section 3.4.9, and village selection is detailed in section 3.4.10. This chapter draws on utilisation data from biodiversity assessments (section 3.5), household surveys, livelihood matrices, focus groups and key informant interviews as described in section 3.6.

The wealth status of each household was ascertained unobtrusively by the research team based on indicators from elsewhere in Tanzania (Van Campenhout, 2007). Indicators used included the materials of the house and roof, quality of clothing, and visible assets (e.g. bicycle, solar panels, motorbike). Households were classified based on their perceived wealth against the rest of the community into five groups (much better off, better off, average, worse off and much worse off). The research assistants recorded why they felt that this classification was justified, and classifications were reviewed throughout the research period.

Ecosystem service use

To determine the ecosystem services that were used within each village a range of methods were deployed. During pilot studies open questions were asked to identify the ecosystem services that may be used in the villages to produce an exhaustive list to use in the HHS. Each household was asked whether they used the service indicated on the list, how often they used them, where they got them from, and whether they were for home use, sale, or both. These data were then summed across the villages. Within each village a focus group took place dedicated to determining the range of ecosystem services used, and the degree to which people relied on the woodland for their income. Woodland visits were conducted with forest dealers and traditional healers to understand what uses different plants and trees have, and identify them to species level. Transects within the woodland quantified ecosystem service use. Utilisation of poles and timber was determined by calculating the proportion of cut poles and timbers within the available poles and timbers (dead and alive). All other signs of utilisation such as pitsaw sites, beehives, rope extraction and bark removal were counted and summed across the sites.

Freshwater provision

Freshwater provision was calculated using daily rainfall data recorded at the Lupatingatinga Weather Station from 1977 to 2014, and levels of the River Lupa, recorded twice daily from 1975 to 2014 (Lake Rukwa Water Basin River Board, 2014). Rainfall data were collected consistently throughout this period, and were summed per year. To determine whether rainfall has changed over time the Mann-Kendall trend test was performed in R (McLeod, 2011). To determine river levels the daily average height of the river was calculated, and these data were used to calculate average monthly levels per year for the full data set. Data throughout the 1990s were collected irregularly. Therefore to determine whether there has been a change in water levels over time the average monthly levels were calculated using 8 years of complete data between the period

1975-1993, and 2005-2014. Water availability was discussed within Village Elders and Villagers focus groups, and within key informant interviews.

Ecosystem disservices

Types of ecosystem disservices were identified during Agriculturalist and Pastoralist focus groups, and field visits were conducted to increase understanding. The impact of crop raiding was addressed within the HHS. Households were asked which animals caused damage to what crop, how often and when this occurred, and if this had changed over time. This was then analysed at village level, and then amalgamated across the villages. Following descriptions of livestock diseases at village level key informant interviews were conducted with Ward, District and Regional Livestock officers to verify the type of diseases and their extent.

Ecosystem service users

To identify trends in particular characteristics of ecosystem service users, a generalised linear model (function glm) with two way model selection (function stepAIC, MASS package (Venables and Ripley, 2002)) was performed on total ES used and five categories based upon household and village characteristics. Categories included: wealth, household size, time in area, village, and age of respondent. To further test the relationship between wealth and individual ES (rope, building poles, grasses for construction, mushrooms, fruits, vegetables, wood for tools, and total ES used) a generalised linear mixed effects model was used (function glmer in package lme4 (Bates et al., 2014)) with 'Village' as the random effect. Firstly the interrelationships between all variables were tested for correlation using the Pearson's correlation test. Variables that were not highly correlated were used ($r<0.7$) (Loos et al., 2014a). The Mann Whitney U test was used to explore linkages between the average number of ES used per household in each village, and the distance of the village from the main supply village and the percentage of harvested poles and timber (utilisation) at the nearest biodiversity site. Gender, education and ethnic group were not tested because there were too few variables within the categories. Statistical analyses were conducted using the statistical package R, version 3.1.0 (2014-04-10) (R Core Team, 2014).

Impacts of rapid land use change

To identify perceived changes in the availability of ES over time households were asked if they had noticed any changes in availability during the time that they had been resident in the village. Perceived changes in availability of ecosystem services over time were pooled per village and across all villages. Where no clear consensus of trend was revealed the data (firewood and mushrooms) were tested for significant differences between responses for all pooled data, and per village and timeframe using Fisher's exact test, which is suitable for count data.

Perceptions of future livelihood impacts

To identify the impact of decreases in ecosystem services on households respondents were asked how they would be affected if the ecosystem services were not available in the future. They were also asked what they thought the village and environment would look like in 10 years' time. Responses were coded and pooled across the villages.

6.4 Results

6.4.1 Provisioning ecosystem service use

During the household surveys 17 provisioning services were identified as used by households (Figure 6.1). Similar lists were produced by focus groups within each village, with the addition of 'fish', which can be caught in the rivers and some tributaries.

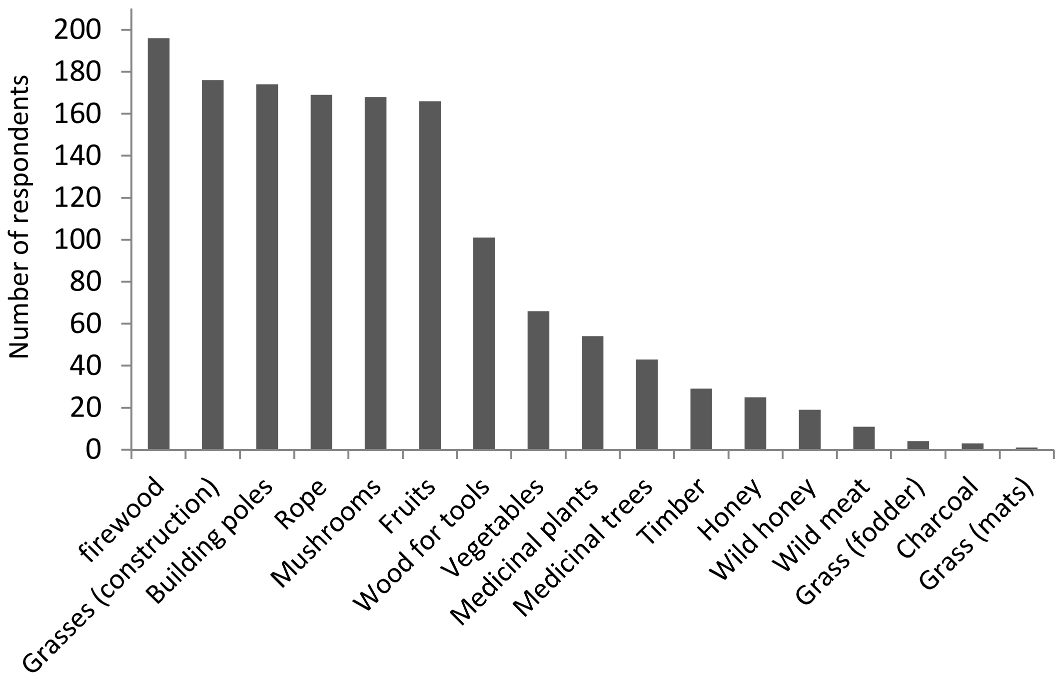

Figure 6.1: Number of households using each provisioning service (source: HHS, n= 196). Honey is defined as being harvested from designated beehives; 'wild' honey is that from natural hives.

Provisioning ecosystem services are collected from a range of areas (Table 6.1). All respondents depend on firewood from the miombo woodlands for their energy needs. The importance of the woodlands for energy was also highlighted by the Regional Officer 2: *"People rely on the forest, especially for energy".* All but two households collected it themselves. One respondent bought firewood from other villagers, and a teacher got it from school. Ten respondents also used charcoal for cooking, however only three of these associated charcoal as an ecosystem service from the forest, with one person buying it, and the other two making it once a year, in open access woodland and regenerating woodland. Four charcoal pits were observed during ecological surveys.

Timber was used by 31 households, of whom 19 bought it locally and one bought it 'from town'. One household bought both poles and timber from Mbeya. One household used mountain bamboo for building poles. Cut poles and timbers were recorded on transects, however it is difficult to differentiate between that harvested for construction use and that harvested for use in tobacco burners, and therefore these data are not presented here. However, nine pitsaw sites, eight incidents of logging and six incidents of discarded timber were recorded during ecological surveys. District Officer 3 said that "*…there are many illegal loggers*".

Two households employed people to cut grasses for them. No one bought wood for making tools, but one respondent commented that suitable wood was less likely to be cut because people *"buy [tools] from carpenters now".* Medicinal plants and trees were used by 58 households, of whom 6 did not harvest them directly, but used the services of local traditional healers. Woodland walks conducted with forest dealers and traditional healers provided an initial insight into the uses of miombo products, these are listed in Appendix D. Wild meat was used by 10 households, of whom 8 bought it from local hunters. The two people who hunted themselves went into open access areas or their own land, and they said they hunted very infrequently, because the animals were moving away now. Hunting is illegal without a license, so this may have affected response rates. However, both Villages A and D Officers 3 said that there was very little poaching in the area. Village A Officer 3 said that occasionally eland, buffalo and hartebeest are poached for food, and that occasionally this is sold locally, but it happens rarely. This may vary from village to village – in Village C the research team was offered eland meat, and during biodiversity surveys at one site there were encounters with poachers and gun shots were also heard. Village C PFM committee said that no licenses for hunting had been issued. Illegal commercial hunting takes place in the north of Kipembawe (discussed in Chapter

9). There was evidence of hunting/poaching activity recorded four times during ecological survey transects, and one record of baited poison for baboons.

Figure 6.2: Grasses for construction - roofing (source: E Jew, 2013)

Figure 6.3: Making mats with grasses (source: E Jew, 2013)

Table 6.1: Areas of provisioning ecosystem services collection by households. Numbers of households collecting from each area - multiple answers could be given (n=196)

Ecosystem service	Area ES collected					
	^Personal land	Open access woodland	No particular area	Seasonal Floodplain	Bought from other villagers	Other*
Firewood	129	6	63	0	1	13
Building poles	117	42	19	0	0	7
Grasses for construction	72	36	35	28	7	3
Mushrooms	122	51	13	0	0	5
Fruit	94	46	38	0	0	7
Vegetables	19	45	1	0	0	19
Medicinal trees and plants	38	24	28	0	0	1
Rope	131	29	14	0	0	8
Wood for tools	55	30	21	0	0	3

* (Neighbours' land, village woodland, regenerating woodland, termite mounds)

^Personal land is that which is held in tenure/allocated to the household by the village, or claimed

Two households collected grasses for construction, both for sale and for home use, with one household collecting once a year and the other every week (Figure 6.2). One household collected grasses to make mats to sell (Figure 6.3). One household collected forest fruits for both purposes every wet season. One household collected building timber twice a year for both purposes. Households were asked if they collected products for household use, sale or both. Two households collected honey from beehives to sell, and one person collected wild honey for sale. There were 187 signs of activities relating to honey production on the ecological survey transects (Figure 6.4).

6.4.2 Relationship between users and use of products

In order to determine who uses each type of ES within the community the relationships between the household and village characteristics and the use of ecosystem services were examined. Two-way stepwise selection for a generalised linear model based on AIC demonstrated that there were no significant associations between the total number of ecosystem services used and wealth, age of respondent, length of time in area and household size. However, there was a significant difference between the number of services used between the villages, with households within Nkung'ungu using significantly fewer than households within the other villages (GLM, df=191, χ =102.62, P=0.00377). There were no significant relationships between the wealth status of households and the type of ecosystem services they used (Table 6.2). The distribution of the services used in relation to wealth categories are displayed in Figure 6.5.

Table 6.2: Relationships between use of ecosystem services and wealth of household, calculated using a generalised mixed effect model with 'Village' as the random effect. Significance levels indicated by: *P<0.05; **P<0.01; ***P<0.001.

Ecosystem Service	Predictor variable	Estimate	SE	Z	Pr>|z|)
Rope	Intercept	-0.09148	0.21461	-0.426	0.670
	Wealth	-0.02055	0.06023	-0.341	0.733
Building poles	Intercept	-0.105619	0.212321	-0.498	0.619
	Wealth	-0.004007	0.059192	0.068	0.946
Grasses for construction	Intercept	-0.08211	0.21144	0.389	0.697
	Wealth	-0.01101	0.05911	-0.186	0.852
Mushrooms	Intercept	-0.29799	0.22398	-1.330	0.183
	Wealth	0.03536	0.06148	0.575	0.565
Fruit	Intercept	-0.23227	0.22178	-1.047	0.295
	Wealth	0.01422	0.06138	0.232	0.817
Vegetables	Intercept	-1.101794	0.346392	-3.181	0.00147**
	Wealth	0.003968	0.096260	0.041	0.96712
Wood for tools	Intercept	-0.64384	0.28251	-2.279	0.0227*
	Wealth	-0.00500	0.07831	-0.064	0.9491
Total ES used	Intercept	1.932258	0.080653	23.959	<2e-16***
	Wealth	0.008824	0.021701	0.407	0.684

Mann Whitney U tests did not demonstrate a significant relationship between the number of ecosystem services used and the distance to the nearest supply village (P=0.6905) or with utilisation in adjacent biodiversity sites (P=0.1508). However, these results suggest a correlation, which indicates that more ES are used when the distance to the nearest supply village is greater, and that more ES were used in areas that were less utilised through the cutting of poles and timber than in those that had been heavily utilised.

Figure 6.4: Bark used to make beehives (source: E Jew, 2013)

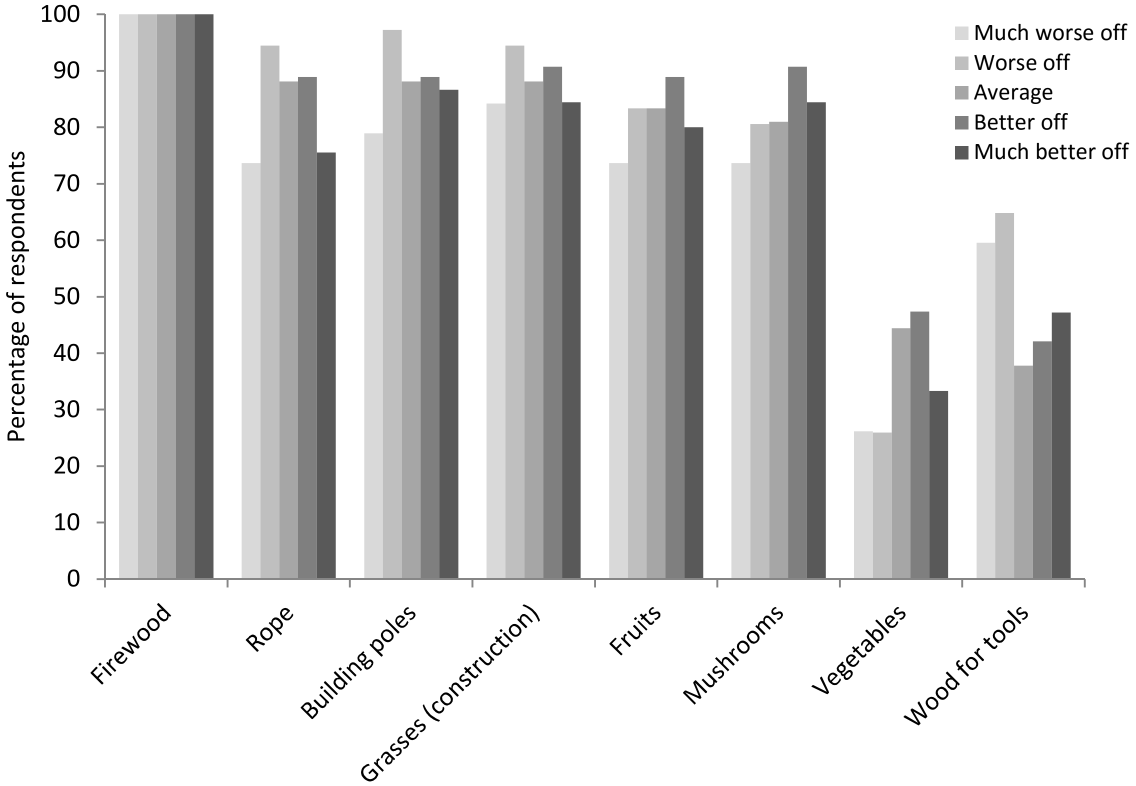

Figure 6.5: Distribution of ES use per wealth category (n=196)

6.4.3 Changes in availability of ES over time

Perceptions of the trends in availability of each service varied considerably. Grasses that could be used for construction and medicinal plants were widely thought to be decreasing over time. The availability of rope and building poles was thought to be stable. Very few respondents thought that any services were increasing in availability (Figure 6.6). For some services (mushrooms, firewood and fresh water) there was considerable ambiguity in the perceptions, and these were analysed further.

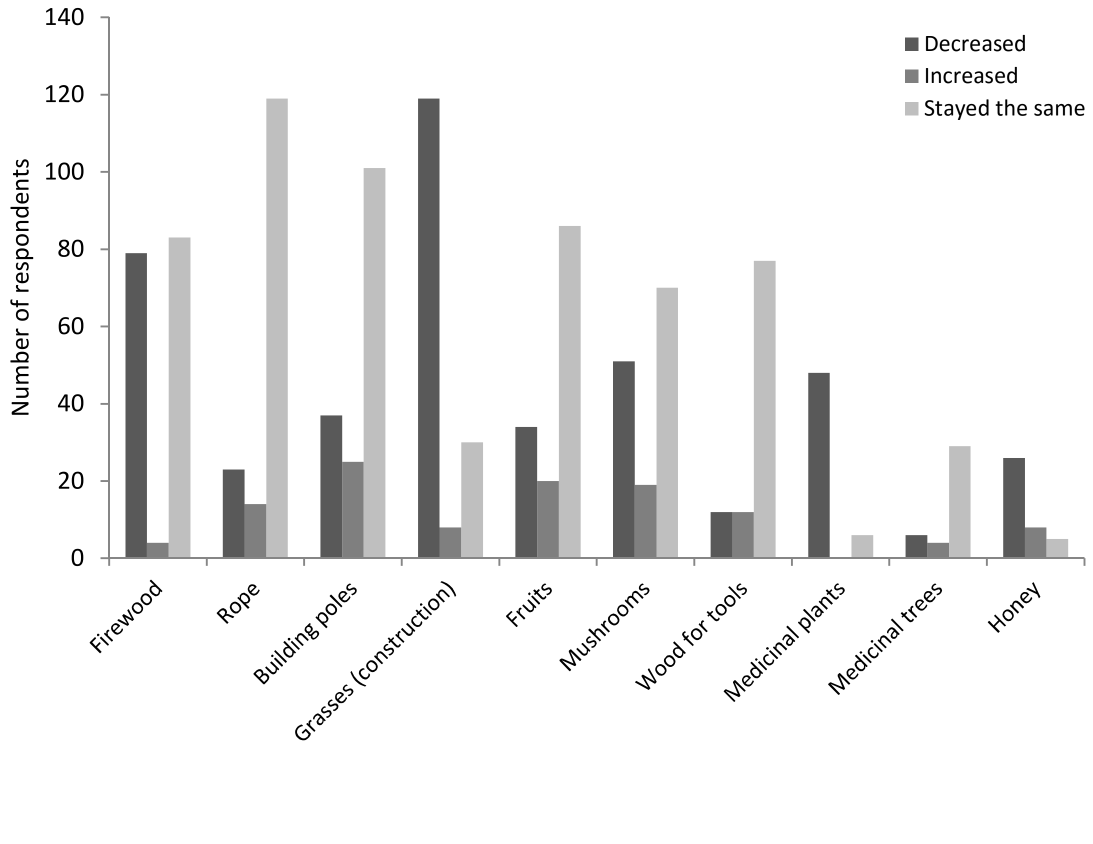

Figure 6.6: Perceived trends in availability of ecosystem services over the time the respondent was in the village

Firewood and mushrooms

Perceptions of trends in firewood were analysed at village level and according to the length of time that respondents had been resident in the village. Respondents in the villages of Matwiga and Mazimbo thought that firewood availability had declined (Fisher's exact test (FET): Matwiga:

P=0.02; Mazimbo: P<0.004). Respondents in Mwiji (FET, P=0.01) and Nkung'ungu (FET, P<0.004)) felt that firewood availability had stayed the same. There was no significant difference between those who thought that firewood had decreased and those who thought it had stayed the same (P=0.19) in Lualaje. There were no significant trends detected in respondents' opinions according to the length of time that they had been in the area. Perceptions in the availability of mushrooms did not show any clear spatial or temporal trends.

Freshwater provision

A perceived reduction in the availability of water was apparent. This was demonstrated by the Village A Villagers focus group: *"Water is the most important part of the environment. It is available but it is not good for drinking, because we use the same water as other people wash in. Getting clean water for drinking is a problem".* Village A Officer 1 said that this was different to the past "*When I was growing up there was plenty of water, and now there isn't".* Awareness of water issues extends to Regional levels: *"The water table is becoming lower as everyone is digging boreholes, and an increased demand for water is increasing conflict over water, as there are increasing numbers of cattle that need water. The demand for water is increasing, but its availability is decreasing*" (Regional Officer 3). The availability of water was cited as the biggest problem facing the villages across the survey, and has led to water restrictions in one village: *"Since 2012 we have restricted people to 3-4 buckets of water a day per household"* (Village E Officer 1, 2013). People believed that forest cover has an impact on the amount of rainfall that they receive: *"We depend on the forest for rainfall"* (Village B and E Villager focus groups, 2013): "*The main source of the reduction in rainfall is tobacco cultivation, because of the cutting of trees*" (Village B Officer 1, 2013). All five Village Elder focus groups thought that the amount of rainfall had decreased over time, and that river levels had decreased.

The volume of annual rainfall recorded in Lupatingatinga varies considerably annually (Figure 6.7), but there is no evidence of long term declines (Mann-Kendall trend test tau=0.00901, 2 sided p value = 0.94786). Water levels at the River Lupa have decreased by between 14-90% per month between 1975-1993 and 2005-2014 (Figure 6.8).

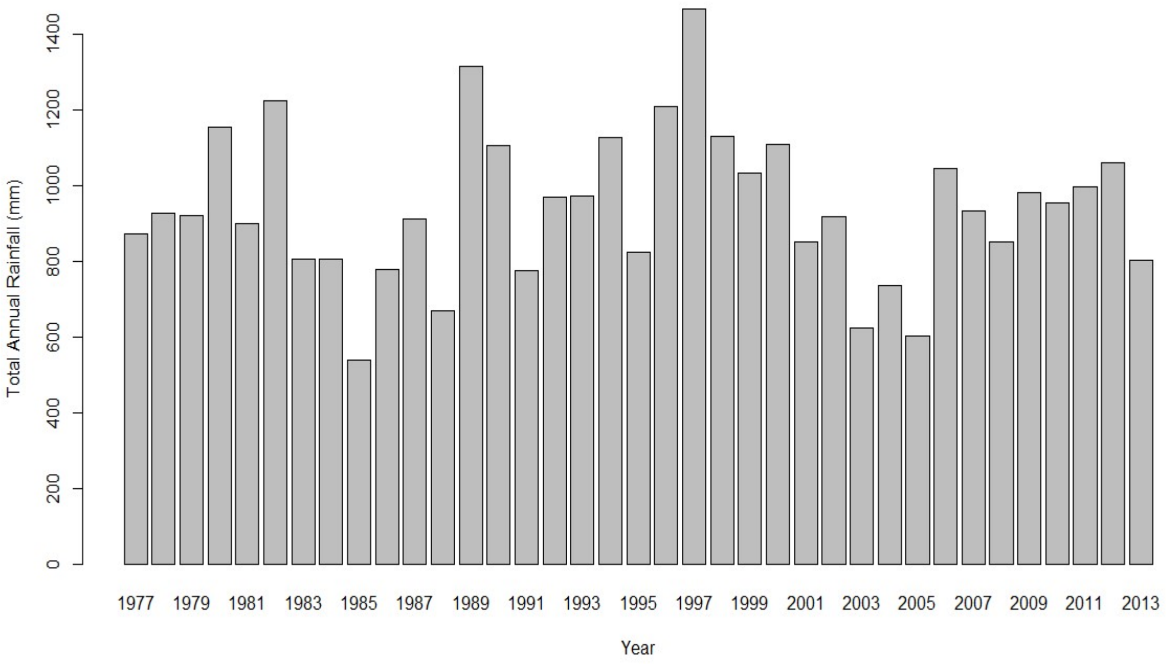

Figure 6.7: Trends in annual rainfall 1976-2013, Lupatingatinga Source: Lake Rukwa Water Basin River Board, 2014).

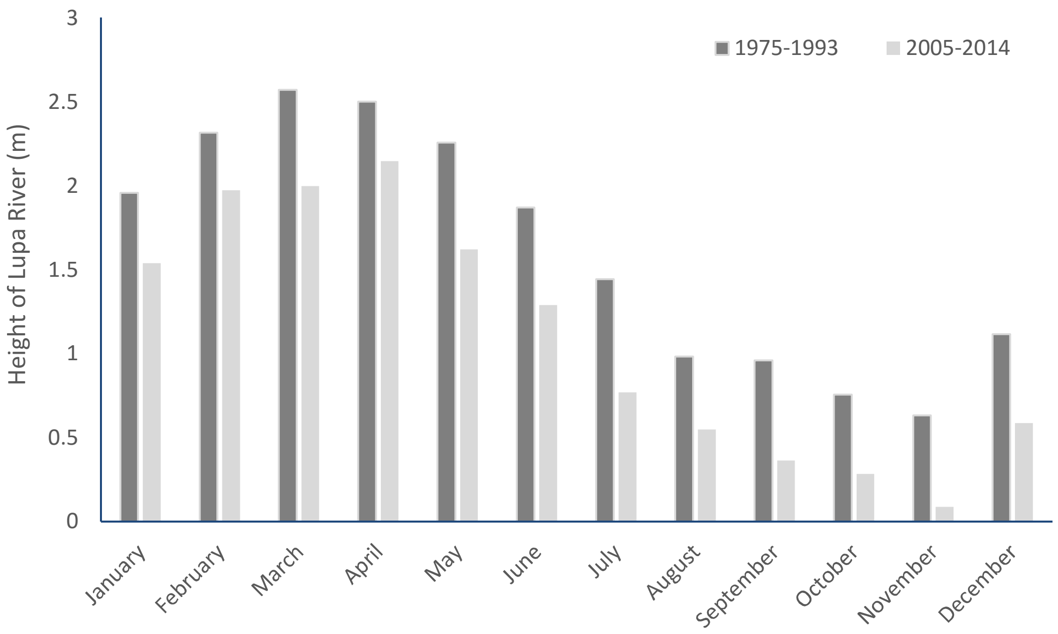

Figure 6.8: Height of the River Lupa per month between 1975-1993 and 2005-2014 (source: Lake Rukwa Water Basin River Board (2014)).

6.4.4 Perceptions of the future

If the woodland was no longer able to provide ecosystem services it would be 'bad' for households according to 78% of those sampled, 11% of respondents thought that it would not affect them, and 12% did not know or did not answer the question (Table 6.3). A third of the people who said that they didn't know said that the forest would always be there, so it would never be a problem. Many of the people who thought it would be bad for the household had similar opinions: *"The forest will always be there, there is no way of surviving without it"* (HHS, Matwiga); "*We depend on the forest for everything*" (HHS, Nkung'ungu). People who thought that it would not affect the household said that "*I don't depend on it much because I have [products on] my farmland*" (HHS, Mwiji), or that they would have to find alternatives. Village A Villagers focus group said that the forest didn't just provide these services, but it also acted as a windbreak and provided water, so without it the place would be "*like a desert".* They also said that the single most important thing about the forest is the trees, because they need them for drying the tobacco.

In 10 years' time 31% of HHS respondents thought that there would be no trees, and 46% thought that there would be issues with water, including desertification. The majority of answers associated with the environment in the future were negative (Table 6.4). The reasons given for these changes included 'cutting trees', 'tobacco cultivation', 'livestock', and 'increased population'.

Most respondents (39% of those who responded (n=164), Table 6.5) thought that villages would be 'more developed' in the future, although many said that this would depend on the price of tobacco; if it was low then there would be no development, and the population would decrease. If the price was high there would be an increasing population and people would be able to build modern houses. Three respondents associated the condition of the environment in ten years' time with the state of the village.

The lack of association between use of the forest now and how this may affect the future was evident in several focus groups. Village D Agriculture focus group said when asked about the future of the area they said "*We need to have the reserved area so future generations will have forest*". When asked about the current availability of agricultural land they said "*We need more land for agriculture. We need to use the land that is in the reserved area for agriculture now*". Village C Villagers focus group said "*We need to increase the land for agriculture for the future* *generations from the livestock and reserved areas. The population has increased….. so we need more agricultural land from the reserved area*".

District Officer 3 explained that "*There is a perception that the forest will always be there, but there is damage from livestock, mining, fire, and illegal harvesting of charcoal and timber – even reserved areas are in danger*". Both the Nkung'ungu Village C and E PFM Committees said that they did not have the funding or the capacity to patrol the reserves, and therefore the areas were still being used.

Table 6.3: Effect of unavailability of services on household, should the forest no longer be able to provide them (HHS, n=196). Don’t know/no answer (n=22)

It will be bad for my household because… (n= 152)	Number of responses	It will not affect my household because… (n=22)	Number of responses
We depend on the forest for everything	97	I will move away	2
It will have a negative financial impact	16	We will find alternatives	6
It will affect tobacco cultivation	5	We plant our own trees	3
No alternative way to cook food	29	Don’t use them enough to have an impact	7
[But] the forest will always be there	9	Other	4
It will affect the climate/no rainfall	4		
I will move away	4		
It will have an effect on inheritance/spiritual values	2		
It will affect development activities	1		
Don’t know	1		

Table 6.4: How will the environment look in 10 years’ time? (HHS, n=196). Don't know/no answer (n=31)

Farmland	Number of responses	Forest	Number of responses
Agricultural expansion	22	No trees	51
Land shortage (for agriculture)	35	Reduced forest	1
Conservation awareness will increase	1	Regenerated forest only	1
Desert	35	No change	35
Drought/no water	21	Environmental destruction	5
People will move away	1	Moved by TANAPA – it will be a Reserve	2
Infertile soils	24	More forest	2
No agriculture	6	No rain	5
Tractors	2		

Table 6.5: What will the village be like in 10 years' time? (HHS n=196, Don't know/no answer (n=32))

What will the village be like in ten years' time?	Number of respondents	What will the village be like in ten years' time?	Number of respondents
Positive		*Unambiguous*	
Better communication network	4	No change	4
Better transport infrastructure	19	Change in population because of tobacco price	3
Better water supply	9	Population increase	38
Electricity	10	low population - others will go back to their hometowns or move away	3
Improved education	7	More livestock	2
Improved infrastructure – hospitals, market areas, small businesses	10	village will expand	15
More skilled people	1	Village will shift to Isangawana and the rest of the village will be farm and forest	1
More maize processors	2		
Modern houses – tin roofs rather than grass	52		
More developed	64		
More livelihood activities	2		
Negative			
Less development - irresponsible leaders	7		
It will be very hard here because of the damage to the environment - clearing trees, burning, water source damage. No farmland, no forest.	3		
No electricity	3		
No water - because now it is scarce	2		
A Reserve here - it will be taken by TANAPA	2		

6.4.5 Ecosystem disservices

Three main ecosystem disservices were identified through the study: 1) Crop and livestock damage by wild animals; 2) diseases affecting livestock (particularly cattle) and 3) crop suppression (particularly maize) by the weed *Striga spp*.

Crop and livestock damage

The majority (72%) of households (n=195) who farmed experienced some damage as a result of wild animals. It generally occurs on a yearly basis, just before the crops are ready to harvest. The main crops that are damaged are maize and groundnuts, although tobacco was affected by greater kudu (*Tragelaphus strepsiceros*). The animals that were most regularly cited as causing damage were yellow baboon (*Papio cynocephalus*) and bushpig (*Potamochoerus larvatus*). Damage can range from 0.1 ha to the whole crop. All five villages experienced similar levels of occurrence. Predation on livestock was very low, with some isolated reports of attacks by leopards on goats and lion on cattle over the last 5 years. For example, one respondent at the Village D Pastoralist Group Interview said that *"Two weeks ago a leopard killed two goats at my house, and one calf last month".*

Striga is a parasitic weed that can seriously impede productivity of cereal crops, particularly in sub-Saharan Africa (Abdul et al., 2012). The presence of this plant in the fields was noted by the research team, and was mentioned in several of the Agriculture focus groups. Ward C Officer 2 explained that there are two species that cause the most problems, *Striga forbesii* and *Striga asiatica*. He said that it was a *"big problem in the area".* There are also other pests such as termites and other insects that damage the crops (Village D Agriculture focus group, 2013).

Pests and diseases

Disease in livestock, particularly cattle, was cited as a problem for livestock keepers in all interviews with pastoralists. Village D Pastoralist focus group said that the number of cattle they were keeping had decreased due to increased mortality, and they thought that the prevalence of diseases may be linked to tobacco farmers contaminating the water with chemicals when they prepared seedbeds nearby. The decreasing numbers of cattle due to disease was supported by the Village D Officer 2. A list of the diseases that are found in the area in cattle was provided at District and Regional level (Table 6.6).

Table 6.6: Diseases in cattle

Disease	Cause	Vector/source	Source
East Coast Fever	Parasite *Theileria parva*	Ticks	(Olwoch et al., 2008)
Contagious Bovine Pleuropneumonia (CBPP)	Bacterium *Mycoplasma mycoides mycoides*	Airborne	(Kairu-Wanyoike et al., 2014)
Foot and Mouth Disease	Virus *Aphthovirus sp.*	Airborne, contact with contaminated equipment	(FAO, 2015b)
Lumpy Skin Disease – known locally as Black Cotta Disease	Virus *Capripoxvirus, Poxviridae*	Mosquitoes and flies	(FAO, 2013)
Trypanosomiasis	Parasite *Trypanosoma sp.*	Tsetse fly	(Mweempwa et al., 2015)
Bovine Tuberculosis	Bacteria *Mycobacterium bovis*	Inhalation or ingestion of the bacteria, and from contaminated food and water	(Roug et al., 2014)
Rift Valley Fever	Virus *Phlebovirus sp.*	Mosquitoes	(Mansfield et al., 2015)

Tsetse flies are associated with dense woodland, and livestock keepers often clear forest in order to reduce trypanosomosis infection. District Officer 4 said that *"While this is effective it contributes significantly to deforestation".* Trypanosomosis also affects people, where it presents as sleeping sickness.

6.5 Discussion

6.5.1 Ecosystem service use

The miombo woodlands of the Kipembawe Division provide local communities with 17 identified provisioning ecosystem services, in addition to other cultural, regulating and supporting services, which all contribute to the well-being of the population. All households were dependent upon the woodland for firewood for heating and cooking. The Kipembawe area was markedly different to other areas of miombo woodland in that only 11 respondents (5.6%) also used charcoal for cooking fuel. The use of other products, such as building materials (poles, grasses, and rope), fruits and mushrooms, and medical plants, are similar to those recorded elsewhere (Dewees et al., 2011, Kalaba et al., 2013a, Syampungani et al., 2009), demonstrating that miombo woodlands continue to support local populations throughout their range.

6.5.2 Influences on provisioning ecosystem service use

There were no significant differences in the total number of ecosystem services used and different socio-economic factors. As described in Chapter 4 (section 4.2.5) Kipembawe is very remote, and for the majority of people the only goods and services that are available are those that they and their neighbours produce themselves, and those that can be harvested from the woodland. Therefore households are almost entirely dependent upon local resources to meet their basic needs. The findings presented here show that this situation appears to be true of all households, regardless of their wealth status, due to the lack of alternative sources – there simply is nowhere to buy alternative products from, regardless of a household's purchasing power. This finding is in contrast to that of Dewees et al. (2010) who found that people with low incomes were most reliant on forest goods to prevent them from falling deeper into poverty. Additionally, households within the sample did not gather woodland products in order to generate income, as has been found in other areas of miombo (Kalaba et al., 2013a). This may be due to a lack of demand, but may also be due to the relatively high income generated by tobacco cultivation (Chapter 9), which reduces the need to seek income from elsewhere. Shackleton and Shackleton (2006) also found little difference between the use of NTFPs and wealth. However, they did find that wealthier households purchased more goods than poor households, but this was not the case within Kipembawe, probably because there are few people selling products.

6.5.3 Changes in the availability of provisioning ES

Globally land use change causes losses in a range of provisioning ecosystem services including food, fresh water and fuelwood (Foley et al., 2005) In areas of miombo woodland that were highly utilised in the study area fewer ES were collected, suggesting that utilisation may have reduced the availability of products in these areas. Within Kipembawe the main ecosystem services that households perceived to be decreasing were firewood and water, both of which contribute to maintaining food security (Poppy et al., 2014). Declines of these services were also seen in tobacco cultivation landscapes in Uganda, where wetlands, savannah woodlands and forest have been converted to agriculture (Speziale and Geneletti, 2014). Households reported that they have to travel further to fetch firewood, which reduces time spent cultivating or in education, and can reduce livelihood security (York Jr, 1990). Water levels in the Lupa River appear to have decreased since the 1970s, whereas rainfall amounts do not appear to have altered. This could be due to increased groundwater extraction through shallow wells as a result of increasing populations (Beck and Bernauer, 2011). Water shortages are being reported now, and this is likely to get worse without management, and will reduce food security (Besada and Werner, 2015). Grasses for construction were frequently reported as decreasing, and these are more likely to be gathered from open access areas, such as seasonal floodplains. Open access areas can be at risk through over-exploitation, due to a lack of regulation and management (Ostrom et al., 1999). It is difficult to determine whether reductions in the provisioning services discussed above are a result of land use change, or increasing populations which lead to more demand; however, they are inextricably linked, and result in the same conclusion - resource use needs to be managed sustainably.

6.5.4 Future consequences of reduced provisioning ES availability

A reduction in the availability of ecosystem services to the local community can have serious implications for local livelihoods, particularly in areas where there are no suitable alternatives. Respondents within Kipembawe demonstrated a high level of awareness of the impact that deforestation is having on the environment, and also of the value of tobacco cultivation to contributing to the development of the area through the income it generates. Respondents made the connection between tobacco cultivation and environmental damage. They also recognised the value that ecosystem services provide to their households. However, when asked about the future of the village only three people connected loss of forest to loss of ecosystem services, and then to future of the villages. These questions were deliberately asked 'out of order' to avoid leading respondents to connect them. This is important because it demonstrates that some people do not recognise the impact that the activities of today will have on the future, and can mean actions to support sustainability or to introduce alternative methods are not taken. An example of this is the tree planting programme initiated by the tobacco companies and the government within Kipembawe to replace trees harvested for tobacco drying. While the implementation of this scheme is not conducive to its full uptake, there is also community disengagement with the project, often because farmers do not really understand why it is necessary (Chapter 9). Therefore increased environmental education and awareness is a key component of any land use management scheme that intends to address sustainability within the landscape. One such technique would be scenario building, where participants are encouraged to envisage different future scenarios (Johnson et al., 2012) based on current and future land use strategies to increase awareness and understanding of natural resource use and availability.

6.5.5 Ecosystem disservices within miombo woodlands

Two main ecosystem disservices were identified in this study, a reduction in crop yield caused by animal and plant pests, and diseases in livestock which result in increased mortality and subsequent losses in meat and dairy yields, as indicated by pastoralist focus groups. They also result in actions and attitudes towards the ecosystem which may have negative consequences for the provision of other ecosystem services.

Crop raiding is the movement of wild animals from their natural habitat onto agricultural land where they consume or damage a crop that was intended for human consumption (Sillero-Zubiri and Switzer, 2001). Large mammals are usually recognised as responsible for crop raiding, although damage caused by insects and rodents is often significant (Naughton-Treves, 1997). Crop raiding results in major proportions of the crop being unsuitable for human use, and consequently a shortage of food stuff and saleable products is experienced by the farmer. In Kipembawe the main animals responsible for crop raiding were baboon and bushpig. Crop raiding can result in farmers laying traps and snares for animals, or poison (as recorded in this study). Additionally, farmers may develop a negative attitude towards wild animals, and this has consequences for the success of any reserved areas or conservation strategies (Treves et al., 2006). It is therefore important to take this into account when developing land use management strategies, and to attempt to avoid human wildlife conflict through planning the location of reserves and agricultural areas (Redpath et al., 2013).

Diseases in livestock can be difficult to control and treat, particularly in areas where there is little or no access to veterinary treatment or vaccinations, such as in the Kipembawe Division. The tsetse fly is a well-known vector for trypanosomosis, and it is associated with woodland. Many livestock keepers in sub-Saharan Africa clear woodland to reduce the number of tsetse flies, in the belief that it will reduce infection rates (Mweempwa et al., 2015). This has led to widespread forest clearance, particularly in the north of Tanzania. However, it has been shown that in highly degraded areas where woodland has been cleared, the infection rate actually increases (Mweempwa et al., 2015). This is an example of an ecosystem disservice that is leading to environmental damage which could be avoided through education, and better funding and implementation of other strategies to reduce tsetse fly numbers.

6.6 Conclusion

Within this remote area of Tanzania, where access to alternative products is limited, households depend upon the woodland for ecosystem services, regardless of their economic status. At least 17 ecosystem services were used by local communities, and over 80% of those surveyed used firewood, building poles, rope, and grasses. Few goods and services are harvested from the forest for further sale. Decreases in firewood and fresh water availability may lead to reduced food security, and water availability is already showing substantial decreases. Future reductions in the availability of ecosystem services will be damaging for the sustainability of livelihoods within this region. A wide range of ecosystem disservices are experienced by both pastoralists and agriculturalists, which could result in unwillingness to participate in land management strategies that incorporate woodland protection. Measures to reduce tsetse fly numbers directly contribute to woodland degradation. There appears to be a lack of understanding about how current resource use will impact the future of this landscape, and land management strategies should incorporate education and scenario workshops to increase understanding and co-operation for sustainable land use practices.

Chapter 7

Miombo woodland under threat: Consequences for tree diversity and carbon storage[3]

Chapter summary

This chapter contributes to Objective 4 by identifying and assessing the response of tree communities to changing levels of human utilisation within the miombo woodland. This chapter examines the effects of the types of utilisation described in Chapters 5 and 6 on tree species richness, diversity, and abundance. It examines the consequences for a further ecosystem service – carbon storage – and identifies threats to specific species. Chapter 8 continues this theme through a similar study of the responses of butterfly communities to woodland utilisation.

7.1 Abstract

Agriculture is expanding rapidly in the miombo woodlands of sub-Saharan Africa. Clear felling results in the loss of species and ecosystem services. The remaining woodland is used as a vital support system for the farming communities, and the impact of this utilisation on biodiversity and ecosystem service provision is not clear. Understanding these effects will aid the development of effective, sustainable land management strategies for multiple outcomes, including biodiversity conservation and resource utilisation. This study provides new data on miombo woodland tree species diversity, structure and carbon storage from an 8,766km^2 landscape in south-western Tanzania, which is undergoing rapid conversion to tobacco cultivation.

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[3] A version of this chapter has been published in *Forest Ecology and Management* **261**:144-153 (2016). The article and the supplementary material can be accessed here.

Human utilisation of the woodland was classified by ground surveys which recorded evidence of use (e.g. cut poles and timber, removal of bark and roots, access routes). Nine sites were surveyed and categorised into three groups: high, medium and low utilisation. To determine the effect of utilisation on the tree community stem density, diameter at breast height, tree species richness and carbon storage were recorded. In the low utilisation sites carbon storage was similar to that found in other miombo woodlands (28 t Ha^{-1}), and the Shannon Wiener diversity score for tree species diversity was 3.44. However, in the high utilisation sites, tree species diversity (2.86) and carbon storage declined (14.6 t Ha^{-1}). In areas of moderate utilisation diversity and carbon storage were maintained, but the structure of the woodland was affected, with a reduction of Class 1 (Diameter at Breast Height (DBH) <10cm) stems, demonstrating low recruitment which leads to a reduction in sustainability. Tree species richness and abundance demonstrated an intermediate disturbance effect in relation to utilisation, with highest levels at medium utilisation sites.

Key miombo woodland species from the subfamily Caesalpinioideae in the two genera *Brachystegia and Julbernardia* were present in all sites, but the frequency of *Brachystegia* species declined by 60% from low to high utilisation. The IUCN near-threatened timber species *Pterocarpus angolensis,* highly protected in Tanzania, was harvested throughout the study site, and the majority of trees recorded were immature (DBH≤20cm), suggesting that it is commercially extinct for the foreseeable future.

These findings illustrate that in miombo woodlands with low to medium utilisation levels key miombo species are retained, and tree species diversity and carbon storage remains optimal. Sustainable land management plans need to regulate utilisation within miombo landscapes and retain areas of woodland. This will ensure their long term viability, and continue to support the 100 million people who are reliant on miombo woodlands for their goods and services.

7.2 Introduction

The miombo ecoregion covers approximately 3.6 million km^2 in 10 countries of central and southern Africa (Byers, 2001), and has been identified as one of five global wilderness areas that should be prioritised for conservation (Mittermeier et al., 2003). This is due to its large area, high levels of endemicity, and importance as habitat for several threatened species (Conservation International, 2012). One such species is the IUCN near-threatened timber species

Pterocarpus angolensis (World Conservation Monitoring Centre, 1998b). This slow growing tree (Stahle et al., 1999) has very low recruitment levels (Boaler, 1966b) but is heavily sought after for export and domestic use (Caro et al., 2005). Within this ecoregion, miombo woodlands are the most extensive tropical woodlands in Africa, covering 2.4 - 2.7 million km^2 (Dewees et al., 2010, Frost, 1996, Kutsch et al., 2011). Miombo woodland is characterised by tree species from three genera in the legume subfamily Caesalpinioideae; *Brachystegia*, *Julbernardia* and *Isoberlinia*, although their dominance varies throughout the ecosystem based on rainfall and soil type (Banda et al., 2006). Over 100 million people are directly or indirectly dependent upon miombo woodland for their daily needs (Syampungani et al., 2009). With the population of sub-Saharan Africa expected to double by 2050 (Eastwood and Lipton, 2011) pressure upon miombo woodland is increasing (Cabral et al., 2011, Dewees et al., 2010). Miombo woodlands are therefore receiving increasing attention as areas where sustainable land management is required (Williams et al., 2008), and have also been highlighted for Reducing Emissions from Deforestation and Degradation (REDD+) projects (Bond et al., 2010, Munishi et al., 2010).

The majority of studies in miombo systems describe species composition and structure within protected areas, yet most miombo woodlands lie outside of protected areas (Timberlake and Chidumayo, 2011), and are affected by human disturbance (Dewees et al., 2011). Most published studies are conducted in areas of dry miombo woodland, and almost none assess miombo in areas where cultivation is currently occurring. Only a few studies are in areas that receive over 900mm of rainfall a year (Boaler, 1966a, Munishi et al., 2011), and only one has been completed in a high rainfall setting (1200mm/year (Kalaba et al., 2013b)). These are areas where diversity is likely to be higher, with fertile soils providing more attractive arable land which is more profitable to develop, and thus more threatened.

Miombo woodlands demonstrate a remarkable capacity to recover after disturbance, due to tree regeneration from the roots and stumps (Shirima et al., 2015a), and they have been shown to do this after agriculture, charcoal production and selective logging (Chidumayo, 2002, Chinuwo et al., 2010, Kalaba et al., 2013b, Williams et al., 2008, Schwartz and Caro, 2003). However, it is unlikely that in the future cultivated areas will be left to regenerate for the 20-30 years required to return them to a mature woodland structure (Kalaba et al., 2013) and recover carbon stocks (Williams et al., 2008). Much of the threat to miombo woodland comes from smallholder clear-felling for agriculture (Abdallah and Monela, 2007) and wood extraction for energy (Cabral et al., 2011). Clearance of woodland for agriculture can be detected through remote sensing images (Sedano et al., 2005) and the associated losses in tree species richness, diversity and carbon storage are clear. Disturbance caused by the selective removal of woodland products for subsistence and livelihood purposes are not as easy to detect, and their impacts are more challenging to determine. Throughout this chapter the term 'utilisation' is used to describe human utilisation of the woodland. Such types of utilisation include the collection of both dead and live wood for cooking (Abbot and Homewood, 1999), the removal of trees for construction, sale, and charcoal production (Kutsch et al., 2011), and the collection of Non-Timber Forest Products (NTFP) for medicines, food and livestock fodder (Dewees et al., 2010). This type of utilisation usually occurs in easily acessible areas, such as around field margins and alongside paths and tracks. Within western Tanzania there is also an additional demand for fuelwood to cure tobacco (Sauer and Abdallah, 2007, Waluye, 1994). The impacts of utilisation on miombo woodlands have received limited attention (see for example Chidumayo, 2002, Banda et al., 2006), as have the effects of selective logging for commercial timber (e.g. Schwartz and Caro, 2003, Schwartz et al., 2002), and require further study.

This study aims to address these knowledge gaps by using a case study site in south-western Tanzania to investigate the impact of differing intensities of woodland utilisation on tree species richness, abundance, diversity, and carbon storage. In this case-study site the miombo woodland is open access with few restrictions on its use; agricultural activities are ongoing; and there are higher levels of rainfall than in many previous studies. This is an area that is in need of effective land management as there is pressure to convert the woodland to tobacco cultivation (Maegga, 2011). It is an appropriate area in which to investigate the effect that utilisation of the woodland has on tree species richness, diversity, composition and structure, and carbon storage, and will enable comparison with previously studied miombo woodland sites. This information can then be used to inform land management strategies and conservation programmes such as those linked to the UN funded REDD+ programme.

7.3 Materials and methods

Site selection is detailed in Chapter 3, section 3.4.9. The Kipembawe Division is described in Chapter 4. Methods to determine land cover type and utilisation intensity are described in Chapter 3, section 3.5.

7.3.1 Vegetation sampling

To measure tree species diversity, composition, structure and carbon storage across the landscape vegetation was surveyed within a 4 ha subplot at each biodiversity site. Sampling took place within 25 m^2 quadrats (from here referred to as plots) (Kati et al., 2004), which were randomly selected using a random number generator in Microsoft Excel, based on xy coordinates. In total 106 plots were sampled, covering a total of 6.63 ha. Within each plot all trees and shrubs with a DBH>5 cm were measured. Stems forking below 1.3 m were measured and recorded separately (Williams et al., 2008, Kalaba et al., 2013b), and where there were deformities or injuries at breast height the stem was measured above or below it, whichever was judged most appropriate (Shirima et al., 2011). Bole and canopy heights were estimated, species were identified and verified using field guides (Dharani, 2011, Smith and Allen, 2004). Where necessary specimens were collected and deposited at the University of Dar es Salaam herbarium for verification by Yahya Abeid, a qualified and experienced Tanzanian botanist.

7.4 Data analysis

7.4.1 Land use and utilisation

Data were analysed according to both land cover and utilisation, and were calculated at plot and site level. To identify land cover type the number of sections on each transect that were covered by each land cover type were calculated as a percentage, and then grouped into four main land cover categories. ‘Agriculture’ represented all land cover that was cultivated. This included areas that had been prepared for cultivation, as well as land that was under crop. The main crops are tobacco and maize, and small amounts of other food crops such as sweet potato and beans are also grown. ‘Regenerating miombo’ encompassed all woodland that was regenerating as a result of disturbance. This is identified by the presence of many stems sprouting from stumps or roots that are all of a similar age. The final two categories are ‘Miombo woodland’, which is evident by the presence of mature trees and ‘Seasonal floodplain’ - areas that are seasonally inundated with water, identified by a lack of mature trees and the presence of grasses.

The type of utilisation within this area includes harvesting poles and timber for construction of houses, tobacco burners and stores; the collection of non-timber forest products such as roots and bark for rope and medicine; the construction of beehives; commercial logging; and collecting timber to cure tobacco.

To determine utilisation levels the numbers of harvested timber and poles were calculated as the percentage of poles and timbers that were cut from all available poles and timbers (dead and alive) and allocated to the category 'CutTrees'. All stumps were summed per vegetation plot, and allocated to the category 'Stumps'. For other types of utilisation the number of each type was summed across the site. The nine sites were then grouped into three utilisation categories (low, medium and high) based on the results for each type of utilisation. Differences between each variable category were calculated using a one-way ANOVA and the post-hoc test Tukey's HSD in R (R Core Team, 2014) (Appendix E, Table E1).

7.4.2 Tree species richness, diversity and composition

Plot data from all sites were pooled. Diversity scores for each plot were calculated using the Shannon Wiener Diversity Index using the 'Diversity' function in the package 'Vegan' in R (Oksanen et al., 2013). Diversity, richness and abundance were plotted according to utilisation category using the first 10 plots for each site to ensure equal sampling effort.

The effects of utilisation on tree species richness, abundance and diversity were statistically modelled using generalised linear models. The predictor data were centred and scaled prior to analysis by calculating the mean and standard deviation of each variable and then scaling each data point through subtracting the mean and then dividing by the standard deviation. The predictor data were allocated as follows: 'Site' as the random effect; 'CutTrees', 'Stumps', 'DistSettle' (Distance from site to settlement), 'AgeAg' (the length of time the area had been cultivated), Non-Timber Forest Products (NTFP) and the quadratic terms of each variable as fixed effects. The models were simplified to minimal adequate models by backwards selection using likelihood-ratio tests, validated and checked for over-dispersal (Zuur et al., 2009). The effect on species richness was calculated using a generalised linear mixed effects model with Poisson error distribution, the effect on abundance was calculated using a negative binominal generalised linear model due to over-dispersal; and the effect on diversity used a linear mixed effects model. All models were calculated in R using the packages 'lme4', 'nlme', 'rcpp' and 'MASS' (Bates et al., 2014, Pinheiro et al., 2014, Venables and Ripley, 2002, Eddelbuettel and Francois, 2011).

Detrended Correspondence Analysis (DCA (Hill and Gauch Jr, 1980)) was performed to detect any relationship between the species composition and the explanatory site-level land use variables, also using the R package 'Vegan', function 'decorana',with a down-weighing of rare species. Prior to this, the interrelationships between all variables were tested for correlation using the Pearson's correlation test. Only variables that were not highly correlated were used ($r<0.7$) (Loos et al., 2014a). A permutation test was used to fit and test the correlation of the land use variables with the ordination.

The species composition was examined in greater detail using the Importance Value Index (IVI). The IVI describes the floristic structure and composition of the woodland, and has been used frequently in miombo systems (e.g. Kalaba et al., 2013b, Giliba et al., 2011, Munishi et al., 2011, Mwakalukwa et al., 2014). It demonstrates how often a species occurs at a site, the size of the trees and how abundant they are. It is calculated for each species using the equation:

IVI = (Relative frequency + relative basal area + relative density)/3

(Curtis and McIntosh, 1951)

The IVI was calculated for each utilisation level category. The value that is produced is a score, which is then ranked against the other species within that category - i.e. a rank of 1 demonstrates that the species is the most dominant within that category. The highest 10 ranking species for each utilisation level were identified. Protected species were identified and examined to determine any trends and patterns in their distribution and sizes.

7.4.3 Woodland stand structure and carbon storage

Site-level stand structure was determined based on the size classes of the trees. All trees were classified according to their DBH, into six classes (1) DBH<10cm; (2) DBH 11-20cm; (3) DBH 21-30cm; (4) DBH 31-40cm; (5) DBH 41-50cm; (6) DBH 50+cm (Mwakalukwa et al., 2014). The abundance of trees in each class was used to record the age and structure of the woodland.

Stem biomass was calculated using four allometric equations from similar ecosystems with DBH and height data (Table 7.1); using multiple approaches to estimate biomass allows realistic uncertainties to be generated (Williams et al., 2008). The mean of these equations was then used to produce a final estimate of biomass (Williams et al., 2008, Shirima et al., 2011, Kalaba et al., 2013b). Wood biomass was assumed to be composed of 50% carbon (IPCC/OECD/IEA, 1997). Data from each plot were then summed to utilisation level and mean and standard error calculated per hectare.

Table 7.1: Allometric equations used to estimate biomass

Author	Equation	Source country	Total above-ground biomass
(Brown et al., 1989)	B=34.4703 – 8.0671(D) + 0.6589(D2)	Dry tropical, not miombo specific	For all trees
(Malimbwi et al., 1994)	B=0.06*D^2.012*H^0.71	Dry miombo, Tanzania	For trees ≥ 5cm DBH
(Chidumayo, 1997)	B=3.02D-7.48 B=20.02D-203.37	Wet miombo, Zambia	For trees ≤ 10cm DBH For trees ≥ 11cm DBH
(Chamshama et al., 2004)	B=0.0625 x D2.553	Tanzania	For trees ≥ 5cm DBH

B = Biomass (Kg); D = Diameter at breast height (cm); H = crown height (m)

Differences between carbon storage at each utilisation level were calculated with plot-level data using a one-way ANOVA and the post-hoc test Tukey's HSD in R (R Core Team, 2014). Subsequently these data were introduced to a linear mixed effects model with the fixed effects 'CutTrees', 'Stumps', 'AgeAg' and 'DistSettle', with random effect 'Site'. These fixed effects allowed for a temporal effect on stand structure. All response variables were centred, scaled and run using the 'Maximum Likelihood' estimation in the 'nlme' package in R (Pinheiro et al., 2014), then selected using backward selection.

7.5 Results

7.5.1 Species richness, diversity and composition

Across the nine sites 3,252 stems were recorded, representing 122 species from 86 genera in 46 families (Table E3). The dominant family was Fabaceae, the legume family, with 21 species. Fabaceae contains the subfamily Caesalpinioideae, which is dominant within miombo systems. From this sub-family the genus *Brachystegia* was represented by six species. Only the five species *Brachystegia boehmii, Julbernardia globiflora, Lannea schimperi, Pseudolachnostylis maprouneifolia* and *Pterocarpus angolensis* were present at all nine sites. Within the high utilisation sites (which included the highest amounts of regenerating miombo) species from the defining miombo genera (*Julbernardia*, *Brachystegia* and *Isoberlina*) were either absent or present in low densities. The presence of *Brachystegia* species declined by 60% from low to high utilisation levels.

Species richness and abundance were not significantly different across the three utilisation levels (Figure 7.1) (richness: ANOVA: df=2, F=0.854, P=0.431; abundance: ANOVA: df=2, F=1.109, P=0.336). Species diversity showed a significant difference between high and low utilisation levels (ANOVA: df=2, F=4.094, P=0.0214, Tukey's HSD: P= 0.0162 (Table E2)), but note that the variances may be different between the two categories.

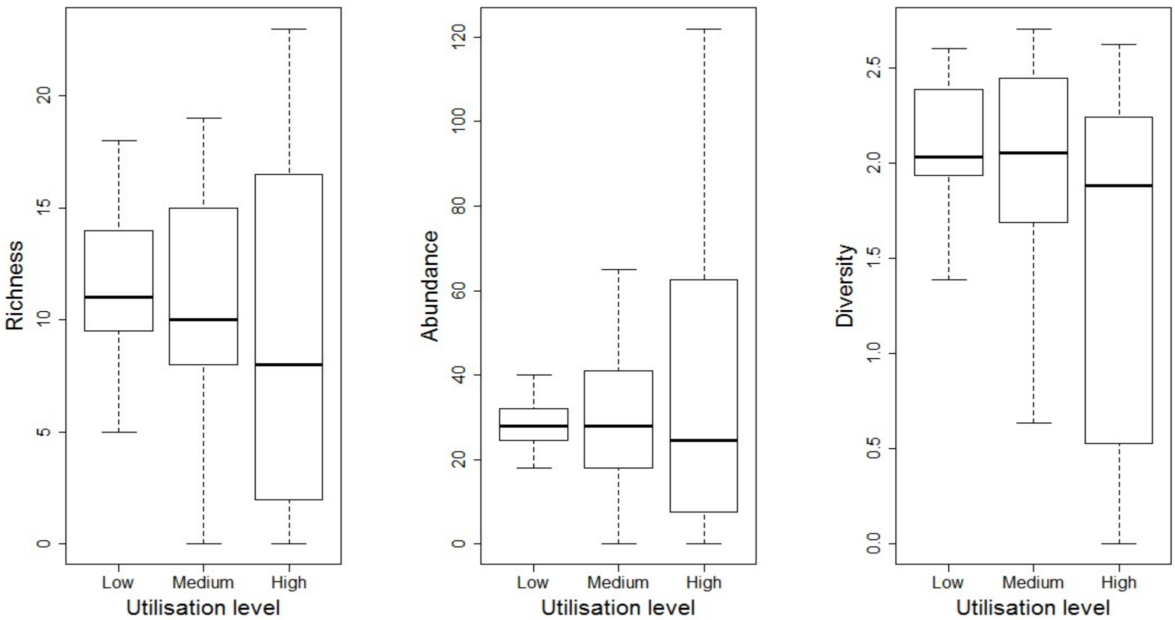

Figure 7.1: Tree species richness, abundance and diversity at different utilisation levels

There was a significant relationship between the number of stumps and all three metrics. The relationship with diversity was linear, but the relationships with abundance and richness were significantly non-linear and were modelled with quadratic regressions (Table 7.2). These humped relationships (Figure 7.2) are perhaps best described as "an intermediate disturbance effect" (Connell, 1978) – moderate levels of utilisation can be associated with increased richness and abundance as it allows recruitment of new species, but higher levels of utilisation result in decreased richness and abundance. Tree species richness also demonstrated a significant linear relationship with the length of time the area had been cultivated (AgeAg) and a quadratic relationship with the numbers of cut poles and timbers (CutTrees) (Table 7.2). All other utilisation variables were not significantly associated with the three metrics.

Table 7.2: Relationships between species abundance (negative binominal generalised linear model); species richness (generalised linear mixed effects model); and species diversity (linear mixed effects model) and agricultural utilisation and timber use (assessed by density of stumps) with significance levels indicated by: *P<0.05; **P<0.01; ***P<0.001.

Response variable model	**Predictor variable**		**estimate**	**SE**	**Z**	**Pr>|z|)**
Abundance Negative binominal glm	Intercept		3.38156	0.07555	44.761	<2e-16***
	Stumps		-0.12274	0.10814	-1.135	0.256
	Quadratic term of stumps		-0.15815	0.05548	-2.850	0.004**
Richness glmer			estimate	SE	Z	Pr>|z|)
	Intercept		2.61473	0.08484	30.819	<2e-16***
	CutTrees		0.10968	0.4301	2.550	0.011*
	Quadratic term of CutTrees		-0.22299	0.06806	-3.277	0.001**
	Stumps		-0.07637	0.07477	-1.021	0.307
	Quadratic term of stumps		-0.14087	0.04248	-3.316	<0.001***
	AgeAg		-0.12599	0.05575	-2.260	0.024*
Diversity lme		Value	SE	DF	t-value	p-value
	Intercept	1.8598682	0.08398535	90	22.145151	0***
	Stumps	-0.3529426	0.05604944	90	-6.296987	0***

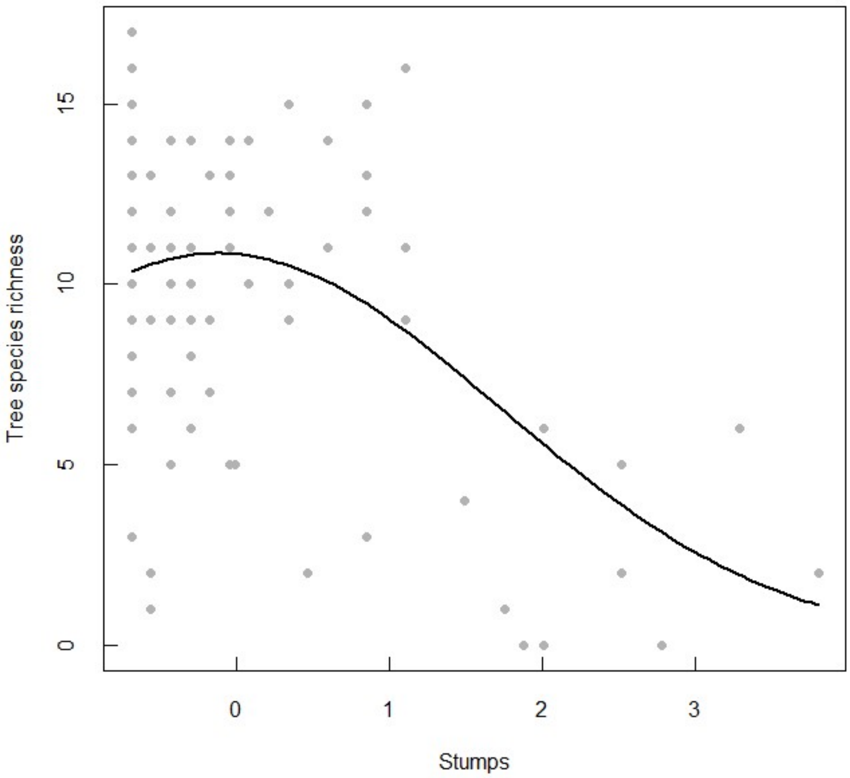

Figure 7.2: The quadratic relationship between tree species richness and stumps (glmer, -0.14087, SE = 0.042, P<0.001). Stumps data are centred and scaled (see methods for details). This demonstrates an intermediate disturbance effect where richness initially increases with the number of stumps before decreasing.

Changes in land use and utilisation do influence species composition. The variables that have a significant effect on species composition are distance from settlement, regenerating miombo, the collection of NTFP and harvesting of poles and timbers (Figure 7.3). This shows that as the distance from settlements increases and miombo regenerates there is a positive effect on species composition, whereas the collection of NTFPs, poles and timbers has a negative effect. Disturbance also influenced the species composition of the woodland. The first axis on the DCA estimates that 43% of the changes in species composition are associated with a gradient from extractive utilisation (cutting timber and poles, and extracting NTFPs and honey) to regenerating miombo. The second axis demonstrates that a further 25% of changes in species composition is associated with the distance to settlements.

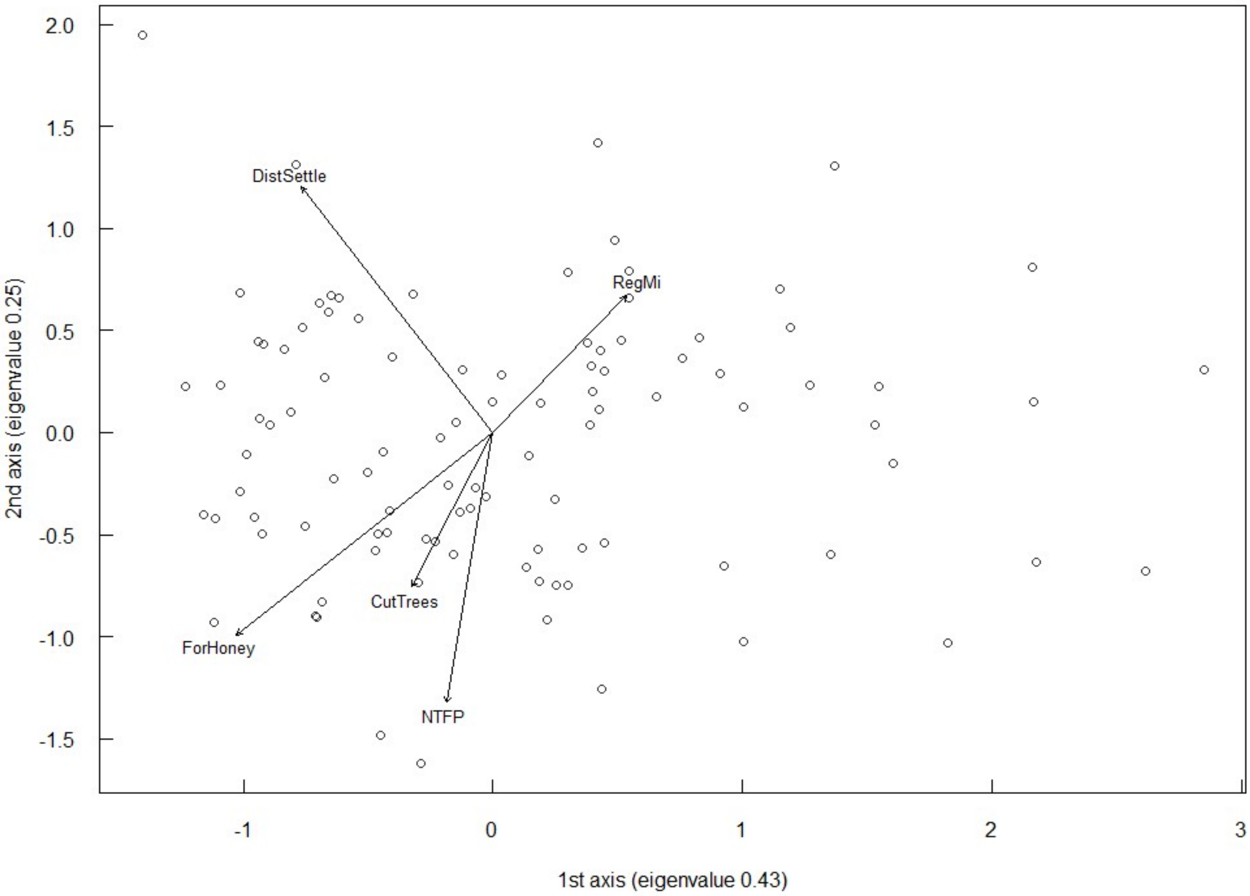

Figure 7.3: DCA of tree species community. Variables which had a significant association (p<0.05) with community composition are represented by arrows: 'DistSettle' – distance from settlement; 'RegMi' – regenerating miombo woodland; 'ForHoney' – extraction of resources for the purpose of collecting honey; 'NTFP' – collection of Non-Timber Forest Products; 'CutTrees' – harvest of timbers and poles.

A change in species composition in response to utilisation is further evidenced by the changes in species dominance according to the Importance Value Index (IVI). In lightly to moderately utilised areas, the key miombo species from the genera *Julbernardia*, *Brachystegia and Isoberlina* were dominant. However, in sites of high utilisation they were replaced by other species. Table 7.3 illustrates the reducing dominance of *Brachystegia* species and *Pterocarpus* *angolensis* with increasing utilisation, which are both absent from the top 10 highest ranking species in the high utilisation site. Typical medium utilisation vegetation is illustrated in Figure 7.4. There is also a reduction in species that are utilised for medicines, alternative food sources, and fibres, such as *Lannea schimperi*, *Uapaca kirkiana* and *Oldfieldia dactylophylla* (Smith and Allen, 2004).

Figure 7.4: Miombo woodland at a medium utilisation site (source: E Jew, 2013)

Table 7.3: Important Value Index

		Utilisation level	
IVI Rank	**Low**	**Medium**	**High**
1	*Brachystegia boehmii*	*Julbernardia globiflora*	*Combretum zeyheri*
2	*Julbernardia globiflora*	*Brachystegia spiciformis*	*Pseudolachnostylis maprouneifolia*
3	*Pseudolachnostylis maprouneifolia*	*Pseudolachnostylis maprouneifolia*	*Isoberlinia angolensis*
4	*Lannea schimperi*	*Brachystegia boehmii*	*Julbernardia globiflora*
5	*Brachystegia spiciformis*	*Burkea africana*	*Pericopsis angolensis*
6	*Pericopsis angolensis*	*Pterocarpus angolensis*	*Clerodendrum sp.*
7	*Parinari curatellifolia*	*Diplorhynchus condylocarpon*	*Terminalia sericea*
8	*Uapaca kirkiana*	*Pericopsis angolensis*	*Diplorhynchus condylocarpon*
9	*Pterocarpus angolensis*	*Lannea schimperi*	*Piliostigma thonningii*
10	*Oldfieldia dactylophylla*	*Anisophyllea boehmii*	*Mangifera indica*

7.5.2 Vegetation structure

Woodland stand structure varied in relation to the utilisation of the sites, with the woodland classified as low utilisation demonstrating a typical reverse J-shaped curve (Hörnberg et al., 1995), with the highest numbers of stems in Class 1. The numbers of stems in Class 1 in the high utilisation sites are due to regenerating trees of a similar age (5-10 years). There are relatively few class 1 stems in the medium utilisation sites. There are also no stems in classes 5 and 6 in the high utilisation sites (Figure 7.5).

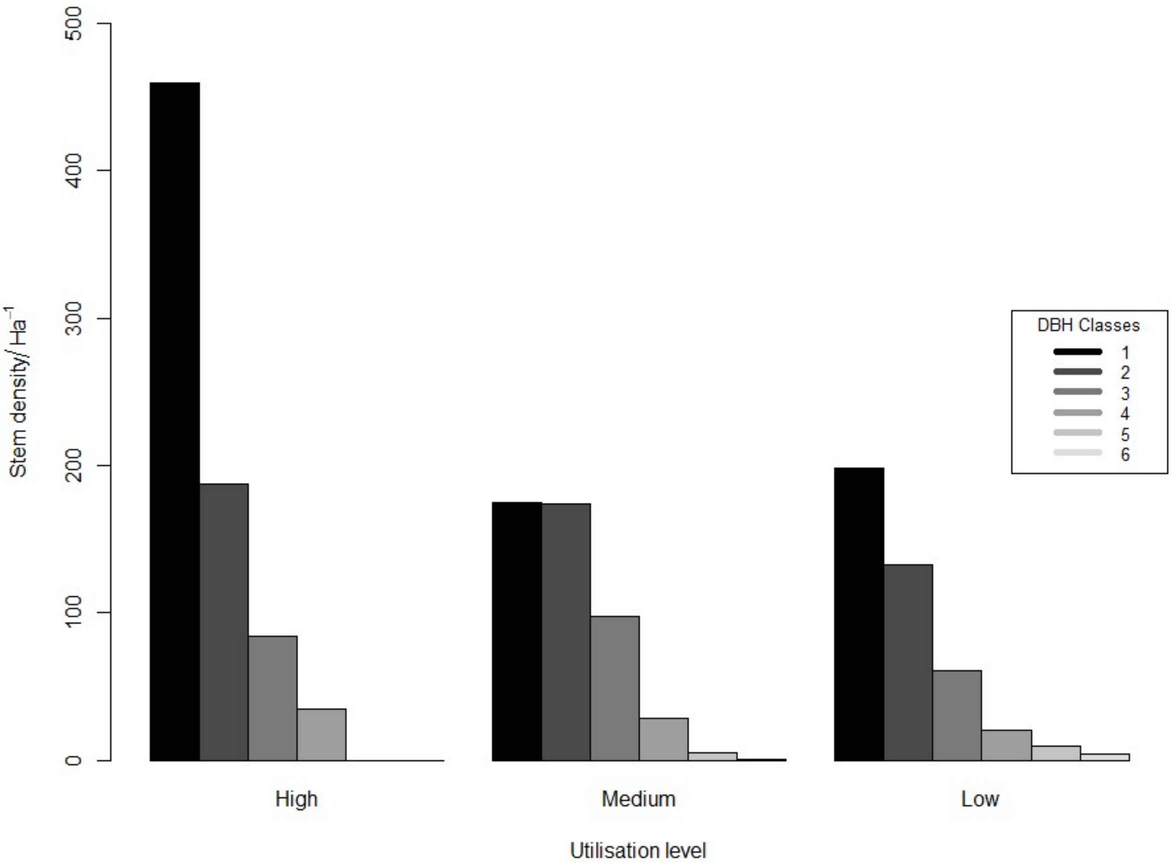

Figure 7.5: Stand structure according to DBH classes at sites representing different utilisation levels. Class 1) DBH<10cm; 2) DBH 11-20cm; 3) DBH 21-30cm; 4) DBH 31-40cm; 5) DBH 41-50cm; 6) DBH 50+cm.

7.5.3 Carbon storage

At high utilisation sites average carbon storage was 14.6 (±0.94) t Ha^{-1}; at medium utilisation sites 33.1 (±3.46) t Ha^{-1}; and at low utilisation 28.5 (±2.46) t Ha^{-1}. There were significant differences in carbon storage between high utilisation sites and low utilisation sites (ANOVA, df=2, F=12.38, P<0.0001, Tukey's HSD: P=0.004), and between high and medium utilisation sites (Tukey's HSD: P<0.0001), but not between low and medium sites (Tukey's HSD: P=0.13). The linear mixed model demonstrated that as the number of stumps (cut stumps of trees DBH > 15cm) increased, the amount of carbon stored decreased (lme, F=14.15, P<0.0001), which is expected, and is consistent with the results for carbon storage at utilisation level.

7.6 Discussion

Miombo woodlands are affected by both deforestation through the clearance for agriculture and degradation through the utilisation of woodland products. Agriculture provides both income and food for local people, and the utilisation of woodland products is equally vital to their livelihoods, as their use can prevent households falling into poverty by providing alternative food sources, medicines and fuelwood (Campbell et al., 2007). This paper discusses the impact that this use has on the tree community, and provides insights that can be used to inform the future management of miombo in Africa.

7.6.1 Species richness, diversity and composition

There were 122 species recorded across the study area. Shannon Weiner diversity scores ranged from 2.86-3.44. These are similar to scores found in Zambia by Kalaba et al. (2013b) (2.8, average rainfall 1200mm/yr), but much higher than those of Shirima et al. (2011) (1.05-1.25, average rainfall 720mm/yr) in the Udzungwa Mountains in Tanzania. Differences in richness and diversity throughout miombo habitats are likely to be due to differing rainfall regimes, because many of the differences in woodland composition are dependent upon the amount of rainfall that is received, leading to the 'dry' (<1000mm/yr) and 'wet' (>1000mm/yr) miombo classifications (Frost et al., 2003). Tree species richness, diversity and abundance all declined with increasing disturbance in the study landscape. However, in areas of moderate utilisation these values were retained, and species richness and abundance initially increased with disturbance. Similar responses to disturbance such as selective and reduced impact logging have been observed elsewhere (Imai et al., 2012, Putz et al., 2012), and indicate that management strategies can accommodate low to moderate levels of utilisation whilst maintaining tree species richness, diversity and abundance.

Regional changes in miombo woodland species composition are well documented, and can be due to various environmental factors such as altitude, rainfall, soils and underlying geology (Banda et al., 2006, Giliba et al., 2011). However, the landscape changes reported here, when geology, soil type and altitude are relatively uniform, are more likely to be due to land use changes. Replacement of *Brachystegia* in particular may be due to the genera being preferred for drying tobacco and it is therefore overharvested in highly utilised areas. Additionally, *Brachystegia spiciformis* was absent in regenerating areas; probably because previously farmed areas have usually been burned frequently, and this species is fire-sensitive (Cauldwell and Zieger, 2000). The loss of defining miombo species such as this from regenerating areas has been found elsewhere (Williams et al., 2008). In high utilisation sites *Combretum zeyheri* became dominant. *Combretum spp.* are fast growing, and dominate in early stage succession (Backéus et al., 2006). This is likely to occur in these high utilisation areas, when short fallow periods occur, and typical miombo species are unable to become established.

There were two species of vulnerable trees in the study site, *Pterocarpus angolensis*, listed as near-threatened on the IUCN Redlist of Threatened Species (World Conservation Monitoring Centre, 1998b), and *Prunus africana,* listed as vulnerable (World Conservation Monitoring Centre, 1998a). *P. africana* was recorded once at a low utilisation site, demonstrating that it is rare within this area. It is an evergreen tree which usually occurs in riparian woodlands (Dharani, 2011), and the rarity of this habitat type within this area of miombo woodland may explain its low abundance here. *P. angolensis* was recorded at all sites, with the highest abundance in moderate utilisation sites, most likely due to the identified intermediate disturbance effect. Due to this species' threatened status, the Tanzanian Government stipulates that only trees over 60 DBH may be harvested (Caro et al., 2005). The average time for *P. angolensis* to reach a DBH of 35cm is 88-137 years when rainfall is 600-700mm/year, although this can vary considerably, particularly with higher rainfall (Stahle et al., 1999). At this DBH trees are able to produce a larger number of seedlings to enable a greater change of regenerative success, although only 2% of fruits produced germinate in the field (Boaler, 1966b) demonstrating its very low recruitment rate. This was evident within this study site, where only five *P. angolensis* seedlings were detected within the regeneration quadrats. Of the 88 individual *P. angolensis* that were observed in this study there were no trees over 60cm DBH, and only two were over 35cm DBH, with the majority (71) being in the lowest two DBH classes (DBH≤20cm). It was noted that *P. angolensis* was harvested, regardless of the size of the tree. However, in areas where trees have been selectively logged there has been no reported increase in the recruitment of trees, where compensatory recruitment would be expected to occur due to the increase in light (Schwartz and Caro, 2003). The long-term viability of this species within this area is in doubt, as it is in other areas (Caro et al., 2005, Schwartz et al., 2002, Stahle et al., 1999).

7.6.2 Vegetation structure

The reverse J-shaped curve of woodland structure is an indicator of a steady and expanding population, which has more trees in the smaller classes (Peters, 1994), indicating continuous recruitment in a sustainable system (Hörnberg et al., 1995). Other studies in miombo woodland in protected areas demonstrate this structure (Giliba et al., 2011, Mwakalukwa et al., 2014, Shirima et al., 2011), as do the sites within this study with low utilisation. However, harvesting of trees significantly affects the structure of the woodland (Luoga et al., 2004). In the moderately disturbed sites there are low numbers of trees in Class 1 due to overharvesting of this class, which suggests that utilisation is not sustainable. In the high utilisation sites, there are an unusually high number of trees in Class 1; this is due to the stems regenerating at the same time, approximately 10-15 years ago. The lack of large trees in these sites also indicates that they are overharvested. Sustainable management of these areas would require restricting utilisation of younger trees.

7.6.3 Carbon storage

Although miombo woodlands store up to 10 times less carbon per hectare than tropical forests, they cover a much greater area and are therefore an important carbon store (Munishi and Shear, 2004, Shirima et al., 2011, Shirima et al., 2015b). Carbon storage in this study is similar to that in other studies, demonstrating that miombo generally holds similar carbon stocks, regardless of the rainfall regime (Shirima et al., 2011, Williams et al., 2008). Increasing utilisation resulted in the decline of carbon stored across the study area. However, in areas of moderate utilisation carbon storage was similar to that in low utilisation areas, suggesting that in areas where utilisation is managed carbon stocks will be retained.

7.7 Conclusion

Miombo woodland in sub-Saharan Africa will continue to be converted to agriculture and utilised for the needs of local people. If left without regulation and landscape management planning, it is likely that such utilisation will not be sustainable, with the loss of biodiversity and ecosystem services provision. Therefore it is vital that sustainable land use management plans are developed that incorporate biological concerns and also take into consideration the needs of the local communities. This research has demonstrated that areas of high utilisation, which have little remaining mature miombo and large areas converted into agriculture, result in decreases in species richness, abundance and diversity, carbon storage, and a loss of large trees and key miombo species. In these areas fallow periods are not long enough to return to a woodland habitat similar to miombo, and instead a shift to a more fire-resistant shrubland thicket may occur (Stromgaard, 1986). It is also apparent that in areas where mature woodland is maintained within a mosaic of agriculture, and utilisation levels are moderate, these metrics are maintained at similar levels to low utilisation sites. However, over-exploitation at a moderate level of utilisation can severely damage the stand structure of the woodland, and therefore careful monitoring of the woodland is required.

Land management options should aim to create a mosaic of woodland and agriculture, and avoid total clearance. A comprehensive monitoring programme is necessary to monitor the levels of utilisation and impacts on the woodland. Enforcement of current restrictions of harvesting is required, as demonstrated by the overharvesting of *P. angolensis*. However, the practical application of such management strategies remains challenging given the lack of capacity in forest governance. To achieve more sustainable woodland management strengthening of capacity in forest and natural resource governance is required to enable the regulation of utilisation and maintenance of mature woodland; this will ensure the long term viability of miombo woodlands, and their continued support of local and wider communities.

Chapter 8

Butterfly communities in miombo woodland: biodiversity declines with increasing woodland utilisation[1]

Chapter summary

This chapter contributes to Objective 4 by identifying and assessing the response of butterfly communities to changing levels of human utilisation within the miombo woodland. Additionally it identifies extinction risk for specific species, and detects species that may indicate different levels of utilisation. Now that the impacts of land use change have been identified Chapter 9 goes on to evaluate current land use and environmental programmes to assess the local capacity for future land management strategies.

8.1 Abstract

Deforestation and degradation is threatening forests and woodlands globally. The deciduous miombo woodlands of sub-Saharan Africa are no exception, yet little is known about the flora and fauna they contain and the implications of their loss. Butterflies are recognised as indicators of environmental change; however the responses of butterflies in miombo woodlands have received little attention. This paper describes butterfly assemblages and their response to woodland utilisation in an understudied area of miombo woodland in south-west Tanzania. This is an area representative of miombo woodlands throughout sub-Saharan Africa, where woodland is utilised by local communities for a range of products, and is being rapidly converted to agriculture. Baited canopy traps and sweep nets were used to sample frugivorous and nectarivorous butterfly communities at different vertical stratifications in nine different study

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[1] A version of this chapter has been published in *Biological Conservation* **192**: 436-444 (2015). The article and the supplementary material can be accessed here.

sites. 104 species were recorded, of which 16 are miombo specialists that have been recorded in Tanzania to the west of the country only. Indicator species were identified for three different levels of utilisation, with species from the sub-family Satyrinae indicating moderate utilisation. Generalised linear mixed effects models showed that butterfly species richness, diversity and abundance all decreased in response to increasing agriculture and anthropogenic utilisation. The loss of miombo woodlands is likely to result in declines in butterfly diversity. However, there was evidence of an intermediate disturbance effect for butterfly species richness, diversity and abundance with one utilisation variable, suggesting that a miombo woodland management plan that allows moderate sustainable utilisation in a heterogeneous landscape of mature miombo woodland and agriculture will simultaneously maintain butterfly communities and enable agricultural production.

8.2 Introduction

The expansion of agricultural land is recognised as a major driver of global deforestation (Kissinger et al., 2012) resulting in the loss of global and local biodiversity (Green et al., 2005). In order to reduce the negative impacts of this land-use change it is necessary to identify suitable areas for agriculture, and to understand the dynamics of biodiversity within these areas (Scherr and McNeely, 2008). This knowledge can then be incorporated into land management plans that are developed in collaboration with relevant stakeholders (Sayer et al., 2013) to achieve both agricultural productivity and biodiversity conservation and hence support the sustainability of a developing social-ecological system (Berkes et al., 2003).

Very few areas have been identified that are suitable for some form of cultivation, are not under formal protection and have low human population densities (Lambin and Meyfroidt, 2011). Those that have are within the dryland forest belt, including the Cerrado and grasslands of Latin America, and the savannahs and miombo-mopane woodlands of sub-Saharan Africa (Lambin and Meyfroidt, 2011, Laurance et al., 2014). However, the miombo-mopane woodland ecoregion is also one of only five global high biodiversity wilderness areas highlighted for conservation priority (Mittermeier et al., 2003) as a ‘proactive’ conservation strategy (Brooks et al., 2006). This is because the potential for biodiversity loss is high if large areas of woodland are converted to agriculture, and as such this area has been recognised as an area of high conflict between conservation and agriculture (Shackelford et al., 2015).

Better understanding of the vulnerability of miombo systems is essential to support the design and implementation of conservation and land management strategies. Miombo woodlands form part of the miombo-mopane ecoregion, and cover approximately 2.4 million km^2 of sub-Saharan Africa (Dewees et al., 2011). Virtually no areas of miombo woodland remain uninfluenced by human impacts (Dewees et al., 2011). They are vitally important, supporting over 100 million people for ecosystem services, including fuel, food and medicines (Syampungani et al., 2009). Additionally they provide crucial habitat for threatened species, and contain high levels of plant endemicity (Mittermeier et al., 2003). However, miombo woodlands have received little conservation and research attention to date, particularly regarding the response of biodiversity to land-use change, such as conversion to agriculture, and to disturbance caused by human utilisation of remaining woodland.

Butterflies are known to react sensitively to environmental changes (Uehara-Prado et al., 2007). Butterfly species richness has been shown to decrease along a gradient from woodland to agriculture in mixed woodland in Zimbabwe (Tambara et al., 2013) and agroforestry systems in Uganda (Munyuli, 2012). Additionally butterflies have been shown to respond to anthropogenic disturbance, both in tropical (Ghazoul, 2002, Hamer et al., 2003) and temperate areas (Kocher and Williams, 2000). However, there are few published studies of the impact of anthropogenic disturbance on butterflies across sub-Saharan Africa (Munyuli, 2012) and none in miombo woodland.

Butterflies are the best known major group of arthropods in Africa (Larsen, 1995) and the butterfly fauna of East Africa is relatively well studied (Kielland, 1990, Larsen, 1991). Despite this there is little consensus as to which methods are most appropriate for sampling tropical butterflies (Dumbrell and Hill, 2005). Many surveys that use butterflies as indicators focus on fruit-feeding butterflies using bait traps (e.g. Lewis, 2001, Hamer et al., 2003, DeVries et al., 2012), and occasionally supplement with other methods, such as transect walks, observation platforms and sweep-netting. Vertical stratification of fruit-feeding butterflies occurs in tropical forests, and this may be affected by disturbance, a factor often taken into consideration in sampling design (Fermon et al., 2005). Such focus on fruit-feeding butterflies ignores nectar-feeding species, and has contributed to a lack of knowledge surrounding tropical butterflies (Bonebrake et al., 2010). Hence, the response of nectar-feeding insects to environmental changes is not clear.

The paucity of knowledge about the biodiversity in miombo systems, coupled with a lack of understanding of how this biodiversity responds to land-use change and human utilisation, severely hampers the production and implementation of land management plans. This paper aims to reduce these gaps by presenting original data on butterfly communities along a gradient of land-cover change and utilisation intensity from extensive miombo woodlands in the Kipembawe Division, a remote area of south-west Tanzania. It assesses the response of butterfly communities to the changes occurring within the woodlands, identifies potential indicator species, and discusses how the loss of butterfly diversity may be avoided through sustainable management of miombo woodland. The following research objectives are addressed:

1. To describe the butterfly species composition of the Kipembawe area, south-west Tanzania;
2. To determine if fruit- and nectar-feeding butterflies have similar or different responses to land-use change and human utilisation;
3. To determine whether and how butterfly species richness, abundance and diversity respond to land cover and utilisation changes within miombo woodland, and to identify appropriate indicator species.

8.3 Research design and methodology

Site selection is detailed in Chapter 3, Part 2. The Kipembawe Division is described in Chapter 4.

8.3.1 Butterfly sampling

Butterflies were recorded in nine sites which were each sampled for a period of five consecutive days. Sampling took place within a 4ha sub-block which was divided into 25m^2 quadrats (plots). Butterflies were sampled using sweep netting for nectar feeders (Ricketts et al., 2002) and canopy traps for fruit feeders (Austin and Riley, 1995). Canopy traps were set in pairs (one in the lower canopy/understory and one in the upper canopy (Aduse-Poku et al., 2012). Using two different sampling methods enabled both nectar and fruit feeding communities to be sampled, and setting the canopy traps at different heights captured any potential variations due to vertical stratification. Sweep-netting occurred in ten randomly selected plots using a random number generator in Microsoft Excel, based on xy co-ordinates, covering 0.63ha in total at each site.

Timed one-hour sweep netting took place in the morning and afternoon in different plots, with a total of 10 person-hours of sampling per site. All butterflies were removed from the nets into a polythene bag until the end of the session, when they were identified, photographed and released.

At each site, 10 canopy traps (constructed after Austin and Riley (1995)) were set for five consecutive days, 100m apart through the centre of the 4ha sub-block (Ribeiro and Freitas, 2012). Traps were opened between 8-9am, and closed between 4-5pm, when the trap was emptied by identifying, photographing and releasing each individual. Traps were baited with bananas which had been left to ferment for 48 hours (DeVries and Walla, 2001). At each site 50 trap-days of data were collected, with a total of 450 trap-days across the study site.

Identifications were made using national and regional field guides (Kielland, 1990, Larsen, 1991). When identifications could not be made voucher specimens were taken and sent to a specialist from the African Butterfly Research Institute for identification.

8.3.2 Land cover, utilisation and environmental variables

To determine what affects the butterfly species composition, richness, diversity and abundance a range of environmental, land cover and utilisation variables were recorded at each site.

8.3.3 Land cover variables

Land cover was measured through ground surveys along 1.5km transects. Transects were placed 500m apart and ran from north to south. Each transect was 10m wide and divided into 20m sections. The dominant ground cover type for each section was described. These descriptions were categorised into four variables: ‘Agriculture’ (‘Ag’) described some form of agricultural activity (prepared land, cultivated land, fallow land); ‘regenerating miombo’ (‘ReMi’) described miombo which had regenerated after previous cultivation; ‘Open miombo woodland’ (‘Mio’), included all areas of mature woodland, and ‘seasonal floodplain’ (‘SFP’), represented all areas of habitually flooded grasslands. For each butterfly sweep-net plot and canopy site habitat type was allocated to eight categories. In order to fully describe heterogeneous landscapes a habitat was described as ‘adjacent to’ if a different habitat was 100m or less away from the sample plot.

8.3.4 Utilisation variables

Utilisation was used to describe extraction of resources from the woodland. Methods to assess timber and pole extraction are described in Chapter 3, section 3.5. Data from this survey is allocated to the variable 'CutTrees'. All other signs of human utilisation (e.g. beehives, burned trees, tobacco burners, paths) were also recorded and categorised into nine variables (Table F1). 'NTFP' represented all woodland utilisation and disturbance for the purpose of collecting Non-Timber Forest Products, such as products for rope, medicine and food. In 10 plots within the 4ha sub-block all stumps of trees with an estimated diameter at breast height of >15cm were recorded, and allocated to the variable 'Stumps'. The age of the agriculture at each site was ascertained through local knowledge, and allocated to the variable 'Age'.

8.3.5 Environmental variables

Altitude was recorded at each site, and the maximum and minimum temperature and rainfall were recorded daily at each site for the duration of the research period. Additionally the number of tree species per hectare ('Trees') was calculated using tree species counts from ten randomly placed 25m^2 plots within the 4 ha sub-block.

8.4 Analysis

Each butterfly species was assessed according to descriptions in Kielland (1990) to determine habitat preferences and ranges. All data analysis was conducted using R version 3.1.0 (2014-04-10) (R Core Team, 2014). Utilisation variables for each site were grouped into three levels of utilisation – "Low" (n=3), "Medium" (n=4) and "High" (n=2) according to the values of each utilisation variable (Table F1). The average of each group was calculated to demonstrate the differences between the levels, differences between the utilisation levels for each variable were calculated using one-way Analysis of Variance (ANOVA) and the post-hoc Tukey´s Honest Significant Difference test (HSD) (R Core Team, 2014).

Changes in the composition of nectar- and fruit-feeding butterfly communities (sampled through sweep netting and canopy trapping respectively) in response to land cover, utilisation and environmental variables were analysed using Detrended Correspondence Analysis (DCA) with a down-weighing of rare species using the function 'decorana' in the package 'vegan' (Oksanen et al., 2013). DCA was chosen because this ordination technique is able to deal with many zeros in the data set, and because it removes possible arch effects by splitting up the axis into segments and detrending the scores in each segment (Zuur et al., 2007). The environmental, land cover and disturbance variables were then superimposed using the function 'envfit', also in 'vegan' in order to find significant influences on the ordination. ANOVA and the post-hoc test Tukey's HSD was performed to examine the differences in species richness, abundance and diversity across the eight habitat categories (pooled across all the sites) and the three utilisation levels (using the first two sites from each level to ensure equal sampling size), which were then displayed using boxplots.

Total species richness across the entire study site was estimated using the Chao estimator in the package SPECIES (Wang, 2011), which is suitable for non-parametric data containing single- and doubletons, and uses abundance data (Chao, 1984). Species richness was analysed using non-rarefied data to avoid the loss of power associated with singletons; the results are qualitatively similar to the use of rarefied data. Species richness, species abundance and species diversity (calculated as the Shannon-Wiener index) were further examined using a model approach. Species richness was modelled in a generalised linear mixed effects model with Poisson error distribution in the 'lme4' package of R (Bates et al., 2014). Abundance data were over-dispersed, and therefore a negative binominal generalised linear model was fitted using the 'MASS' package of R (Venables and Ripley, 2002). A linear mixed effects model with Gaussian distribution was used to examine species diversity with the 'nlme' package of R (Pinheiro et al., 2014). `Site` was included in mixed models as a random effect, because the plots are nested within the sites. Data were pooled across all the sites (n=177) by trap. These data did not demonstrate temporal autocorrelation. The full models contained the following variables as fixed effects: 'CutTrees' (linear and quadratic term), 'Stumps' (linear and quadratic term), and 'NTFP' (linear and quadratic term). None of these variables correlated with any other utilisation or land cover category. The model was simplified to minimal adequate models using backwards selection (Zuur et al., 2009). The models were validated and checked for over-dispersion using the package 'blmeco' of R (Korner-Nievergelt et al., 2015).

Indicator species were identified using the Indicator Value (Indval, Dufrêne and Legendre, 1997) with the multipatt function in the package 'indicspecies' of R (De Caceres and Legendre, 2009) and assessed according to utilisation level. This method assesses the frequency of a species within a habitat and the strength of its association with that habitat (Cleary, 2004). Significance was based on a randomisation procedure of sites, with 1000 iterations. Only species with

Indicator Values ≥ 0.25 and P<0.01 were considered to remove species with weak indicating capacities (González et al., 2013).

8.5 Results

8.5.1 Butterfly assemblages in Kipembawe

In total, 45 days of sampling throughout a four month period with canopy traps and sweep netting caught 4,608 individuals, representing 104 species in 5 families and 51 genera (Appendix F, Table F5). The total minimum species richness across the study site is estimated at 144, using the Chao estimator (Chao, 1984). Miombo specialists were represented by 22 species, of which 16 species are only found in Tanzania to the west of the country (Tables 8.1 and F5 and Figures 8.4 and 8.6).

Table 8.1: Miombo specialists only described in Tanzania in the west of the country. Their frequency of occurrence per site for each utilisation level is shown.

	Frequency per utilisation site		
Species	**High**	**Medium**	**Low**
Acraea caldarena	0.5	0.75	0.00
Acraea utengulensis	1	0.5	2.00
^Belenois calypso	0	0.25	0.00
^Bicyclus cooksoni	0	0.25	2.33
**Charaxes castor*	0	0	0.33
Colotis regina	0.5	0.5	1.00
Crenidomimas concordia	0	5	16.00
Hemiolaus caeculus dolores	0.5	0	0.00
Junonia artaxia	0.5	1	6.33
Junonia touhilimasa	0.5	0.25	0.00
**Meza larea*	0	0	0.33
^Precis actia	0	3.75	5.00
Precis ceryne	0.5	0.25	1.00
Precis pelarga	0.5	4.25	1.33
**Pseudacraea poggei f carpenteri*	0	0	0.33
Teracolus subfasciatus ducissa	0.5	1	0.67

*Highly likely to become extinct in Tanzania if miombo habitat within Western Tanzania is utilised – did not occur in high or medium utilisation sites
^Highly likely to become extinct in Tanzania if miombo habitat in Western Tanzania is highly utilised – did not occur in high utilisation sites

8.5.2 Effects of environmental and land-use variables on the composition of fruit- and nectar-feeding butterfly communities

A Detrended Correspondence Analysis (Figure 8.1) with superimposed environmental variables illustrates the effects of land-use and environmental variables on the composition of both fruit and nectar-feeding communities, and demonstrates the lack of overlap between communities sampled by different methods. Canopy traps sampled fruit-feeding butterflies, while the sweep nets sampled nectar feeders. Rainfall appeared to influence species composition along the first axis, and on the second axis utilisation had the most impact, on a gradient from agriculture to miombo woodland.

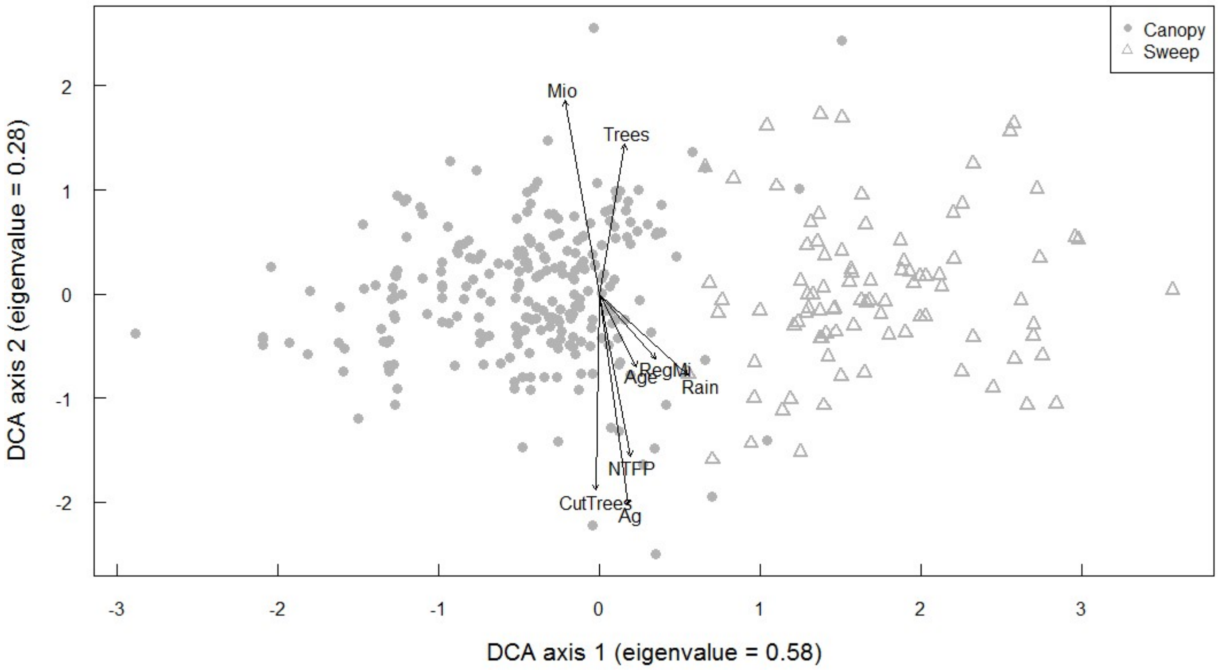

Figure 8.1: DCA ordination plot of the butterfly community sampled by sweep netting and canopy traps. Variables which had a significant association (p<0.05) with community composition are represented by arrows. Environmental variables - rainfall ('Rain'); tree species richness per hectare ('Trees'): Land cover variables - Agriculture ('Ag'); open miombo woodland ('Mio'); regenerating miombo woodland ('ReMi'): Utilisation variables – cut timbers and poles ('CutTrees'); Non Timber Forest Products ('NTFP') and the age of the agricultural land ('Age').

Separate analyses of the frugivore community sampled by the canopy traps and the nectarivore community sampled by the sweep nets demonstrate that they have different associations with the land cover, utilisation and environmental variables. Species composition of frugivores showed correlations with various environmental variables, with a gradient from the number of tree species to the age of the agricultural land along the first axis and a gradient from the amount of natural habitat (miombo) to variables representing disturbance of the natural habitat along the second axis. Species composition of the nectarivores was influenced by fewer variables than the frugivores, with the most important influence along the first axis being a gradient of high temperatures and extraction of NTFP to a greater amount regenerating miombo woodland, and the only influential variable along the second axis being the age of the agricultural land (Figure 8.2). DCA analysis was performed on the upper and lower canopy traps, which did not demonstrate any significant differences in species assemblages (Figure F1).

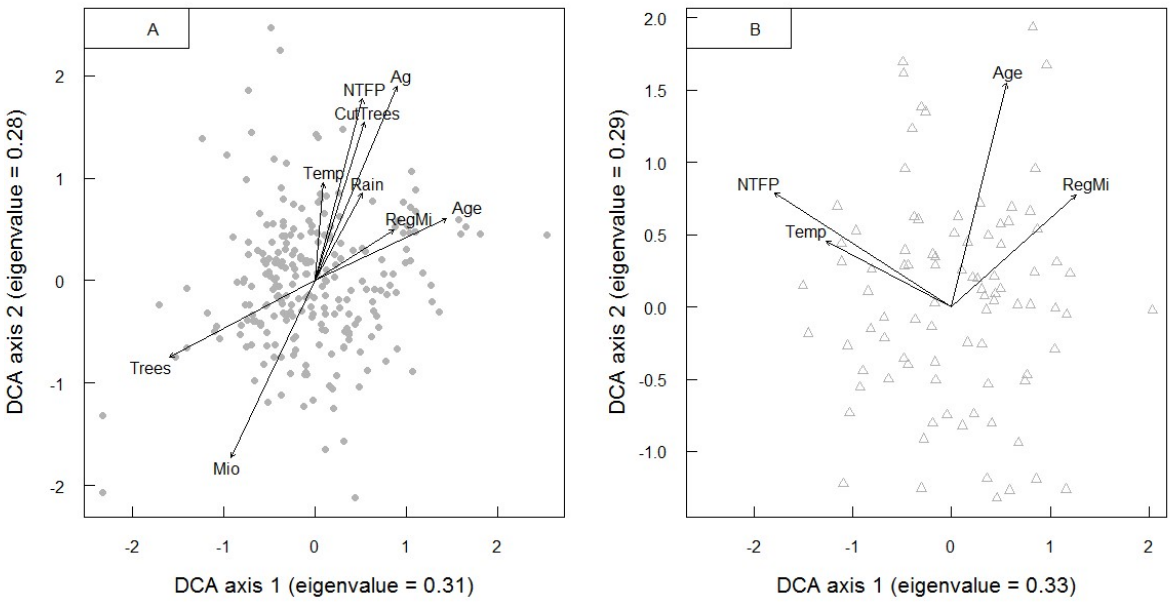

Figure 8.2: DCA ordination plots of butterfly communities sampled by different methods (A. Canopy traps; B. Sweep netting). Variables which had a significant association (p<0.05) with community composition are represented by arrows. Environmental variables - rainfall ('Rain'); temperature ('Temp'); tree species richness per hectare ('Trees'): Land cover variables - Agriculture ('Ag'); open miombo woodland ('Mio'); regenerating miombo woodland ('ReMi'): Utilisation variables – cut timbers and poles ('CutTrees'); Non Timber Forest Products ('NTFP') and the age of the agricultural land ('Age').

8.5.3 Differences in species richness, diversity and abundance with habitat and utilisation levels

Species abundance (ANOVA, df = 2, F=33.34, P<0.0001) richness (ANOVA, df = 2, F= 19.32, P<0.001), and diversity (ANOVA, df=2, F=26.61, P<0.0001) varied significantly between all three levels of utilisation (Figure 8.4B, Table F2). Butterfly species abundance, richness and diversity were lower in modified habitat (agriculture and regenerating miombo) than in miombo woodland. However, values from disturbed miombo habitat were similar to those in miombo woodland (Figure 8.4A, Tables F3, F4).

Analysis of the relationship between species abundance, richness and diversity with the predictor variables demonstrated that there was a significant negative relationship of stumps on all three metrics, and that the collection of Non-Timber Forest Products also negatively correlated with abundance and richness (Table 8.2). The quadratic term of stumps was also significant for all three metrics, showing that as the number of stumps increased butterfly species abundance, richness and diversity increased, until a point where they declined with increasing numbers of stumps, producing a hump-shaped relationship (Figure 8.5).

Figure 8.3: ***Hemiolaus caeculus dolores*** **top: upperside, bottom: underside. Subspecies endemic to Western Tanzania (source: E Jew, 2013)**

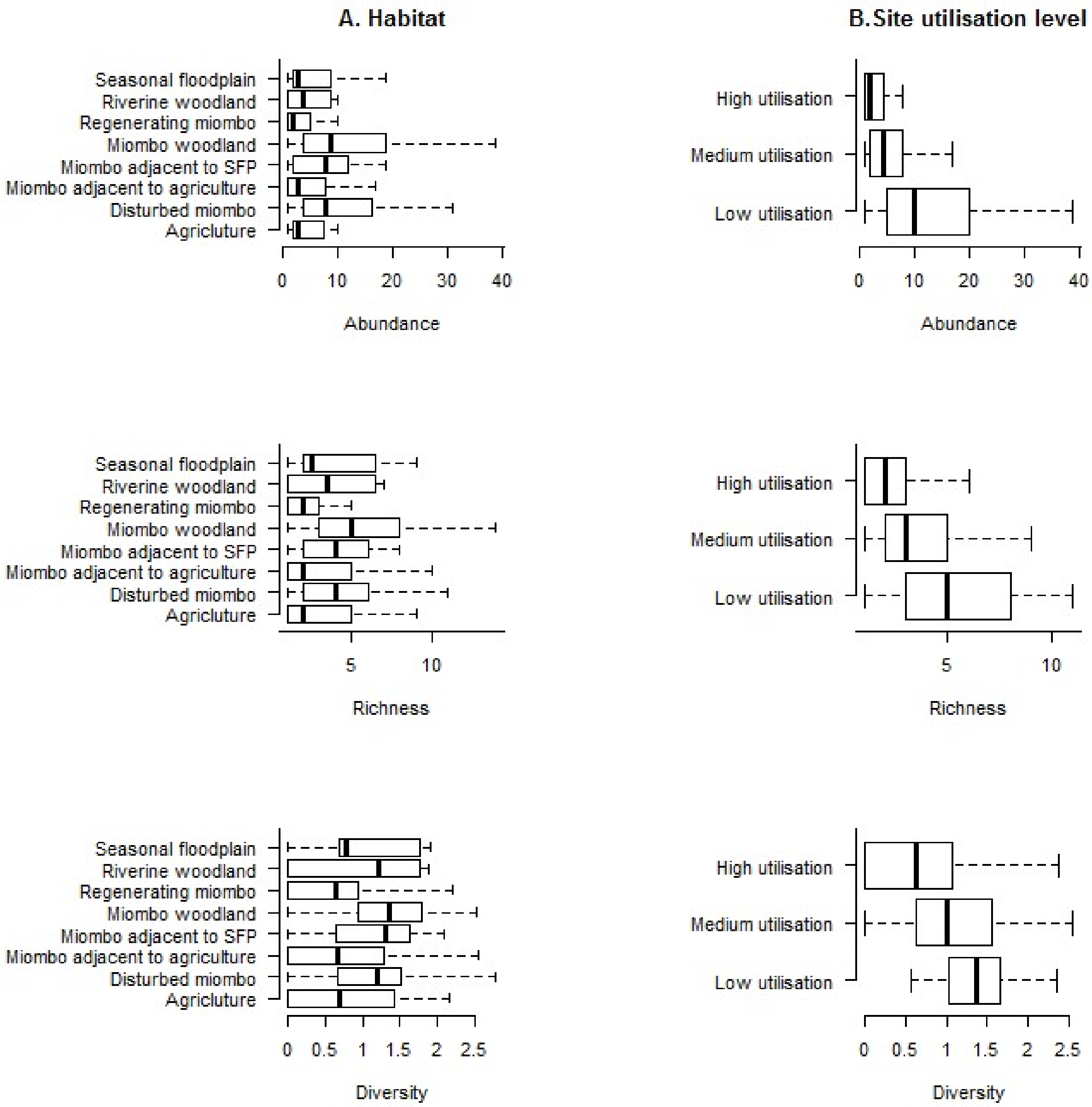

Figure 8.4: Species abundance, richness and diversity in response to A) Habitat type and B) Utilisation level.

Table 8.2: Results for the three different linear models : species abundance (negative binominal generalised linear model); species richness (generalised linear mixed effects model); and species diversity (linear mixed effects model). P values (Pr(>Chisq)) for the glmer determined using the 'car' package in R (Fox and Weisberg, 2011). Significance levels indicated by: *P<0.05; **P<0.01; ***P<0.001.

Response variable *model*	**Predictor variable**	**DF**	**Deviance**	**AIC**	**LRT**	**Pr(>Chi)**
Abundance *Negative binominal glm*	Stumps	1	197.09	1461.2	7.8911	0.004968**
	Quadratic term of stumps	1	211.01	1475.1	21.8102	3.010E-06***
	NTFP	1	208.22	1472.3	19.0221	1.292E-05***
		estimate	SE	Z	Pr>|z|)	Pr(>Chisq)
Richness *glmer*	Intercept	2.2594	0.04566	49.48	<2E-16***	
	Stumps	-0.06411	0.03269	-1.96	0.04987*	9.101E-05***
	Quadratic term of stumps	-0.23745	0.0413	-5.75	8.95E-09***	1.669E-07***
	NTFP	-0.08108	0.02932	-2.77	0.00568**	0.06304
		Value	SE	DF	t-value	P-value
Diversity *lme*	Intercept	1.8431	0.06548	166	28.14706	<0.001***
	Stumps	-0.08970	0.0434	166	-2.06667	0.0403*
	Quadratic term of stumps	-0.18727	0.05375	166	-3.48418	0.0006***

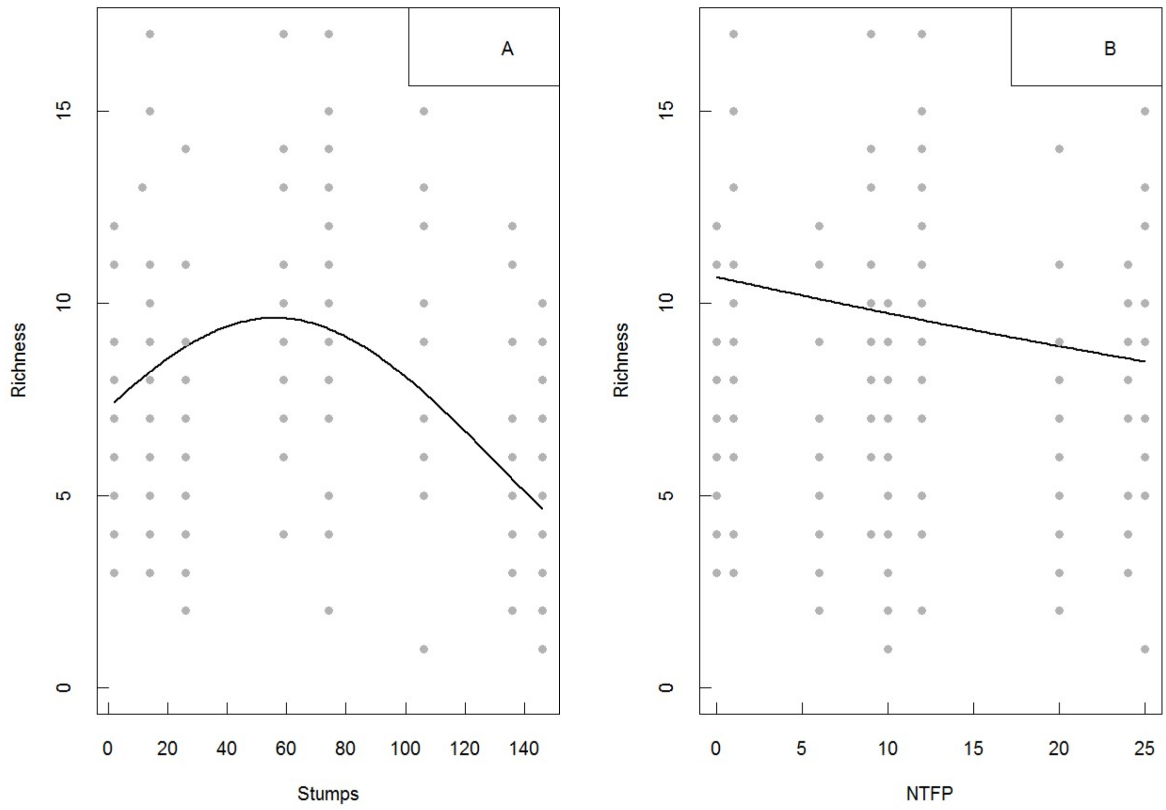

Figure 8.5: Butterfly species richness relationship between A) Stumps, with a negative unimodal response (glmer, -0.23745, SE = 0.04, P<0.0001), and B) Non-Timber Forest Products (NTFP), demonstrating a negative linear response (glmer, -0.06411, SE = 0.03, P<0.0001).

8.5.4 Indicator species

Indicator species were identified for all three utilisation levels (Table 8.3). Fewer species were significantly associated with high utilisation sites than medium and low utilisation sites.

Table 8.3: Indicator species for high, medium and low utilisation levels (Indval = Indicator Value, significance levels indicated by: **P<0.01; ***P<0.001).

High utilisation			**Medium utilisation**			**Low utilisation**		
Species	**Indval**	**P-value**	**Species**	**Indval**	**P-value**	**Species**	**Indval**	**P-value**
Eurema hecabe solifera	0.279	0.001***	*Belenois thysa thysa*	0.294	0.002**	*Byblia ilithyia*	0.718	0.001***
Eurema regularis regularis	0.326	0.006**	*Bicyclus anynana*	0.383	0.003**	*Catacroptera cloanthe cloanthe*	0.261	0.002**
Ypthima sp.	0.259	0.008**	*Bicyclus campina*	0.354	0.001***	*Crenidomimas concordia*	0.392	0.001***
			Bicyclus ena	0.357	0.005**	*Henotesia simonsii*	0.625	0.001***
			Charaxes guderiana rabiensis	0.543	0.002**	*Neptis morosa*	0.474	0.001***
			Sevinia rosa	0.493	0.002**			

8.6 Discussion

8.6.1 The butterfly assemblages of Kipembawe

This study provides original data regarding butterfly communities within Tanzania, and adds to the understanding of butterflies within miombo woodlands. Sixteen species were recorded that are both miombo specialists and are only found in Tanzania to the west of the country, and are therefore at high risk of extinction within Tanzania should the miombo woodlands in this area become heavily degraded. Two of these are subspecies (*Teracolus subfasciatus ducissa* and *Hemiolaus caeculus dolores*) that are endemic to West Tanzania. Additionally *Acraea utengulensis* has been found occasionally in other areas of Tanzania, and may be present in North-East Zambia, but the main global population of this species is in West Tanzania (Kielland, 1990). Therefore these species are at risk of global extinction should the area become heavily utilised. They have not been assessed on the IUCN Red List of Threatened Species (IUCN, 2015). This demonstrates the value of the miombo woodland in the Kipembawe Division, indicating that conservation efforts are required to maintain viable woodland in this area.

Developing indicators of disturbance within forests and woodlands can assist in developing rapid, cost effective measures of land use change, and butterflies are recognised as suitable indicators (Bhardwaj et al., 2012). This study identified *Bicyclus* species from the sub-family Satyrinae as indicative of medium utilisation (Figure 8.6). Satyrinae are shade-loving, but the larvae food preference is grasses (Kielland, 1990), which are most likely to occur in woodland gaps, therefore making moderately disturbed habitats preferable. This supports research elsewhere that suggests that Satyrinae are suitable indicators of disturbance (Bossart et al., 2006).

8.6.2 Response of butterfly communities to land cover and utilisation changes disturbance

When considering the entire butterfly community it is evident that there are responses to land cover and utilisation changes, altering species composition and decreasing species richness, abundance and diversity as the landscape becomes more utilised, as has been found with intensive logging and cultivation in tropical forests (Dumbrell and Hill, 2005, Lewis, 2001, Ribeiro and Freitas, 2012), in dry savannah forests (Fitzherbert et al., 2006, Tambara et al., 2013, Akite, 2008) and in coffee-banana agroforests (Munyuli, 2012).

There was little overlap in species composition between the fruit-feeding butterfly community sampled by canopy traps, and the nectar-feeding community sampled by sweep netting. The need for multi-dimensional sampling techniques has been highlighted previously (DeVries et al., 1997) although much of the focus surrounding sampling techniques has addressed vertical variation in fruit feeding species assemblages within tropical rainforests (e.g. Aduse-Poku et al., 2012, Dumbrell and Hill, 2005, Fermon et al., 2005, Molleman et al., 2006). Miombo woodlands have canopies of 8-25m (Frost et al., 2003), and lack a significant understorey layer. Therefore, although canopy traps were positioned in the lower and upper canopies for this study, there was not a significant difference in species composition, and it is recommended that traps should be set in the lower canopy where wind has less impact on capture rates.

The majority of fruit-feeding butterflies caught in the canopy were from the family Nymphalidae, which are often the focus of indicator species research (Bobo et al., 2006, Bossart et al., 2006, Dumbrell and Hill, 2005, Hamer et al., 2003, Lewis, 2001) because they are easy to sample simultaneously in several locations, and have correlated with total butterfly and bird diversity elsewhere (Ribeiro and Freitas, 2012). Within this study the fruit-feeding communities showed significant responses to a range of different land-use, utilisation, and environmental variables, whereas the nectar-feeding butterflies showed responses to fewer variables. However, given the lack of overlap between the two communities comprehensive species inventories require sampling from both guilds.

The decline in abundance, richness and diversity in areas of high agriculture and utilisation may be due to the loss of food sources, increased amounts of pesticides and herbicides (Tambara et al., 2013), and the distance between habitat patches (Loos et al., 2014b). Diversity is unlikely to remain in homogenous agriculture (Benton et al., 2003), yet utilised or degraded forests may retain significant diversity (Larsen, 1995). This was evident in this study, where abundance, richness and diversity were maintained in habitats with some disturbance (Figure 8.4A). Additionally, a significant quadratic relationship was detected between the three metrics and ‘stumps’, showing that highest levels of species richness, abundance and diversity were predicted at medium utilisation levels. This supports the intermediate disturbance hypothesis (Connell, 1978) which suggests that at intermediate levels of disturbance diversity is highest because species are present which are both colonising the area and regenerating within it, and inter-specific competition is low. This is aided by the increase in heterogeneity in the landscape (Bennett et al., 2006) which leads to a greater range of ecological niches (Bazzaz, 1975). A peak in butterfly species richness and diversity has been seen at intermediate disturbance levels in a range of habitats (e.g. Nyafwono et al., 2014, Hamer and Hill, 2000, Blair, 1999). However, this finding should be approached with caution, as the intermediate effect was only demonstrated with one utilisation variable, and it is not evident in Figure 8.4B. Nevertheless, this is of particular importance for conservation, as it demonstrates the need for conservation of areas that are utilised, as they are still of value (Gardner et al., 2007), and also demonstrates that it is possible to retain communities in areas which are utilised, meaning that the implementation of land-use strategies to achieve dual goals of biodiversity conservation and woodland utilisation can be successful.

8.6.3 Management of miombo woodland

High levels of human utilisation and conversion of woodland to farmland alters butterfly community compositions and reduces species richness, diversity and abundance in miombo woodlands, however, with one utilisation variable they were predicted to increase at moderate levels of utilisation. Despite a lack of information on the consequences of different management regimes for lesser known taxa (Gardner et al., 2007), the likelihood that there will be further pressure to expand agriculture into miombo woodland suggests that effective land-use management plans are required now to prevent substantial biodiversity loss in the future. Such land management plans will need to regulate utilisation to moderate levels, and create a heterogeneous landscape which will enable effective conservation outcomes and also accommodate sustainable agricultural production (Bennett et al., 2006). In order to develop such plans the full participation of all relevant stakeholders is essential to enable understanding of the interactions between people and miombo, and the future needs of local communities which can then be incorporated into land management plans. Long term biodiversity monitoring would be required to identify any impacts of the land use plan, and ongoing stakeholder participation would be needed to ensure that their needs continue to be met.

8.7 Conclusion

Butterfly communities within miombo woodland systems respond to a changing woodland landscape by decreasing in species richness, diversity and abundance with increasing utilisation and agricultural land cover. However, there is evidence of an intermediate disturbance effect, with the highest values for all three metrics predicted at medium utilisation levels for one utilisation variable. Species were recorded here which are not found in other parts of Tanzania, indicating the conservation value of these woodlands. Miombo woodlands are under threat from agriculture and excessive utilisation, and as such require effective, sustainable land management. Empirical data such as those presented in this paper will contribute to the development of such land-use management plans, in conjunction with the full participation of local communities and land-users. Evidence of an intermediate disturbance effect suggests that it may be possible to create sustainable land-use management plans that allow moderate woodland utilisation, thereby enabling biodiversity conservation and agricultural production goals to be achieved.

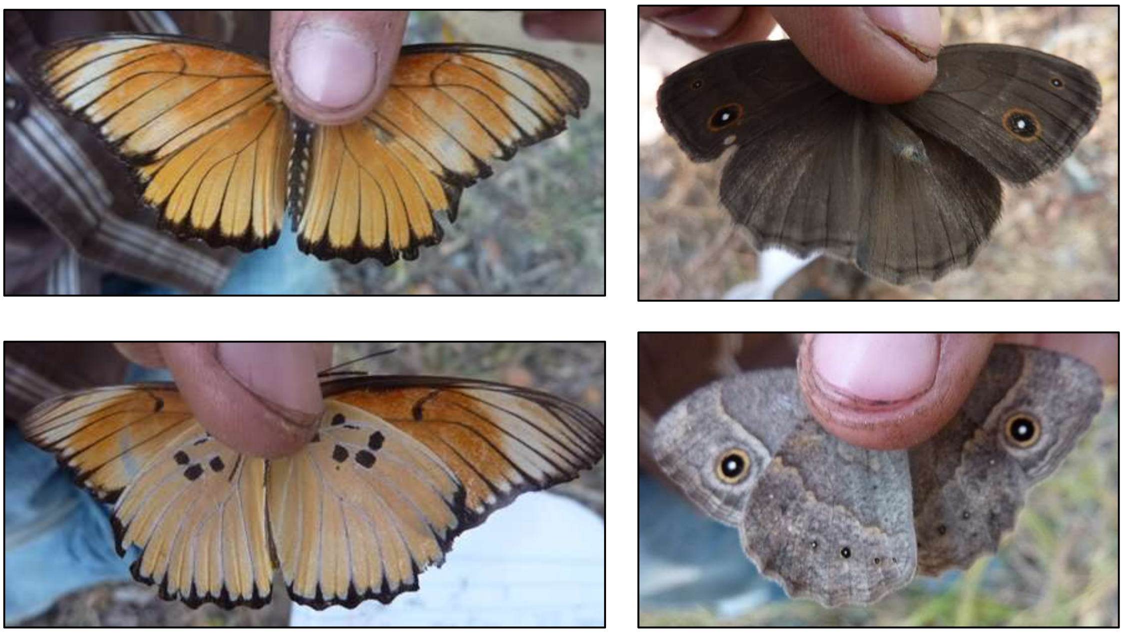

Figure 8.6: Butterfly species . Left: *Pseudacraea poggei f. carpenter*, only found in low utilisation sites. Right: *Bicyclus ena*, an indicator of utilisation (source: E Jew, 2013)

Chapter 9

Weak governance affects environmental and social welfare in miombo woodland, south-west Tanzania

Chapter summary

This chapter contributes to Objective 5 by identifying local level challenges to the implementation of future land use management strategies by examining current programmes and governance in the area. The chapter returns to topics introduced in Chapter 4, and considers them in greater detail, enabled by a deeper understanding of Kipembawe gained through Chapters 5-8. This chapter is the final empirical chapter, and is followed by chapter 10, which draws the thesis together to identify challenges to land management identified throughout the thesis.

9.1 Abstract

Rapid land use change within the miombo woodlands of south-western Tanzania has led to decreasing biodiversity and a reduction in the availability of ecosystem services. This indicates that there is a need for sustainable land use management strategies to be implemented in the area. Before such strategies can be developed it is necessary to determine the local capacity for change, and to identify potential challenges to the design and implementation of possible strategies present at household and landscape scale. Using household surveys, focus groups and key informant interviews, this chapter explores how current land and environmental facing programmes are being implemented, finding that governance at local and district level has been weakened through corruption, low financial capacity, a lack of rule enforcement, and low human capacity, which is resulting in such projects being little more than 'paper projects'. Reducing tobacco cultivation will require the provision of viable alternative livelihood opportunities. The benefits incurred from tobacco cultivation are examined, and alternatives currently proposed are discussed. Tobacco cultivation also generates problems at a household and community scale. These problems are explored alongside consideration of the possibility that solving these issues at a cost of reduced personal income is incentive enough to result in change. Weak

governance, coupled with a lack of alternative livelihoods, demonstrate that a shift from tobacco cultivation to a more sustainable land management strategy will be challenging. Options where tobacco remains a significant part of livelihoods are more likely to achieve some measure of success.

9.2 Introduction

Developing land use management strategies to adopt sustainable natural resource use requires an understanding of how current land and environmental policies are designed and implemented, and how these can guide future land use planning decisions in an area. This means that the strengths and weaknesses in current programmes must be identified. It is also necessary to understand the relationship between the community and the activity which is driving environmental degradation (in this case tobacco cultivation) for example, why they cultivate tobacco preferentially over other crops. Understanding the benefits and challenges that tobacco brings to the community will inform the development of alternative livelihoods and land use decisions.

Within the Kipembawe Division there are three environment/land management facing programmes that can be evaluated. The first of these is a tree planting programme run by the tobacco companies and facilitated by the Primary Co-operative Societies. The second is the Government Village Land Use Management Plans which have been implemented in four of the five surveyed villages, and the third is a Participatory Forest Management Scheme which applies to two villages. Additionally lessons can be drawn from other government policies and regulations that affect the area, including forestry and wildlife management, and livestock movement control.

This chapter uses empirical qualitative data to examine these programmes to identify challenges and opportunities that can inform the development of further land use strategies. It then examines the benefits and challenges associated with tobacco cultivation on household and community levels to determine whether farmers would be receptive to altering their current livelihood strategies. Finally, the chapter investigates what alternative livelihood options may be possible for tobacco farmers in this area.

9.3 Background context

One of the greatest risks to the success of natural resource-based projects is governance (Huettner, 2012). Governance refers to all processes of governing that determine how people in societies make decisions, share power, exercise responsibility and ensure accountability (Cundill and Fabricius, 2010). It does not refer purely to the government, but extends across civil society, also including non-government organisations, institutions and community groups. Governance occurs through multiple levels and has multiple actors, particularly for land tenure and environmental management (Doherty and Schroeder, 2011). Good governance "*promotes equity, participation, pluralism, transparency, accountability, and the rule of law in a manner that is effective, efficient and enduring..[and] threats to good governance come from corruption, violence and poverty, all of which undermine transparency, security, participation and fundamental freedoms*" (UN, 2015). Governance that suffers from these threats is a risk to the success of land tenure and environmental projects because it reduces the effectiveness of a project's implementation, reduces the willingness to participate and prevents monitoring. In Chapter 4 the governance structures within Kipembawe were illustrated, including those overseen by the government and those devolved to the local level. Other actors involved in governance that have been identified within the thesis thus far include the tobacco companies and the Primary Co-Operative Societies.

Another risk to project success is whether local communities are truly 'on board' and willing to engage in a project to make it successful. They are more likely to do so if they can see clear and sustainable benefits (Blom et al., 2010) both in the short and long term. It is therefore necessary to understand the benefits and challenges that are associated with their current activities to determine how improvements can be made in the process to increase the positive outcomes for the local communities involved.

Tobacco cultivation occurs predominantly in developing countries (Geist, 2009) and usually by subsistence farmers, who experience both positive and negative consequences of farming tobacco. The negative consequences of cultivating tobacco are many and varied, and are associated with financial risk, health and labour (Lecours et al., 2012). Most farmers do not have the capital to purchase seeds, fertilisers or pesticides which are needed to cultivate tobacco, and therefore receive these inputs through Primary Co-operative Societies (Chapter 4). This can make them vulnerable to default on loans if the crops fail or are damaged, and high charges for inputs can result in low net returns (Maegga, 2011). Farmers often reduce the amount of land they cultivate for food crops in order to grow more tobacco (Kweyuh, 1994). This has a double-edged effect of reducing the amount of food grown, and the intensity of farming extra tobacco reduces time to cultivate food crops, and the quality of them decreases (Kweyuh, 1994). Farmers are then forced to buy food, and because it comes from further away the price is higher (Kweyuh, 1994). These combined factors may lead to food shortages for the family (Muwanga-Bayego, 1994). Cultivation time can also be reduced through poor health.

Exposure to pesticides and fertilisers cause health problems for workers in the short term, and may also lead to long term neurological and psychological conditions (Lecours et al., 2012). Exposure to nicotine causes Green Tobacco Sickness which can be debilitating (Arcury and Quandt, 2006). This usually occurs when green tobacco leaves are wet, and nicotine is absorbed through the skin on contact, usually when farmers are pruning the leaves (McBride et al., 1998). Additionally they are exposed to secondary smoke within the tobacco burners, and many workers also smoke raw tobacco, which leads to lung problems (TTCF, 2012). Child labour is a major issue within the tobacco industry, and it is suggested the tobacco industry benefits from US$ 1.2 billion in unpaid labour costs by exploiting child workers (Otañez and Glantz, 2011). Due to labour intensive nature of tobacco cultivation and the difficulty of finding additional workers farmers often use their families for labour (Mkwara and Marsh, 2014, Otanez, 2008). Children therefore provide essential labour at all stages of tobacco cultivation (Muwanga-Bayego, 1994), and miss out on education (Mkwara and Marsh, 2014), in addition to being exposed to hard labour and tobacco-related illnesses. Children in rural areas in Tanzania are more likely to be engaged in work (Mudzongo and Whitsel, 2013), and the increase in tobacco farming in Tanzania has been shown to have resulted in an increase in child labour, human trafficking, slavery and bonded labour in the Urambo District (TTCF, 2012). The Eliminating Child Labour in Tobacco Growing Foundation was set up in 2001 after a major convention on the issue (ELTC Foundation, 2014), and works in various countries to reduce child labour.

There are few studies documenting positive outcomes from the cultivation of tobacco. Tobacco companies lobby governments by claiming that tobacco farming provides employment and provides cash payments (Hu and Lee, 2015), yet studies in Kenya have demonstrated that alternative crops can provide higher incomes (Ochola and Kosura, 2007). Case study evidence which includes benefits (at community and household) from tobacco cultivation is needed, and this study contributes to this research gap. Alternative livelihood options for tobacco farmers need to be able to provide benefits equal to those attained from tobacco cultivation, and eliminate the negative aspects associated with it in order to incentivise farmers to cease tobacco cultivation. Alternative livelihoods approaches aim to relieve pressure on an exploited resource by substituting a livelihood strategy that is causing harm for one that has a more positive outcome (Roe et al., 2014). Such approaches have been instigated in many environments, and particularly within forestry; where a key aim is to reduce deforestation, as advocated by the United Nations Reducing Emissions from Deforestation and Forest Degradation (REDD+) (Groom and Palmer, 2012). One of the greatest challenges that has been uncovered throughout several decades of projects and programmes addressing alternative livelihoods is that in many cases the alternative livelihood has become an 'addition' rather than 'substitute' (Wicander and Coad, 2015). This means that the original detrimental activity continues, and the environmental damage that was to be avoided has continued, although local communities can benefit in the short-term by increasing incomes. To be a successful substitution there has to be sufficient incentive to change livelihoods, and the incomes generated must be either equal to or better than currently practised. Additional benefits such as reduced labour or reduced risk can also increase chances of success. The alternative must align with the needs and aspirations of the community (Wright et al., 2015). Additionally the way the programme is set up will also be important to end results – training, guidance and support are necessary to encourage and facilitate change.

In an effort to reduce deforestation rates tobacco companies have introduced reforestation schemes throughout tobacco growing countries, usually involving reforestation with non-native species for tobacco curing (BAT, 2014b). Native species, such as *Brachystegia spp.* and *Pterocarpus spp*. germinate poorly from seed (Boaler, 1966b), making them unsuitable for large scale reforestation programmes. Planting eucalyptus, cypresses and other non-native plants is problematic because the trees absorb excessive amounts of water which harms food crops and reduces drinking water tables (Otañez and Glantz, 2011). *Eucalyptus grandis* is known to cause reductions in streamflow from increased uptake of groundwater (Van Lill et al., 1980), and afforestation with eucalyptus species need managing across water catchments (Dye, 2013). The impacts of the 'cut a tree, plant a tree' initiative in Kimpembawe are addressed within this chapter.

This chapter provides case study evidence regarding the effectiveness of governance in relation to environment/land use programmes, and identifies the positive and negative consequences of tobacco cultivation and the alternative livelihoods which may be suitable for this case study area.

9.4 Research design and methodology

The study area is described in Chapter 3. Social survey data including household surveys (HHS), key informant interviews, focus groups and participatory matrices are described in Section 3.6. All data were coded into themes that emerged, and data were triangulated across the different methods.

9.5 Results

The results from the empirical data are now presented. Section 9.51 examines the tobacco industry tree planting programme 'Cut a tree, plant a tree'. Section 9.5.2 assesses the Government led Land Use Management Plans. Section 9.5.3 addresses governance within the Government Wildlife and Forestry departments at District level and below. Allegations of corruption in general are then reported. Section 9.5.6 then moves from the governance of existing plans to the current income activities of local communities, and examines the positive and negative aspects of cultivating tobacco. Section 9.5.7 then considers what current alternative income activities are being proposed.

9.5.1 'Cut a tree, plant a tree'

The issue of reforestation was the biggest query that the cigarette company Philip Morris International made to the tobacco merchants (Tobacco Company 1, 2013). Many respondents in the HHS (n=170) recognised that there is an impact on the environment as a result of tobacco cultivation. When asked if they thought tobacco had an impact on the environment, 40% said "yes", 27% said "no" and 30% "didn't know". Reasons that respondents gave for an environmental impact included the clearing of forest leading to climatic changes such as reduced rainfall, loss of the forest and what it contains, and pollution of water sources. Ward B Officer 1 thought *"[There is a] lack of awareness of the effect [of tobacco] damaging the environment"* (2013), which was echoed by Division Officer 2, who said that there was a real need for more education about the environment (2013).

There is a programme in place to replace the trees harvested for tobacco production. The ‘Cut a tree, plant a tree’ programme was established in 2001 as a National Forest Programme (Tobacco Company 1, 2013). It is now undertaken in this area by the two tobacco companies, “*which are working together because their common goal is to reduce deforestation*” (Tobacco Company 1, 2013). The eventual aim is to establish woodlots which can then be used for tobacco curing, rather than using miombo trees. The tree seedlings supplied are exotic, fast growing and suitable for burning; including *Senna siamea* (Siamese cassia) and *Eucalyptus grandis* (flooded gum) (Tobacco Company 2, 2013).

Tree seedlings are provided to farmers by the tobacco companies through the Primary Co-operative Society (PCS). The PCS rear the seedlings, also using a local NGO (the Kalangali Agricultural and Environmental Advocacy group). They are then distributed to the farmers depending on the amount of land they farm for tobacco, or the amount of fertiliser they take. There is considerable confusion about this, from the tobacco companies, agricultural extension officers, and farmers:

> *“50 trees for one bag of fertiliser”* (1 acre requires 4 bags of fertiliser, 2.4 acres to a hectare which would mean 10 bags of fertiliser per hectare = 500 trees) **Tobacco company 1 (2013).**
>
> *“For every hectare of tobacco planted the farmer must plant 550 trees”* **Tobacco company 2 (2013)**
>
> “*200 trees per farmer*“ **Village C Agriculture focus group (2013)**
>
> *“50 trees per acre of tobacco”* **Village C Social Welfare Committee (2013)**
>
> *“50 trees per one bag of fertiliser”* **Ward A Officer 3 (2013)**
>
> *“For every 3 acres of tobacco planted 1.5 acres of trees should be planted”* **Ward C Officer 3 (2013)**
>
> *“You get TSH 50,000 if you plant 1 acre with trees”* **Village D Agriculture focus group (2013)**

> *"If you plant 1000 trees you get some money from AMCOS"* (Agricultural Marketing Co-operative Society). **Village D Environment Committee (2013)**

This programme has been established for over ten years, and this lack of clarity demonstrates that it has not been implemented effectively. Eucalyptus trees were only observed in one small woodlot (Figure 9.1). At no point were eucalyptus trees observed being used for curing. Results from the HHS (n=188) indicated that 44% of tobacco farmers planted trees. Of these, 28 (37%) said that all the seedlings they had planted had died, and many more people had lost the majority of the seedlings. They claimed that was due to insufficient rain, termite damage and fire. Many of the reasons cited for not planting trees was associated with the supply of the seedlings –they were supplied too late, after the rains, so they had no chance of growing. Some people were unaware of the scheme.

Perceptions that water availability is decreasing (Chapter 6), combined with the belief that eucalyptus species deplete ground water means that people are reluctant to plant the trees:

> *"Farmers reject the plan to plant eucalyptus as they believe it will reduce the water supply"* **Lupa Ward C Officer 1 (2013)**

> *"The tree planting programme is not beneficial because it dries the water sources"* **HHS, Nkung'ungu (2013)**

It is also suggested that the seedlings never get planted:

> *"People take the seeds and leave them at home. If they are asked what happened to them they say that the termites destroyed them"* **Lupa Ward C Officer 3 (2013)**

> *"Many people throw the trees away – that is why you do not see* Eucalyptus *trees around"* **Village D Officer 3 (2013)**

The ability of the woodland to regenerate also reduces motivation to plant seedlings:

> *"There is motivation to plant trees, but people don't see the point of doing it because the miombo regenerates - so not many people do it. And anyway we*

are only given the seeds late in the year, when they get here they are damaged and won't grow anyway." **Village D Agriculture focus group (2013)**

"The Eucalyptus *will cause lots of problems in the future. People here are not interested in planting the trees. Luckily the forest regenerates; else it would have become a desert long ago. With different trees and more education people will do it and the forest will be intact again"* **Division Officer 3 (2013)**

"People are not interested in planting trees. A farmer gets TSH 100,000 for planting 1 acre. Even this is not enough motivation for them to do it" **Village D Officer 2 (2013)**

Village C Agriculture focus group (2013) did not think it was a rule for tobacco farmers to plant trees, but rather if you were willing you could. They did not think there was any punishment for those who did not plant trees now, and although there had been some punishments handed out in 2008/09 it had not happened since. Those who did take the trees found that they were damaged by termites, and they were not taught how to plant them and care for them. Conversely, the tobacco companies indicated that the planting of trees by farmers is a rule that is enforced, and that the Tanzania Tobacco Board are the regulators, and conduct site visits. If trees aren't being planted the farmers are not allowed to grow tobacco. Organisation 1 (2013) said that 98% of people plant the trees they are allocated, and Tobacco Company 1's Corporate Social Responsibility Program leaflet claimed that 2,880,000 trees had been planted, giving a 100% replacement rate for trees cut for curing for the 2013/2014 season. However, information gathered during the social surveys and general observations did not support this.

Figure 9.1: ***Eucalyptus spp.*** **woodlot (source: E Jew, August 2013)**

9.5.2 Village Land Use Management Plans

Village Land Use Management Plans are government initiatives to allocate land within villages for different uses, e.g. livestock grazing, urban, agriculture and forest reserves.

There are Village Land Use Management Plans in Matwiga, Lualaje, Mazimbo and Mwiji. According to the Regional Officer 1:

> "*Village land use plans are co-ordinated by the villagers. The village land use plans come from the Land Use Act 7, in 2008. The villagers are the ones that produce the plan, and they are facilitated by experts. Usually the experts gather information about the village, and conduct a detailed analysis, they then listen to the villagers and see if their ideas link. If they don't they talk to them to get them to agree, sometimes the villagers have traditional knowledge so they have to come to common ground. In the 1970s the top down approach failed, now since 2008 they are using a participatory approach, bottom up".*

However, according to the Land Use Planning committee in Village C, in reality it is still a top-down process: *"In 2008 someone from the District came and told us that we had to have a Land*

Use Committee, so we formed one. Then someone from the District walked around the area with the Village Chairman and some Council members and decided where there should be areas for livestock, agriculture and a reserve. They told us what was where at the village meeting".

This was echoed by other groups – Village C Agriculture focus group explained that the Village Council had decided where everything would be. Village C Social Welfare Committee knew there was a plan, but didn't think that it had been implemented. Village C Pastoralist focus group didn't know there was a formal Land Use Management Plan, they knew that there was a place for cattle but they didn't use it because they farm as well.

Another issue of the Management Plans is that there is little consultation – Village B Elders explained that the Land Use Plan doesn't work because "*the area where the cattle were supposed to be has no water and there are tsetse flies, so all the cattle were moved out from it"*. Village A Villagers focus group knew about it because they had heard about it at the village meetings, but didn't know any details.

Additionally there is no co-operation between villages about where each specific area of land should be allocated. In each land use plan areas are allocated for livestock, cultivation, development and a forest reserve. However, there has been no consultation about the allocation of land at or across boundaries, resulting in areas set aside for livestock adjacent to cultivation, where conflict is likely to occur (District Officer 8). There was also no consultation with livestock keepers about the suitability of land for cattle, and generally the location of water sources was not taken into account. Very few participants were aware of the existence of the land use management plans in any of the villages, and few knew where any particular areas are. District Officer 8 explained: "*the plans are not effective on the ground, because people just carry on as usual. The government are supposed to demarcate the different areas, but there is no funding so it is not done, so people do not know where the boundaries are*".

Unfortunately copies of the land use management plans were not available, limiting analysis.

9.5.3 Participatory Forest Management

Participatory Forest Management (PFM) reserves are government-backed initiatives to devolve responsibility of the management of protected areas, in this case village reserves, to the local communities. There are PFMs in Matwiga and Nkung'ungu. Funding initially came from DANIDA, who aimed to fund 20 village forest reserves and/or five PFMs, protecting 50,000ha of forest by 2010 (information from a DANIDA leaflet given to Nkung'ungu PFM). The process and current situation for both villages are described in Boxes 9.1 and 9.2. These show that the process was very similar to that described above for the Village Land Use Management Plans – someone came to the village from the District Council and suggested that they have a PFM. After setting out guidelines for its use, marking the boundary and setting up the PFM committees there has been no support for it, so patrols are not run often. No permits have been issued, and in the case of Nkung'ungu there have been pastoralists in the reserve for the last two years. Despite a gap of nine years between each project the processes are very similar.

District Officer 3's account is very similar:

> *"There are seven steps to setting up a PFM. We identify an area that is suitable for a PFM, and then we go to the village and have a meeting with the Village Council to tell them about PFMs – this is a sensitisation meeting. Then five people are chosen to be the PFM committee, and they decide where the reserve should be – with help so that they choose a good area. A team of 10 people then go to look at the area. Following the location approval some villagers are trained to do tree and animal surveys in the forest, which they do, with Officers to check that it takes place. A report is written of these findings. Then the Officers help the Committee to write a management plan. Bylaws to protect the area are established with the help of a District Lawyer. The management plan and the bylaws are combined, and there is a village meeting to read both. The villagers accept the plan and the bylaws through a vote."*

District Officer 3 also said that there are no plans for further PFMs at the moment because the DANIDA funding has stopped, and the District has no funding.

Box 9.1: Matwiga PFM Committee (2013)

The PFM was established in 2011. Forestry Officers came to the village from Chunya District Council and explained what a PFM is and suggested that it would be good to have one in Matwiga. There were several village meetings, where it was agreed that we would have one, and where it would be, and that we would need a committee to look after it. Then the Forestry Officers wrote a report to say where it would be and what regulations would govern it. This took 6 months. It took 3 weeks to work out where to put the boundaries, and a further three weeks to mark them out, using beacons and red cloth. The PFM is called 'Matwiga Hill' and covers 846.41 hectares. It is surrounded by farmland. We did a tree inventory at some sites within the reserve, but no animal surveys.

Some activities are allowed in the PFM such as fetching water, fruit and firewood. To collect construction poles, timber, grasses, and bushmeat a permit is needed. No permits have been issued.

We had a plan to protect it using a separate security unit that would have gone to the reserve twice a week, however, there is no funding to pay people to this. Therefore we go voluntarily sometimes. The District Council promised that we would have help for different aspects, such as transport, but we have had nothing. After the District Council set it up they abandoned it.

Box 9.2: Nkung'ungu PFM Committee (2013)

The PFM was set up in 2002. It is Igama Forest Reserve (8,420 hectares) about 25km away from the village, three hours walk. It was a government programme, they sent people from the District Council here, and said that we need to protect resources within the village. The District Council went to see the village elders and then they decided where the reserve would be and marked it out. Then they said that the younger members of the village should be in charge – so that is how we came to be members of the PFM committee. There was a village meeting to explain about it, and the villagers were happy because it sounded like there would be benefits such as tourists and traditional healers would come and the forest would be conserved. There were no plant or animals inventories conducted. At the time there were animals there, now the pastoralists are there and there are no animals.

We have issued 16 permits for beekeeping (10,000 TSH/year), and three for timber logging. We run patrols twice a month, but poaching does occur. Forest damage was reducing, but two years ago pastoralists moved into it. They have been clearing the forest for two years. The District Council knows about it but nothing is done. There is a motion dated two months ago that said they must move, but they haven't. So we are waiting for the District Council to come and move them.

We would do more patrols if we had transport – we would be more likely to catch people. We only have three bicycles, we don't have camping equipment or guns, so what we can do is limited. The PFM is funded by the village government from fines from the livestock keepers that damage the forest. There is no additional funding from the District Council. We don't have enough money to run it properly, and we need payment for the days we spend away from the farms as in the forest it is hard work.

9.5.4 Wildlife and forest governance

Regulation of natural resources where power has not been devolved to local communities is the responsibility of government wildlife and forestry departments. This section addresses their effectiveness within Kipembawe. Poaching occurs within the Division, and is the main reason that there are fewer animals in the area according to both the Division Officer 3 and District Officer 2. Species that are hunted for bushmeat include buffalo (*Syncerus caffer*), eland (*Taurotragus oryx*), Kirk's dikdik (*Madoqua kirkii*) and bushpig (*Potamochoerus larvatus*) (Division Officer 3, 2013). Division Officer 3 said that poaching is for personal consumption, the bushmeat trade and for ivory. He said that ivory poaching is increasing around Mafeyko, Kambikatoto and Bitimanyanga, and that he had found military guns used for elephant poaching. This view is supported by the District Officer 2, who said that elephant poaching is increasing because the poachers have better guns, and that people come from Tabora and Singida to poach elephants in Kipembawe, with an estimated seven elephants killed a month in the Division. These statements are underlined by studies demonstrating that the rates of poaching for ivory are currently surging to unsustainable levels (Wasser et al., 2010, Wittemyer et al., 2014). During this study in 2013, an elephant skeleton was found, which the game scout estimated to be five years old. The skull was missing, suggesting that it was poached for ivory. Poaching for elephant was also high in the 1980s, according to the Division Officer 3. This was at a point when an estimated 700 tonnes of ivory was removed from Africa a year, leading to the 1989 Convention on International Trade in Endangered Species (CITES) ban on ivory trade (Douglas-Hamilton, 2009).

The Wildlife Division in Chunya is unable to conduct effective anti-poaching efforts due to a chronic lack of resources, with few staff (four at District level and three at Ward level for the District), no vehicles, and inferior weapons (District Officer 2, 2013). Occasionally an anti-poaching unit comes from Iringa, the *Kikose Dhidiya Ujangili* (KDU), but this is not enough (Division Officer 2, 2013). Additionally, when people do get caught there is so much corruption in the system that they are released without punishment (District Officer 2, 2013). The most effective anti-poaching patrols are run by the trophy hunting companies to protect their hunting blocks (District Officer 2, 2013). TANAPA run patrols within their areas, such as the Ruaha National Park (Village A Officer 3, 2013).

This is similar to the situation within the Forestry Department. According to District Officer 3 protected areas are at risk of deforestation because there is no funding to run patrols; and deforestation and illegal logging is occurring throughout the District. He also said that even in the villages with Forest Reserves as part of their Land Use Management Plans it didn't work, because the plans are not followed.

9.5.5 Allegations of corruption

Whilst conducting research many allegations of corruption were heard. During data collection a village meeting was scheduled to take place in Village A. However, the villagers refused to attend because they didn't trust the Village Executive Officer (VEO), as he was supposed to give them a financial assessment for the previous year (2012), but he couldn't tell them where the money had been spent for that year, and they believed that he had stolen it. In Village D the villagers had forced two leaders who they believed to be corrupt out of office – a village chairperson in 2012 and the Village Executive Officer in 2011. Ward A Officer 2 said that there were no restrictions on the number of cattle that come into the area (yet restrictions are in place for 70 head of cattle per person (Chapter 5)). The research team were told repeatedly that officers in Ward A were taking bribes to allow cattle into the area, and to stay on village land.

These are some examples of corruption that were formally recorded during interviews.

> "*Corruption is a big problem in law enforcement [of protected areas], especially at village level. The whole system is corrupt so it is hard to tell where the problem is*". **Organisation 2 (2013)**

> *"There is a black market in tobacco – employees steal it from their employers and then sell it on. There are three or four markets, so they can take it from one market and sell it at another"*. **Ward A Officer 1 (2013).**

> *"Pastoralists pay the VEOs to graze their cattle*" **Organisation 2 (2013)**

> *"Between 2008 and 2011 the government constructed a dam here. It was supposed to be a national dam for fishing, and to supply the villages with water, but there is no water in it. Even this year [2013] a water person came from the government and said that it would be finished by May, but there is no sign yet.... They told us we would have to contribute TSH 5 million for this water project. Every village has to provide it, and then they would provide water for the villages. So far we have raised TSH 400,000 and nothing has happened*" **Village C Elders (2013)**

> *"The TANAPA people go to frighten the Sukuma and get money off them for bribes….They beat people up. Last year they interrogated someone in Lupa and made him confess to being a poacher, and then they killed him with a bayonet"*
> **Village A Social Welfare Committee (2013)**

This latter quote is a result of antagonism between the villagers and the Tanzania National Parks Authority (TANAPA), which has led to allegations of brutality: *"They will kill you while they laugh"* villager (2013). This antagonism is a result of a project to create a protected reserve that will become part of the Ruaha National Park (Village A Officer 3, 2013). To do this three sub-villages in Village A are being moved. The sub-villages are currently located geographically within the Mbarali District as the border between Chunya and Mbarali is a river, and the sub-villages are on the Mbarali side. Villagers will be moved into other sub-villages of Village A on the Chunya side of the river. At the time of research compensation had not been agreed for the villagers, and no formal dates for moving had been set.

9.5.6 Benefits and challenges from tobacco cultivation

Benefits

Tobacco is the second largest contributor to Mbeya Region's economy after coffee (Regional Officer 4, 2013). The District, Ward and villages also receive revenue or contributions to infrastructure from the tobacco companies (District Officer 7, 2013). "*The tobacco companies give money through AMCOS to the Ward Development Committee, mainly for education and health, and this money goes towards development projects"* Village A Officer 1 (2013).

Tobacco Company 1 explained that the amount that they give to each AMCOS depends on how much tobacco is grown, and on average this represents US$72 per kilo. The money can be used for whatever development project the Village Council decides. The recipient community has to take photos of the project throughout its development to prove that the money is used properly and if it is not, that society will not receive money again. Tobacco Company 2 gave examples of the projects including wells, buildings for the schools and medical centres, books, desks, and chairs for schools.

In addition to benefits through the community, households also benefit from the income generated from their cultivation of tobacco, ascertained through the HHS (Table 1). The most common uses for the income from tobacco include building a house, buying clothes, paying school fees, and buying extra food.

Table 9.1: Benefits of tobacco cultivation (HHS, n=168, multiple answers accepted)

Benefit	No. respondents	Benefit	No. respondents
Building a house	116	Buying land	5
Buying clothes	91	Paying employees	5
Paying school fees	68	Buying electronic goods	5
Buying food	41	Drinking	4
House requirements	25	Processing machines for maize	4
Buying livestock	20	Other personal uses	4
Buying household sundries	16	Future planning	3
Paying for health care	15	Raising living standards	3
Opening a new business	14	Paying village contribution	2
Buying furniture	13	An emergency fund	2
Buying agricultural goods	13	Travel to relatives	2
Buying motorised transport	11	Pay bride price	1
Buying construction material	8	Building a burner	1
Supporting family and relatives	6	Buying a generator	1
Buying school uniform	6		
Buying bicycles	5	No tangible benefits	1

Ward B Officer 1 (2013) noticed a difference between this Ward and previous Wards he had worked in: "*The money from tobacco means that there is an increase in modern houses within the Ward, and it generally increases development, the standard of living here is higher than in other Wards I have worked in*".

There can be significant personal benefits for tobacco farmers, of which an example is given in Box 9.3. For reference, an average yield of tobacco is 1350kg/hectare and a good yield is 1500kg (Tobacco Company 1 and 2, 2013).

Challenges

Tobacco farmers face multiple challenges (Table 9.2). The most common are the impact of variable rainfall upon harvest, destruction of burners by fire, and the insufficient supply of fertilisers from AMCOS.

Box 9.3: Village D livelihood matrix (2013)

Male headed household, aged 30, been in area for 25 years, started farming on his own 8 years ago

2007 was a bad year; he was living on his own and he had 3 acres of tobacco, 2 of maize, intercropped with beans, and 1 acre of groundnuts. There was a lot of rain and hailstones that damaged the crops. He managed to harvest some beans and groundnuts, but it wasn't enough for the whole year. Therefore during the wet season he was able to get work on other people's farms in the village. This was OK because he didn't have anyone else to support.

2010 was a good year, because he got lots of tobacco, 2,400kg from 3 and a half acres [yield of 1,714kg/ha]. Ground nuts were OK too, and from 3 acres he got 180 buckets of maize. He also got 180 buckets of beans, and because the price of beans was high this was good. He also sold 50 chickens at TSH 5,000 each. He met all is household needs, and now he had a wife and child to support. With the surplus money he was able to build a house.

2011 was different, because even though he cultivated lots of tobacco the price was low. They weren't told what price the tobacco would be until the wet season, after they had planted. All his other crops went into compensating for the tobacco. He had enough money for the year, but there was no surplus, so it wasn't what he aimed for.

In 2012 he opened a kiosk to sell goods. He wanted somewhere he could invest his money in. The kiosk doesn't make much money, but doesn't lose any either. Farming is his main income, the kiosk acts like a bank, it keeps money.

2013 was a really good year. He had five workers, the rain was good and the price of tobacco was high, and he got 4200kg from 5 acres. Ground nuts and maize were good crops too. He grew 5 acres of maize, and plans to sell some because the price is good. He also intercropped the maize with beans, and got 42 buckets, better than previous years. The harvest was also good because he loaned enough fertiliser for the whole year. He puts most effort into cultivating the tobacco because it has a good price to support him, the other crops are extra. He will have surplus this year. He would like to invest it in a house, he wants to find a plot or a house in Mbeya. He also will keep money aside to pay school fees.

In 2014 he wanted to clear 7 acres of woodland so he could plant more tobacco, particularly if the price is similar to this year. The kiosk is still not making much money, so he isn't too optimistic about its future. He said that he managed to make money from tobacco because he has a small family (5 members) and he doesn't drink. He went to seminars given by AMCOS about how to manage money, so he has a bank account that he puts his money in. He makes a budget and only takes a certain amount out each time, just what he needs.

Table 9.2: Challenges associated with tobacco cultivation (HHS, n= 168, multiple answers accepted)

Challenge	**No. Respondents**	**Challenge**	**No. Respondents**
Unfavourable weather	61	High costs associated	5
Damage to burners	59	Insufficient burners	4
Insufficient and late supply of fertiliser, pesticides, agricultural tools and trees	49	Need to employ workers	4
Labour intensive	33	selling tobacco in dollars is confusing	2
Illness caused by tobacco	31	packing tobacco - not enough bags to pack	1
Delay in receiving money	26	Accidents	1
Wild animal and pest damage to crop	25	not enough time for food crops	1
Tobacco price low	15	seasonal money	1
Unreliable market	12	lack of storage room	1
Lack of transport	10	Allocation of land unfair	1
Lack of transparency in grading system	9	Low production	1
Issues with co-operative debt system	8	Bushfire	1
Damage to tobacco	7		
Conflict between community members and AMCOS	5	None	12

AMCOS

Several of the problems raised by farmers were related to their relationship with AMCOS. A major problem is the timing of the supply of inputs, including seeds, fertilisers, pesticides, farming equipment and tree seedlings. This has a significant impact on the yields that can be achieved, particularly if crucial periods such as the onset of the rainy season are missed.

Additionally several issues were raised regarding the sale of tobacco. These include the grading of the tobacco leaves, theft of tobacco, irregularity in the markets, and delays in the distribution of payment following sales at the markets. As one respondent claimed: "*The money from the sale of tobacco is delayed, which means we have to sell our maize to afford living costs*" (HHS, Village A, 2013). Many farmers also thought that they might be getting cheated, because the payments are made in dollars and they don't understand the exchange rates (Village D Agriculture focus group, 2013). Participants felt that they are coerced into growing tobacco through the distribution of fertiliser for maize. Fertiliser for maize is only provided to those who grow tobacco. There are no other distributors of fertiliser, and this means people need to grow tobacco in order to receive the fertiliser, or buy it illegally from other farmers.

Food shortages

Households can experience food shortages between November and March, before the next maize harvest: 19% of tobacco farmers (HHS, n=168) experienced food shortages at this time. "*To attempt to address this people sell food crops to raise money and the children may go hungry"* (Village A Agriculture focus group, 2013). Usually this means that they sell maize (at poor prices to middlemen) to buy other food, as small amounts of other crops do not last long. Then they take out loans to cover the shortfall, usually from other farmers. Rates can be at 100% or even 200%, and are not necessarily monetary – e.g. if one bag of maize is borrowed two must replace it (Ward A Officer 1, 2013) and Box 9.2. It can be difficult to repay these loans, particularly if the tobacco harvest is poor, leading to a constant cycle of debt (Village A Agriculture focus group, 2013). This cycle was described in detail (Figure 9.2) by the Village A Officer 1 (2013).

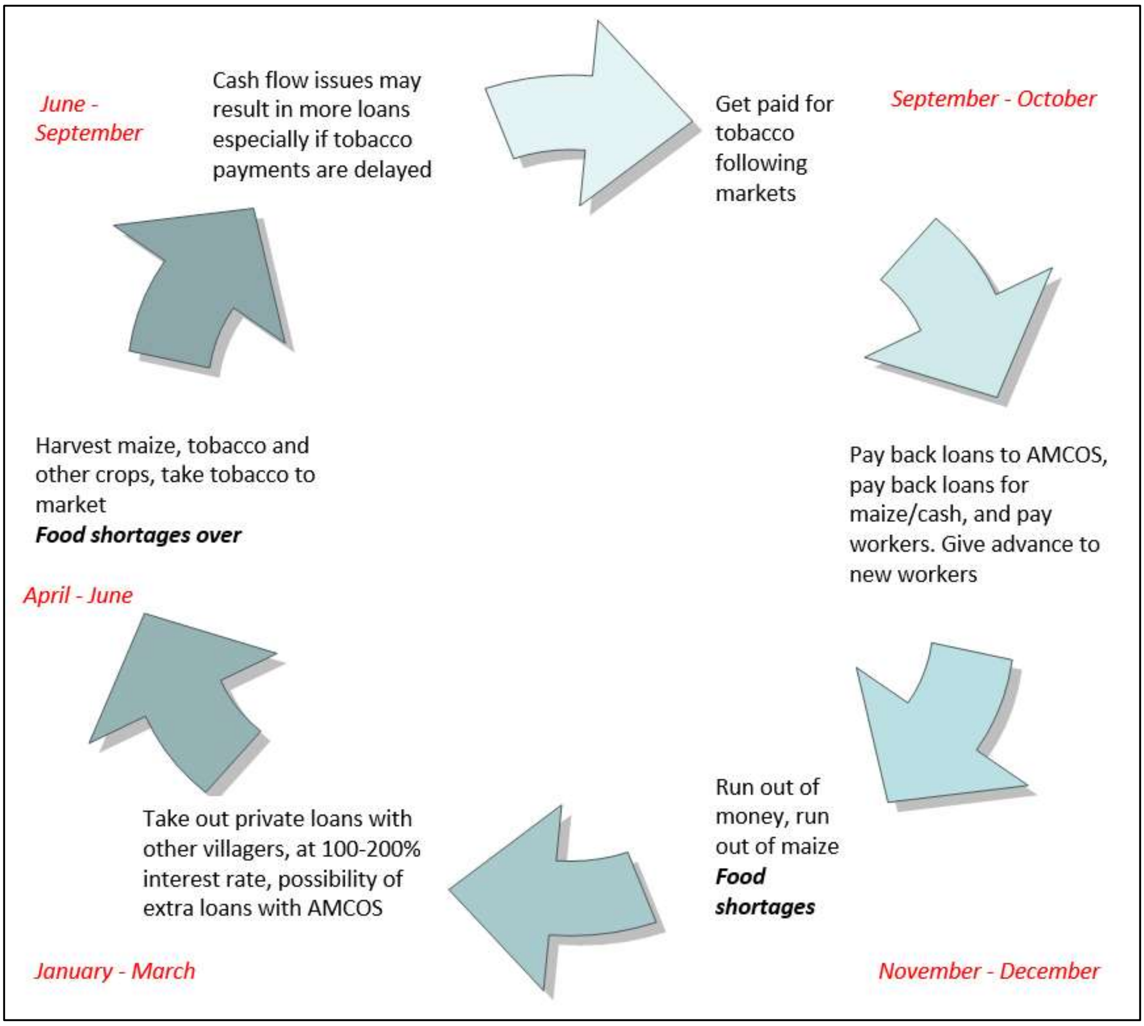

Figure 9.2: Cycle of debt related to tobacco cultivation (based upon information from the Village A Officer 1 (2013)

Health of farmers

Thirty-one households (HHS, n=166) reported ill health as a result of tobacco cultivation, including fever, headaches, and general tiredness. This was also mentioned in focus groups and interviews. Ward B Officer 1 said that there was a lack of awareness of the effect of tobacco on health. This means that appropriate steps to mitigate these hazards are not taken. During the research period, there were no observations of tobacco workers taking any precautions that are recommended by the tobacco companies to reduce exposure to green tobacco sickness, pesticides or tobacco smoke, such as protective clothing and face masks (Figure 9.3).

Tobacco farmers are paid after the markets in September. Around this time, the population in the area increases bringing with it increased levels of alcohol consumption and prostitution (Ward A Officer, 2013). This has been attributed to a rise in HIV in the area (Chapter 4). Many small pubs are opened for the period post-payment when there are no farming activities to attend. Women brew local beer from maize to make money during this time as their access to funds is limited due to their lack of involvement in the sales of tobacco (Box 9.2 - livelihood matrices, 2013; General comment, Village D, 2013).

Figure 9.3: Tobacco workers (source: E Jew, April 2014)

Labour issues

Cases of bonded labour were informally observed by the research team, and children were also seen working in the fields. The following quote encompasses many of the labour problems in the area:

> *"Workers are not paid according to the agreements they have with their employers. They are promised that they will be paid 500,000TSH for the whole season, and then they are only paid 200,000TSH. They say they will be taking their food costs and other costs off, which they are supposed to provide. They*

> *bring people in from other places – Shinyanya, Singida, Kigoma, even from Malawi too, using illegal routes. Even if they die they don't send them back."* **Ward C Officer 3 (2013)**

Child labour is recognised as an issue in tobacco cultivation, and tackling it is part of both tobacco companies' Corporate Social Responsibility Programs. Teachers explained that there was a decrease in the number of children attending school in the last years of primary school:

> *"They leave to work for anything that provides money, not just tobacco"* **Head teacher 1**
>
> *"Most children work in the tobacco fields"* **Head Teacher 4**
>
> *"Sometimes the parents move the tobacco farms a long way from the school so it is too far for the students to come"* **Head teacher 5**
>
> *"Children work in the fields when they are 13-14 years old"* **Head teacher 5**
>
> *"They employ children, people who are 14, 15 years old, and the companies know about it – they see them when they drive through"* **Ward C Officer 3 (2013)**

Organisation 1 representatives stressed that children under the age of 18 are banned from working in tobacco fields, including children from the family. There is thus an obvious discrepancy here between the rule of law and reality in practice.

Box 9.4: Village C livelihood matrix (2013)

Female-headed household, age 44, living in the village for 25 years

1998 was a really memorable year, because it was an El Nino year, and there was a lot of really heavy rain. The whole tobacco crop failed, and she only had two bags of maize, so couldn't make pombe [fermented maize alcohol drink]. There were only a few beans too. But luckily, when she realised that the crops were going to fail because of the heavy rain she planted sweet potatoes because she knew they would be good in the heavy rain. So she had a good crop of potatoes, but they weren't enough to make ends meet. So she had to buy maize, which was really expensive TSH 10-15,000 per bucket [20 litres]. She had to borrow money of other villagers, at 100% rates. She was able to pay these off the next season.

In 2011 they had a bad year, because even though they grew 6 acres of tobacco and had 7 workers her husband was sick, so there was no-one to make sure the workers were working properly. The yield was so poor that they are still paying the loans off now [2013]. They also had to pay the interest on any loans that the workers took out. The maize yield was good, got 30 bags from 4 acres. The beans were poor because they didn't have enough seeds to replant from the previous year – you need 2-3 kilos to replant the following year. She made some pombe although usually she has enough capital to buy extra maize to make it, this year she had to use her own.

In 2013 they farmed four acres of tobacco, and had just the one worker, and had a good crop. Maize wasn't so good, 24 bags off 4 acres; beans were better because they had more seeds to start with. She used her own maize to brew pombe, and made three batches.

In 2014 she would like to plant 6 acres of tobacco. However, the amount that you can plant is dependent upon how many workers you can get. She would like four workers, and then they can clear 2 acres of regenerating woodland, and expand the tobacco. They will plant maize where the tobacco was and hopefully grow more beans, and she will make pombe.

Every year they have to get loans to pay the school fees. One child is at the government school in Isangawana, where the fees are TSH 20,000/year, but with other charges like books, uniform, exam fees and building contributions it is more like TSH 150,000. The other child is at a private school in Mbeya, where the fees are TSH 500,000. They would be TSH 1 million if he boarded there, but he lives with an uncle. Every year when they get the tobacco harvest money they have to pay all the debts off, pay the workers and give the next lot of workers an advance. There is never enough money, so they have to balance between paying people and paying school fees.

9.5.7 Alternative income options

Chunya District Council is trying to introduce cashew nuts, mangoes, sesame, and sunflower as alternative crops, and is "*trying to emphasise the production of sunflower over tobacco as it is more environmentally friendly*" (District Officer 7, 2013). However, as Village D Agriculture focus group (2013) reiterated, people will only switch crops if they pay the same.

One of the most difficult issues will be to establish competitive markets for another product, as there *"… is no market here for maize, and people have to sell to middle men, who come to the area and buy the maize for a price of their choice"* (Village D Agriculture focus group, 2013). This opinion is shared by the Village C Social Welfare Committee, who said that they were 'robbed' by middlemen (2013). Even if a suitable crop is found, persuading people to switch will be challenging. According to Village D Officer 2, attendance at free meetings to learn about different farming techniques, correct fertilisers, pesticides and different seeds is low and many people *"ignore the advice anyway".* However, there does appear to be some desire for change. Village D Officer 2 (2013) said that the "*village has written a letter saying that they want to reduce the amount of tobacco cultivation and instead cultivate sunflower*". The issues surrounding income levels are demonstrated by this comment from Village E Agriculture focus group (2013):

> *"We would like alternative cash crops, such as sunflower or sesame, but we can't introduce a new cash crop because of tobacco – for 1 acre of tobacco you can get TSH 5 million; for 1 acre of sesame or sunflower it is TSH 200,000. We can also get loans now from AMCOS – these aren't available for non-tobacco crops. Sunflower or sesame are easy to grow, everyone can grow them. But there isn't a market here for anything [except tobacco]"*

One possible alternative is beekeeping for the production of honey and beeswax for export. This is being actively encouraged by the Tanzanian Government, with funding for a National Forest and Beekeeping Programme (II) extended through a €6 million grant from the Finnish Government for the period 2013-15 (Embassy of Finland, 2013). The former Prime Minister (Mr. Mizengo Peter Pinda) of Tanzania has been actively promoting beekeeping (Tanzania Forest Services, 2014), and seeking to secure markets overseas. Regional Officer 2 explained that "*there is a good market for honey, because it is almost organic, and there is a market in Asia already, and the Prime Minister has guaranteed a market in Europe*". However, the challenge of providing honey that is of export quality may take time to overcome. He continued to explain that, "*…there is a problem that people use old containers from fertilisers and pesticides to store the honey - education is needed"*. District Officer 1 explained "*we give training to registered beekeepers, to show that……using fertiliser bottles to store honey is bad as they are contaminated"*. Additionally, honey that was reportedly imported to Germany from Tabora in 2011 contained unacceptable levels of nicotine (Bees for Development, 2011) due to the bees harvesting nectar from tobacco plants. It also causes bee mortality: "*If the bees pollinate the tobacco they die*" Ward A Officer 2 (2013). District Officer 1 explained that to combat this it is recommended that honey is collected over 5km from tobacco fields.

District Officer 1 explained about the status of beekeeping within Chunya as a District, and within Kipembawe. Currently the national market for honey is strong (although not guaranteed), with traders in Mbeya, Dar es Salaam and Arusha, and also to Kenya. Beekeeping within Chunya, and especially Kipembawe, is being very actively encouraged. For example, the Forest and Beekeeping Reserve in Kipembawe that was gazetted in 2012 had 431 modern hives in 2013, and the buildings from the old village of Kipembawe will be restored as facilities to provide training, processing and as a place to co-ordinate the markets. Beekeeping (of wild bee populations) is being promoted by suggesting that it is possible to make more money from honey than through tobacco, with a modern hive producing approximately 20 litres of honey a year, at a retail value of TSH10,000/litre).

However, the number of bees and the amount of harvest that they produce to secure such livelihoods on a large scale is debatable: 59% of people who collected honey (HHS, n=44) are finding that the amount of honey available has been declining over time (Chapter 6).

9.6 Discussion

The success of projects associated with natural resource management depends on their implementation. All the programmes described here show little evidence of implementation. Few people were aware of the Village Land Use Management Plans within the villages, and if they had heard of them, they were unaware of the boundaries. Even the livestock keepers who tended to be more aware of the designated livestock areas did not keep their livestock in those areas. The land use plans were instigated by the District as a result of the National Land Use Policy (2007). Despite claims that the plans are developed through 'bottom up' approaches they remain as top-down projects with limited local input, despite Districts only having 'advisory' roles following the 1999 Village land act (Pedersen, 2012). Mollel and Tollenaar (2013) found that in some cases in Morogoro, central Tanzania, local communities were asked for input into planning local facilities, but their ideas were not taken seriously or taken into consideration by the District if they did not match predetermined criteria. This is similar to that reported here, with District Officials indicating that they guide local councils to make appropriate decisions. The policies appear to be aimed at dividing the land and allocating it to different user groups, but without long term or landscape level plans. Similarly, the PFM schemes were initiated in a top-down fashion, with limited local level input, and no incentives for participation. No post-setup financial plan, further support or logistical support has been provided for either scheme. In both these cases start-up funding was available, and therefore the projects were initiated with proper consideration of the need for continued support.

The Forestry and Wildlife sectors demonstrated a chronic lack of capacity to fulfil their roles. This is a result of poor funding from the central government which has meant that there are too few staff to fill the needed roles, and no transport to travel to villages and reserves. Therefore no policies are implemented, and regulations that are supposed to govern forest access are not enforced. This is not restricted to Kipembawe – throughout the miombo region there is a lack of law enforcement that targets illegal harvesting of timber. Increasing the capacity of forest governance is essential (Chirwa et al., 2008).

As the evidence presented shows, these failures are due to shortcomings within the governance system. Despite efforts to reform local governance through decentralisation of power to local communities, the lack of capacity at governance levels below Ward reduces the ability of local authorities to truly use devolved power. This can range from the lack of funds, inadequate stationery, and poor communication networks through to doubts about elected leaders' abilities to manage finances and organise meetings (Kessy and McCourt, 2010). Given that levels of education within Kipembawe are so poor (Chapter 4), it is unsurprising that local leaders may struggle in these areas. A further issue is that of corruption. Corruption undermines governance (UN, 2015). Within Kipembawe there were allegations of corruption surrounding the movement of cattle into the village – similar to that found by Brockington (2007) in the Rukwa Region, to the west of Mbeya Region. Additionally he found that there was no accountability of taxes – similar to that reported here from Village A. Further examples of corruption at village levels can be found throughout Tanzania (Harrison, 2008). This makes local people unwilling to participate in village governed activities because they do not trust those in charge.

As discussed in Chapter 4, there have been many attempts at governance reform within Tanzania, and therefore people are indifferent or unwilling to fully implement new reforms (Mollel and Tollenaar, 2013). It is unlikely that villagers are aware that they are entitled to participate in decision-making, or indeed that there have been any changes to the governance system; for example one lady during a livelihood matrix exercise thought that Julius Nyerere was still the President.

Similar issues contribute to the failure of the 'cut a tree, plant a tree' initiative to address the high deforestation rates caused by tobacco cultivation. Residents within Kipembawe were aware of the impact that eucalyptus can have on groundwater, and given their perception that water is decreasing in the area already it is hardly surprising that they are reluctant to participate in the reforestation scheme. Similar reluctance has been observed in tobacco growing regions of Pakistan (Otanez, 2008).

This, coupled with the failure of seedlings to be distributed to the farmers at a suitable time in year, and added to a lack of information supplied to the farmers about how to care for the trees, means that failure is almost inevitable. Additionally, many farmers do not believe there is a shortage of timber, lack an incentive to participate in the scheme, and penalties for not participating are not enforced. People often don't realise that over-exploitation is occurring (Acheson, 2006) or fail to connect their actions with changes they are witnessing – only 30% of tobacco farmers thought that tobacco had an impact on the environment.

Many tobacco industry programmes aimed at tackling deforestation have failed (e.g. a BAT reforestation scheme in Kenya (Kweyuh, 1994)). However, the presence of such schemes may impede the efforts of governments to push for alternative crops and government-led reforestation schemes (Otañez and Glantz, 2011), as they are required to do under Article 18 of the 2003 World Health Organisation Framework Convention on Tobacco Control (WHO FCTC) (WHO, 2003). It is estimated that the tobacco industry benefits from more than US$ 64 million annually in costs that should have been made to avoid tobacco related deforestation in the top 12 tobacco growing countries (Otañez and Glantz, 2011). Given that the planting of eucalyptus is detrimental to the environment and may endanger food security by reducing access to fresh water, it may be that implementing this scheme may cause more harm than good, meaning that finding a sustainable alternative to using miombo trees for curing is urgent.

If woodland clearance for tobacco cultivation continues at its current rate in Kipembawe it is unsustainable, and any economic and development gains will be short lived. Not only is it necessary to find alternative methods of curing tobacco to make the practice more sustainable, it is also necessary to find alternative livelihoods for tobacco farmers that will 'pull' them away from tobacco cultivation by provide similar benefits without the associated costs, and this is specified in Article 17 of the WHO FCTC (WHO, 2003). In Kenya tobacco farmers were willing to shift cultivation for another crop, if that crop had an assured market with the opportunity for credit to purchase farm inputs and technical support (Ochola and Kosura, 2007, Altman et al., 1996). Similarly, farmers in Kipembawe were most concerned about market access and profitability, but were willing to change if the benefits they receive from tobacco could be matched.

The data collected on beekeeping shows that it is currently the most viable alternative livelihood. However, beekeeping would not be able to support all farmers. Additionally, beekeeping can be damaging for the forest if bark is stripped from trees to make beehives, resulting in the death of the tree (Chapter 6). While beekeeping is a successful livelihood across the miombo region (Syampungani et al., 2009), it does not go hand in hand with tobacco cultivation. Neonicotinoid pesticides have been linked with decreasing bee populations in Europe (Henry et al., 2012). These pesticides are chemical, but mimic nicotine, a natural insecticide. Köhler et al. (2012) found that nicotine in nectar does not repel bees, even at high concentrations. Only high concentrations appeared to effect the survival rates of worker bees, but it is the effect on colony survival that is most detrimental (Henry et al., 2012, Köhler et al., 2012) because it impacts a range of functions, from foraging skills to orientation (Henry et al., 2012). Therefore it is possible that as tobacco cultivation in Kipembawe expands and wild bee populations are increasingly exposed to nicotine higher mortality rates will ensue. Additionally tobacco crops are treated regularly with insecticides (Baris et al., 2000). This would suggest that actively encouraging beekeeping within Kipembawe whilst tobacco cultivation is so prominent, may be misguided.

Studies have shown that other crops can be more profitable than tobacco (Hu and Lee, 2015) once all costs are accounted for. However, the results presented in this chapter show that finding suitable crops may be challenging. Cashew nuts were suggested as a potential alternative crop. However, the high altitude, moderate rainfalls and sandy soils are not optimal for their cultivation (Kasuga, 2013). Bamboo has been suggested as an alternative to tobacco in Kenya by Kibwage et al. (2008), who found that it can grow well in soil and agro-climatic conditions similar to those favoured by tobacco, and additionally it provided approximately four times the income of tobacco. The suitability of this crop in Kipembawe could be explored. The difficulties in finding alternative crops are well known, particularly by the tobacco industry (IGTA, 2014), who, as it has been shown, exploit this dependence. Access to markets will improve as the road network improves, yet this will also enable extraction of natural resources (such as charcoal) to increase.

The problems associated with tobacco cultivation at both a household scale and within the community are significant. Similar issues including child labour, bonded labour, debt, and illness have been documented throughout the tobacco industry (Hu and Lee, 2015, Lecours et al., 2012). Therefore tobacco cultivation has high costs associated with it, which could be used to 'push' people into alternative livelihoods.

The tobacco industry has pledged to address issues of ill health, labour and debt within the farming communities, yet the evidence from Kipembawe would suggest that such efforts are failing. It must be considered whether these failures are a result of the companies failing to begin the task of implementing mitigation, or whether it is failure of the PCS and in-country branches to educate and enforce these rules. This would make for an interesting follow up study. Whatever the case, it is a failure of the industry as a whole, with some of the most vulnerable people in society being put at risk.

Tobacco cultivation is labour intensive, leaving little time to invest in other livelihood activities as insurance against poor harvests. Therefore tobacco farmers are often trapped in a cycle of poverty and indebtedness (Hu and Lee, 2015), and this situation occurs in Kipembawe. However, there is limited evidence that tobacco growing among smallholders may lead to rural household welfare improvements (Mkwara and Marsh, 2014), and evidence from Kipembawe supports this. There are examples of households in Kipembawe (Box 9.1) being able to use loans obtained through AMCOS effectively, and manage their money to significantly improve their living conditions. Therefore it is possible for tobacco cultivation to be used to alleviate poverty, and this also explains the reluctance of some residents in Kipembawe to turn to alternative crops, which are not proven in the area. Many projects fail because short-term use often provide greater economic benefits than long term, sustainable options (Huettner, 2012). However, once alternative crops have been identified, it may be possible to encourage people to change, using the 'push' of tobacco cultivation and the 'pull' of alternatives.

9.7 Conclusion

While tobacco cultivation within Kipembawe does bring some short-term benefits to some people, it also causes many societal problems, including poor health, increasing HIV rates and alcoholism. Issues concerning child labour and bonded labour need addressing urgently. Tobacco cultivation within Kipembawe is unsustainable, and the development of effective land use management strategies and viable alternative livelihoods is critical. Problems associated with governance and enforcement of the tree planting programme and the Village Land Use Management Plans suggest that creating and attempting to implement a landscape level plan would be met with little success. A first step would be to improve the capacity of local institutions and governments to be able to effectively facilitate a land use management strategy. During this process further research into viable alternative livelihoods is necessary, as is the development of markets. Consultation and liaison with tobacco farmers throughout this process is critical.

Chapter 10

Discussion: Five challenges for sustainable land use management in miombo woodlands

Chapter summary

This chapter draws together the findings of the previous six chapters to examine them as a whole and identifies five emergent challenges to land use management. These challenges are discussed in relation to broader land management strategies and theories. Policy suggestions are made for the development of land management strategies in Kipembawe. Chapter 11 then concludes the thesis, summarising the main findings and suggesting future research opportunities.

10.1 Introduction

The aim of this thesis was 'to investigate rapid land use change in miombo woodland, using holistic case study information from a multi-purpose miombo landscape in Kipembawe, south-west Tanzania. The status, trends and challenges of land use change, biodiversity and ecosystem service provision under varying levels of woodland utilisation were explored to guide future land use management strategies for miombo woodland'. In order to achieve this aim five objectives were developed. These have been addressed in Chapters 4-9, their findings are summarised below, and in Table 10.1.

Land cover and land use change is taking place across the world (Lambin and Meyfroidt, 2011). This thesis has shown that south-west Tanzania is no exception. Chapter 5 demonstrated that deforestation rates in this area are currently 7,260 ha p.a., and that much of this represents permanent conversion from woodland to farmland. This is occurring at the forest (woodland) frontier, and is therefore consistent with wider literature that suggests that significant land use change occurs in these areas (van Vliet et al., 2012). Chapter 4 described the history of Kipembawe, and this history demonstrates the classic pattern (Foley et al., 2005) of a change from swidden agriculture (practised by the Kimba prior to Independence), to permanent settlements (through *ujamaa* and villagisation), and then expanding cultivation as the population grows in the area driven by the economic incentives of a cash crop (particularly since 2001).

Miombo woodland regenerates rapidly (Luoga et al., 2004), and in many areas within Kipembawe the woodland has been disturbed and represents secondary growth. This modification is undetectable through remote sensing (Lambin et al., 2001) but, as demonstrated in Chapter 7, results in an impoverished tree species assemblage. Utilisation of the woodland which extracts timber and non-timber products but does not result in clearing areas is equally undetectable. If this utilisation occurs extensively it can affect species diversity, and reduce the availability of ecosystem services (Chapters 6-8). The inability of remote sensing images to record these types of woodland change results in inaccurate reporting of woodland and forest change (Bustamante et al., 2015), which can mean that opportunities for land use management are missed, and degradation continues to occur, with negative effects for both ecological and social systems.

The main driver of land use change is tobacco cultivation (Chapter 5), both through clear felling to plant crops and extraction of timber to cure the harvested crop. The decision by the Tanzanian Government to concentrate on tobacco as an internationally marketable crop draws the region into the international market, which is often a trigger for rapid land use change (Lambin et al., 2001). Land use change within Kipembawe is occurring increasingly rapidly today, as demonstrated in Chapter 5, and this is likely to continue into the future, as people are drawn to the area to profit from tobacco cultivation (Chapter 4). Immigration to benefit from cash crops is seen elsewhere (Thanichanon et al., 2013), and this population increase also drives land use change, both through agricultural expansion and from provisioning ecosystem service use. A further driver of land use change in this area is through increasing numbers of livestock, which are migrating to the area from other parts of Tanzania (Chapter 5). Pastoralism has contributed to land use change in other areas of Tanzania (Charnley, 1997), and also globally (Mann et al., 2014), particularly when large areas of land are deforested to create pasture or to remove the threat of diseases such as trypanosomosis (Chapter 6). Whilst the presence of pastoralists within Kipembawe does contribute to land use change, it is not the greatest driver. However, the perception held throughout the area that pastoralists are responsible for land degradation detracts from the main cause of it, and means that there is less impetus to reduce deforestation and degradation caused through tobacco cultivation. While there was some evidence that people did not accept that tobacco caused deforestation and degradation, as evidenced through responses to the ‘cut a tree, plant a tree’ programme (Chapter 9), it was also evident that some people were aware of the problems that are caused by it, but that due to the lack of alternatives they feel (and are) unable to do anything about it. The following sections continue to explore the challenges to designing and implementing land management strategies for the miombo woodland landscape in the Kipembawe Division, and how these challenges relate to similar issues elsewhere.

Table 10.1: The research objectives

Objective	Findings	Challenges identified
1. To understand the history, social and ecological context, and contemporary background of the case study area (Chapter 4)	Kimba ethnic group originated in the area – hunter-gathers Very low population densities prior to 1960 Tobacco cultivation introduced in the 1960s Social *Ujamaa* villages established in the 1970s High immigration to the area, in conjunction with increasing tobacco cultivation since 2000 Extensive miombo woodland with low-fertility soils Perception of decreasing wildlife populations Main economic activity is tobacco cultivation Main food crop is maize Land administered by Village Councils Some Land Use Management Plans developed, but little evidence of implementation	High immigration into the area to cultivate tobacco
2. To identify and assess the current drivers of land use change (Chapter 5)	Rapid land use change - approximately 7260ha of miombo woodland cleared annually for tobacco cultivation Approximately 1353ha of this is used to dry tobacco leaves Livestock grazing also contributes to woodland degradation Indirect drivers include rising prices of tobacco, which leads to increasing migration to the area and increasing tobacco cultivation Rising populations result in increasing use of ecosystem services and further cultivation for food crops	No alternative options for drying tobacco
3. To identify provisioning ecosystem services that are used by local communities, their perceived trends in availability and the impact this may have on livelihoods.	A large range of ES are used from the woodland ES are used by all households, regardless of their economic status All households entirely dependent upon firewood for cooking purposes	No access to alternative products currently collected from the woodland – remoteness Increasing population increases demand for woodland products

Objective	Findings	Challenges identified
(Chapter 6)	Most building material extracted from woodland Declines in the availability of firewood, water, honey and grasses perceived Evidence of declining groundwater availability Agricultural expansion perceived as the main cause of decline in availability of ES	
4. To identify and assess the current status of biodiversity focusing on trees and butterflies within sites with differing levels of cultivation and woodland degradation (Chapters 7 and 8)	122 tree species and 104 butterfly species recorded Tree and butterfly diversity, abundance and richness decreased with increasing utilisation Intermediate disturbance effect identified where initially tree abundance and richness increased with disturbance, before declining. This was evident also for butterfly species richness, abundance and diversity *Pterocarpus angolensis* commercially extinct in area Butterflies from the Satyrinae family indicated moderate utilisation	Unknown 'tipping point' where too much utilisation results in the loss of biodiversity, and a reduction in ecosystem service availability
5. To identify local challenges to the implementation of land management plans by assessing current projects, and determining community level receptiveness for new strategies (Chapter 9)	High dependency on tobacco and maize Tobacco cultivation is labour and resource intensive High use of agricultural inputs (fertilisers and pesticides) High income generated Debt cycle established Increased levels of alcoholism and crime Few viable alternative incomes Little evidence of tree planting – demonstrating lack of commitment to pursuing sustainable options Little evidence of enforcement and follow up of tree planting initiative Little evidence of current implementation of land use management plans	Few alternative income options available - remoteness Little capacity to move away from tobacco or to develop other farming methods Low governance capacity - remoteness Weak governance

10.2 Barriers to sustainable land management within the ecoregion

Dewees et al. (2011) discussed eight major barriers (Campbell et al., 2007) to sustainable miombo woodland management across the ecoregion (Chapter 2). These barriers are discussed in relation to findings within the thesis, before the five challenges that have emerged from this research are discussed. The barriers were categorised into four main groups (Dewees et al., 2011).

Two barriers were categorised as 'biophysical barriers'; the first of which is the low inherent productivity of miombo woodland, meaning that sustainably harvesting miombo species is only possible at low levels and overharvesting can lead to severe depletion of individual species. The second is the difficulties in managing woodland for multiple products, such as a range of Non-Timber Forest Products, timber products and beekeeping, where seemingly competing outcomes can lead to conflict. Both of these barriers were identified within this research, where the overharvesting of *Pterocarpus angolensis* has led to it becoming commercially extinct within Kipembawe (Chapter 7). The difficulties of managing the woodland landscape for multiple reasons was evident throughout the thesis; in particular the difficulties associated with collecting honey (beekeeping) in areas where tobacco is cultivated (Chapter 9), and clearance of woodland for tobacco cultivation purposes reducing the availability of provisioning ecosystem services.

The second category is that of 'policy barriers' where two challenges are disenabling forest policies and the marginalisation of the forestry sector (Dewees et al., 2011). Disenabling forest policies are those that prevent local communities from utilising the woodland, and effectively remove the responsibility of management away from the forest users. Such policies are usually part of national level policies, and do not achieve resource protection, instead leading to corruption and disengagement. Ineffective devolution is also seen to reduce the ability of those receiving power to develop and implement policies. Marginalisation of the forestry sector within national policies results in poor funding and reduces the ability of forestry personnel to carry out their duties (Campbell et al., 2007). Disenabling forest policies as described above were not identified within Kipembawe, because although policies are in place that could have such an effect they are not enforced. However, both ineffective devolution and marginalisation of the forestry sector were evident, and are discussed in Chapter 9 in relation to the difficulties faced in Participatory Forest Management projects and the lack of resources available to both the Forest and Wildlife Departments to enable them to carry out their roles.

The third category is ‘economic barriers’, where the two barriers are cash constraints, which lead to a preference for rapid exploitation of the woodland, and low margins of forest management, where management and transaction costs are high. Cash constraints are related to low incomes, where opportunities to increase incomes often comes through rapid exploitation of woodland resources, at the expense of sustainability. This occurs within Kipembawe, where farmers can choose to cultivate tobacco, which has a high income incentive but results in unsustainable utilisation of the woodland (Chapter 9). As also discussed in Chapter 9, the lack of alternative income options effectively removes farmers’ ability to ‘choose’ to cultivate tobacco. The limited active forest management within Kipembawe did not enable margins and management costs to be determined.

The final category is that of ‘organisational barriers’ and describes weak local and national organisations. These include a lack of clear and accepted local rules and regulations, elite capture and resource grabbing (Dewees et al., 2007). Weak national forestry organisations which focus mainly on timber production was also listed as a barrier (Campbell et al., 2007) to developing management policies that address other woodland products. The lack of clear and accepted rules was evident both for the ‘cut a tree, plant a tree’ programme, and for the movement of cattle into the area. Weak governance was evident throughout the Kipembawe Division, and is identified as one of the five major challenges to land use management (section 10.3.5).

The barriers identified by Campbell et al. (2007) relate directly to the management of miombo woodland. This thesis took a holistic approach to identify challenges for sustainable land use management across the landscape, drawing from both the social and ecological systems. These challenges are discussed below.

10.3 The five challenges in Kipembawe

Five major interlinking challenges have been identified across the six results chapters: the lack of knowledge regarding the ecological ‘tipping point’, lack of alternatives, high immigration rates, remoteness, and weak governance. The first is ecological and will affect the design of a land use management plan: poor understanding about the relationship between utilisation and biodiversity – the ‘tipping point’ where too much utilisation results in decreasing biodiversity. The second is social, and also relates to design: a lack of alternatives - alternative income options, alternative products to those collected from the woodland, and alternative curing options for tobacco. The third relates both to design and to future implementation: an increasing population through immigration. The differing perspectives of migrants need to be considered in the design of a land use strategy, but increasing populations will affect design and implementation in the future, and require monitoring to enable strategy adaptation, probably to a greater extent than tipping points and alternatives. The fourth challenge relates to implementation, but its impact on alternatives is also considerable: the remoteness of the area. The final challenge is associated with implementation: the lack of local capacity and weak governance. Each of these challenges is discussed below in relation to land management within Kipembawe, and it is also considered in relation to the broader literature.

10.3.1 Ecological ‘tipping point’

Chapters 7 and 8 identified an intermediate disturbance effect, where the diversity of butterflies and trees initially increased with disturbance (quantified by assessing human utilisation of the woodland), before decreasing while disturbance continued to increase. This led to the conclusion that some disturbance within the system can be tolerated. However, with the three relatively broad categories used to determine this (low, medium and high disturbance) the point where acceptable disturbance became too much disturbance could not be identified (the ‘tipping point’).

Tipping points are recognised within a range of ecological processes, and represent the point at which an ecological threshold is crossed and a regime shift occurs, when the system shifts radically and potentially irreversibly into another state (Brook et al., 2013). The loss of resilience with the system can result in the tipping point being reached (Dakos et al., 2015, Dai et al., 2012). Loss of resilience can occur for a range of reasons, such as pollution, degradation and land use change, which can happen over both long and short periods of time (Folke et al., 2004). In the case of miombo woodlands such a shift will not only occur as a result of increasing utilisation; the system could have low resilience as a result of land use change, and an event such as fire could shift the system into another state if it cannot recover.

Tipping points are present at local to global scales, as a response to a range of drivers including climate change, habitat loss, overexploitation and invasive species (Andersen et al., 2009). Planetary boundaries are an example of tipping points at global scales. This concept outlines safe spaces in the Earth System within which humanity can operate and maintain the current stable environment (Rockström et al., 2009). These spaces are associated with nine physical subsystems or processes, including the rate of biodiversity loss, climate change, global freshwater and change in land use (Rockström et al., 2009). Within these processes thresholds – or 'tipping points' have been identified, and should these thresholds be crossed it may result in major disruptions within the system that could result in a shift to another state, with unknown global consequences (Biermann, 2012). As with the miombo woodland system in Kipembawe, it is vital to know where the tipping points are in order for management to be implemented so that these points are not reached. A key part of this is to understand the resilience of the system, and this is relevant to Kipembawe, where the observed increase in biodiversity with disturbance may lead to planned utilisation of the woodland as part of a sustainable land use strategy. However, without understanding where the tipping point is – i.e. how much the woodland can be utilised before resilience is too low and further utilisation or shocks will result in decreasing biodiversity – will make determining utilisation levels very difficult. Allowing too much utilisation will result in biodiversity loss which will lead to a reduction in available ecosystem services, but equally allowing only very low utilisation may mean that households suffer from a lack of available services. This demonstrates the importance of identifying ecological tipping points to land management planning, and the need for further research on this subject.

10.3.2 Lack of alternatives

The lack of alternative options to current income generating activities was a reoccurring theme throughout the research findings. Chapter 5 identified a lack of alternatives for curing tobacco, which means that tobacco is dried using timber from the woodland, leading to deforestation and degradation. Chapter 9 found that there are limited alternative income options that pay as well as tobacco, meaning that the majority of households farm tobacco, the leading cause of land use change in the area. Chapter 6 showed that there are few alternatives to woodland products, such as rope and building materials, and their extraction from the woodland contributes to degradation.

To reduce the impact of tobacco on the woodland it is necessary to both use more efficient methods to cure the tobacco leaves, and also to reduce the number of people who cultivate tobacco. As discussed in Chapter 5, rocket burners have been introduced in Kipembawe that are 43.6% more efficient than traditional burners (Musoni et al., 2013), but building of these burners remains slow. An additional option is to use wood grown for this purpose, as is the intention of the 'cut a tree, plant a tree' programme (Chapter 9), which is having little success. In other countries different fuels are used for flue-cured tobacco. In America most burners are oil, natural gas or liquid petroleum gas (LPG) (CAES, 2015), and in Asia biofuels from waste such as rice husks, sawdust and candlenut shells are being used (BAT, 2015). The remoteness of Kipembawe and the lack of available fuels render many of these options unsuitable. However, encouraging the building of rocket barns will help to reduce fuel consumption, and further improvements to barn efficiency are likely (Musoni et al., 2013).

To reduce the number of tobacco farmers alternative income options are necessary. Providing alternative livelihoods or income streams is an approach that aims to relieve pressure on an exploited resource by substituting a livelihood strategy that is causing harm for one that has a more positive outcome (Roe et al., 2014). Currently there are no realistic, robust and viable livelihood alternatives with suitable markets identified within Kipembawe other than honey production, and this is limited by poor markets, close proximity to tobacco, and declining bee populations (Chapter 9). Accessible markets where farmers can participate and receive competitive process for their products are critical for their ability to raise their incomes (Markelova et al., 2009). Currently there are no such markets for cash crops (or food crops) in the area other than tobacco, and without markets there are no guarantees of a stable income, or one that can compete with the prices offered by tobacco. Finding alternative income options that can compete with cash crops is a common problem, particularly in remote rural areas (Baudron et al., 2009). In addition to economic incentives alternative options should also cohere to cultural beliefs, values and social relations in order for them to be successful (Runk et al., 2007). Ultimately the price of tobacco is linked to global markets, and while this remains high there is greater incentive to cultivate tobacco. Once this price drops households will be more inclined to switch to different crops. However, waiting for this to happen will not solve deforestation issues, and therefore proactive approaches are necessary. Similar challenges arise around protected areas, vulnerable watersheds and fragile environments. The provision of alternative livelihoods that improve human well-being and reduce over-exploitation of forest resources and other land resources is the foremost management challenge in much of the biodiversity-rich developing world (DeFries et al., 2007); Kipembawe is no exception.

Whilst tobacco is the greatest driver of deforestation within Kipembawe, the extraction of other resources such as poles, timber and grasses for construction purposes, and harvesting bark and roots for beehives and rope also cause degradation (Chapter 6). These products are harvested from the woodland because there are no alternative sources for them, they are free to access, and they are currently widely available. The extraction of these products could be regulated to reduce degradation. In other natural resource management projects such as REDD+, and Community Based Natural Resource Management schemes such as Participatory Forest Management, NTFPs are sold and promoted as alternative livelihoods (Belcher et al., 2005). However, it has become increasingly recognised that this policy is not appropriate everywhere (Ros-Tonen and Wiersum, 2005), and in Tanzania such an approach usually has low economic returns because there is a lack in high-value products (Khatun et al., 2015). While further infrastructural development in Kipembawe, such as improved roads and shops, may bring alternative products to the area, and therefore reduce extraction from the woodland, for the foreseeable future there will be not be alternatives that are readily available and within households' purchasing power.

The lack of alternative livelihoods and products causes communities to act in ways that are not sustainable. Many respondents in Kipembawe (Chapter 6) recognised that the environment is affected by resource extraction, but they are unable to act upon this to reduce the impact; the lack of alternatives forces the rural poor to prioritise their short term needs – such as feeding their families – over long term sustainability (Dawson et al., 2010, Butz, 2013). This is hugely significant for natural resource management efforts, because until there are stable, sustainable and economically valid alternatives, local communities will have no choice but to continue to cultivate and collect woodland products to sustain their livelihoods, whatever the cost to the environment. This is a critical challenge for the development of land management strategies in Kipembawe, and further research is required to identify alternative opportunities (Chapter 11). Until suitable alternatives are identified action must be taken to ensure that current livelihood activities are as sustainable as possible, and that resource extraction is managed sustainably.

10.3.3 High immigration rates

Migration to the agriculture/forest frontier resulting in subsequent deforestation to create and expand agriculture is considered as one of the greatest drivers of deforestation worldwide (Carr, 2009). In Kipembawe the majority of households surveyed had migrated to the area (Chapter 4), and most people are economic migrants, moving to the region to profit from tobacco cultivation. While much focus has been on rural to urban migration and international migration, rural to rural movements are significant (Carr, 2009). In developing countries the largest proportion of migrants moves between rural areas (de Haan, 1999) and this group has a proportionately large impact on global deforestation (López-Carr and Burgdorfer, 2013). The forest frontier is the edge of forest or woodland that leads to undisturbed forest. Migration is driven by a combination of push and pull factors at different scales (Hartter et al., 2015), such as abundant available land which encourages people to move to the area (López-Carr and Burgdorfer, 2013) and economic opportunities (Sunderlin et al., 2005). This is the case in Kipembawe, where people have moved from other areas of Tanzania to the miombo woodland frontier. The lack of secure land tenure was evident in the area, where people chose an area of land and settled there, rather than seeking guidance from the village council. This is a common result of poor land tenure, and often results in clearance of greater areas of land than necessary in order to indicate occupancy (Unruh et al., 2005).

Migrants have been described as 'exceptional resource degraders' due to short-term horizons which aim to make rapid economic gains without considering the long term effects of resource extraction, leading them to expand farmland rapidly (Codjoe and Bilsborrow, 2012). Additionally inappropriate technology (fertilisers, pesticides, crop choice) may be used, due to lack of knowledge about the area (Perz, 2003). A reduction in local agrobiodiversity is often matched with by a decline in informal knowledge in the area due to a lack of knowledge transfer to incomers (Perrings et al., 2006). People who have migrated to the area may not have social ties, or an interest in preserving it for future generations, and therefore see the land as available for exploitation, particularly if they do not intend to settle in the area permanently (Codjoe and Bilsborrow, 2012). Within miombo areas increasing populations have been directly coupled with degradation (Grogan et al., 2013, Leventon et al., 2014), and this is the case in Kipembawe too, with rapid land use change occurring through woodland exploitation to gain the high profits available through tobacco cultivation. Throughout the social survey it was possible to detect a lack of connection with the environment, and some people also explained that they would leave the area if they were unable to continue to grow tobacco. However, the majority of respondents surveyed were concerned about the future and a reduction in available resources, demonstrating that although the impacts of migration should be considered in land use management strategies not all migrants wish to exploit the area and move on. However, there is no evidence to suggest that the tobacco companies are committed to the area; it would be simple for them to move to another region once cultivation in Kipembawe becomes unprofitable as they have elsewhere (Lecours et al., 2012). This may explain the lack of commitment demonstrated in implementation of their reforestation programme.

Many studies concern migration into and around protected areas (Hartter et al., 2015), within tropical rainforests, and predominantly in South America (Carr, 2009, López-Carr and Burgdorfer, 2013, Caviglia-Harris et al., 2013), so this study is novel in that it identifies the impact of migration into tropical dry woodlands in open access areas. The importance of migration has yet to be fully incorporated into the LULCC literature (Carr, 2009), and a full understanding of the political, demographic, social, economic and ecological drivers is necessary in areas of high immigration before suitable policies can be developed (López-Carr and Burgdorfer, 2013). Within Kipembawe land use management strategies should take into consideration the effects of migratory community, who are in the area with a dominant goal of generating income, and are therefore unlikely to respond favourably to initiatives that may curtail tobacco cultivation. It may not be appropriate to use ‘bottom up’ approaches to land use management if there is likely to be conflict between personal profit and long-term sustainability of the ecosystem. Therefore a range of considerations need to be incorporated into a land use management strategy, and this may contain top-down enforcement of regulations.

An additional issue associated with high levels of immigration is a rapidly increasing population; the District of Chunya currently has a population increase of 3.5% p.a. (Chapter 4). Rapid population growth will have several impacts on the landscape. There will be more people cultivating tobacco, leading directly to increasing deforestation rates (Chapter 5), and increasing demands on provisioning ecosystem services, particularly firewood and water (Chapter 6), which may lead to decreasing food security (Mazet et al., 2009, Poppy et al., 2014). There will also be greater competition for land (Chapter 9). Population growth is recognised as a key driver of global land use change, both historically (Klein Goldewijk et al., 2011) and today (Foley et al., 2011). Land management strategies will need to plan ahead for continued population growth.

The effects of immigration will need to be taken into account in planning, implementation and monitoring.

10.3.4 Implications of remoteness

The impact of the geographical location of an area in relation to other areas is rarely discussed in the academic literature. There are many studies that address 'rural' and 'urban' areas, but very few consider what is actually meant by 'rural', and that some areas can be more remote than others, with poor access to markets, services and infrastructure (Barbier, 2012). Very little research has focused on farmers in such remote rural areas (Paniagua, 2013), and that which does tends to focus on poverty levels (Minot, 2008). Kipembawe is a remote rural area. It lies in one of the most inaccessible areas of Tanzania, and is far from the headquarters of the local government and police forces (Chapter 4) which means that it is overlooked by institutions and government. Several Government employees at both District and Regional levels had never visited the area, despite representing it and being responsible for policy dissemination.

The remoteness of the area has two main implications for land management strategies. The first is the development of alternative livelihoods and incomes, for which access to markets is required. The distance of the division from markets means that transportation costs are high; and this is compounded by poor access (poor quality roads), which tends to increase the price again (Porter, 2002). This means that markets are hard to establish, and leave rural areas vulnerable to traders who can pay low prices due to a lack of competition (Porter, 2014). Greater accessibility increases the influence of markets, and local livelihoods improve with increasing accessibility (Thanichanon et al., 2013). Access to resources and services is a problem throughout rural sub-Saharan Africa, and rural transport is the worst in the world (Porter, 2002). Remoteness and access also influence access to alternative woodland products, healthcare, education, credit facilities and banks (Linard et al., 2012), all of which are affected within Kipembawe.

Accessibility also affects governance; with accessible areas being more influenced by government than remote areas (Thanichanon et al., 2013). The lack of engagement and visits to Kipembawe by government representatives results in a failure to monitor the implementation of policies, lack of awareness of failures in decentralisation, and dis-engagement within the community. The inability of forestry and wildlife officers to visit the area results in resource exploitation. Within Kipembawe the lack of a police force also means that the laws of the land can be regarded loosely, and this can lead to social uncertainty. Weak local institutions and lack of trust limit the ability to act collectively, and this is seen in other areas of Tanzania (Mathur et al., 2014). Such a *laissez-faire* attitude towards governance, rules and regulations by the government also influences local village level governing committees, who do not have an example of good governance to follow. This leads to a lack of enforcement of locally stipulated rules, e.g. forest management.

The remoteness of Kipembawe will be a challenge both to the development of a land management plan in terms of developing alternative income options, and also in its implementation, due to high costs and poor access for monitoring and support. While improving the road network may solve these issues, it is also likely to create further woodland degradation, as providing access to natural resources results in their extraction (Laurance, 2015), creating further challenges for land management.

10.3.5 Weak governance

The governance of natural resources has been of particular academic interest and debate since *the tragedy of the commons* was published (Hardin, 1968), which highlighted that common-pool resources were likely to become depleted if individuals continued to use them for their own purposes, rather than managing them collectively for the common good. Intensification of utilised land throughout the 20th century saw increased degradation of areas under customary land tenure and communal areas (Chidumayo, 2002). Within the Kipembawe Division the majority of woodlands are common-pool resources, with no restrictions on access or use, and no guidelines in place to prevent over-utilisation.

Given that rapid land use change is already occurring in the area it is clear that some form of governance is required over these resources to ensure that such utilisation is sustainable. In order to determine how successful the implementation of sustainable land use projects will be it is necessary to understand the effectiveness of different governance structures across state governments, civil society, and corporate organisations (Meyfroidt et al., 2013), and to determine who is responsible for the governance of different protected areas and any new programmes (Poppy et al., 2014).

Chapter 9 identified and assessed three forms of governance in the area, and found that there were significant failures throughout, resulting in ineffective policy implementation. The main problems included a lack of funding, staff and equipment; top-down approaches that did not engage with the local communities; poor planning and initial implementation of projects; and no plans to maintain the projects beyond the initial implementation. Additionally corruption and a lack of trust in the governance structure by local communities were evident. Similar examples of weak governance are found through forest management within other parts of Tanzania (Luoga et al., 2005).

Governance is recognised as being influential on national scales, where weak governance appears to reduce biodiversity (Lira-Noriega and Soberón, 2014, Smith et al., 2003). At the local level, control over the forest is increasingly being handed to local authorities and communities, through devolution and government decentralisation. Decentralisation is the dispersal and de-concentration of government administrative and financial functions from national to local levels, and is accompanied by a greater involvement of civil society, international agencies and other organisations (Zimmerer, 2007). However, forest communities are often unprepared, and have low literacy and a lack of formal planning experience (Evans et al., 2010) and this lack of capacity reduces the chances of success of management projects. The PFM efforts to date within Kipembawe appear to be donor driven, and although planning and decision making powers have been devolved to villages there is a lack in capacity to implement the policies (Chapter 9). While such formalised local participation is viewed as a key mechanism to provide incentives to use forests wisely, with stronger accountability and legitimacy of rules (Persha et al., 2011), it will not be successful if there is no support and training, both in initial phases and into the long term. Adaptive co-management (section 10.5) has been advocated as a successful strategy for resource management and biodiversity conservation (Kenward et al., 2011); and this is probably the only viable option in Kipembawe, where neither government staff or local communities have experience or training of designing and implementing land management plans.

10.4 Possible management approaches

Forest governance problems where the state lacks resources to implement programmes, the area is too remote to effectively govern, or where there is a lack of knowledge to effectively design and implement a management programme are frequently found (Lejano et al., 2007, Lambin et al., 2001). Land use sharing and sparing are frequently proposed as possible landscape-scale approaches for increasing crop yields but also conserving biodiversity (Chapter

2), where ‘sparing’ sets some land aside for biodiversity and intensifies production in the remaining habitat, and ‘sharing’ extends the amount of land utilised, has a lower productivity and maintains some biodiversity. Which strategy is followed depends on the characteristics of the landscape, including other land uses and the responses of biodiversity to utilisation. To achieve multiple goals (e.g. increased yields, biodiversity conservation, food security, sustainable livelihoods) it is necessary to integrate across all relevant social and temporal scales, and to involve all relevant stakeholders (Poppy et al., 2014). No single framework can capture all the nuances of the system across multiple scales (Poppy et al., 2014) and therefore an integrated landscape approach is necessary, particularly for an area such as Kipembawe which is at the forest –agriculture interface (Tscharntke et al., 2005). Due to the variety of land use demands within Kipembawe, an integrated land management approach based upon the land sharing/sparing concept may be suitable.

This thesis has described the land use requirements for Kipembawe, and has assessed the response of biodiversity to utilisation. Chapters 7 and 8 demonstrated that moderate levels of utilisation within the miombo system led to increased species richness, diversity and abundance of both trees and butterflies, which can be used as indicators of biodiversity in general (Fleishman et al., 2005). This would suggest that a land sharing option for miombo woodlands would be appropriate. However, as discussed in section 10.2.1, there is a major caveat to this - the lack of identification of a ‘tipping point’ where too much utilisation would result in significant biodiversity and ecosystem service loss, which would be detrimental to the long term sustainability of the system.

Dealing with uncertainties is recognised as a key challenge in natural resource and environmental management, and options for how to handle them are many, and depend on available information (Doremus, 2007). Here the information that is available suggests that some utilisation is tolerated within the system, but too much causes harm. Therefore a precautionary approach (an approach invoked specifically to avoid negative outcomes (Woodward and Tomberlin, 2014)) could be adopted until further research enables the detection of ecological thresholds along disturbance gradients, which will enable management to be informed by predictive science (Sasaki et al., 2015).

This would involve management to ensure that levels of utilisation within the woodlands are kept to a minimum, and therefore access and resource extraction would be strictly regulated.

However, as demonstrated in Chapter 6, woodland resources are heavily relied upon by local communities, and consequently this approach would be unsuitable. Therefore a combination of land sharing and land sharing may be more appropriate, where some land is set aside and not utilised, and other land is utilised at low to medium levels. This would require an adaptive management strategy, which requires careful monitoring, and could be adapted as new information on the ecological tipping point (and alternative crops, increasing population etc.) becomes available.

10.5 The need for adaptive co-management

As indicated above, there remain some aspects within the Kipembawe landscape that are not fully understood, such as the tipping point within the ecological system. Waiting until a full understanding of the system is attained before managing the system may lead to irreversible change, and management intervention may not be able to achieve sustainability. Therefore an iterative management approach which can be adapted as a greater understanding is gained and people learn and situations change is appropriate (Stringer et al., 2006). Most integrated land use management strategies adopt an adaptive management approach (Estrada-Carmona et al., 2014), because there are many unknowns in the system, and many actions that take place can result in change – for example, sustainable management with secure land tenure and improved development may become a further incentive for immigration, and numbers of migrants will increase further (Scholte, 2003). Adaptive management is suitable for maintaining multiple objectives over time, and can encourage social learning and multi-stakeholder dialogue, from the bottom up and top down (Guariguata et al., 2012). This is particularly necessary in a setting such as Kipembawe, where the migratory nature of residents may limit engagement in sustainable management efforts. Therefore initially a top-down approach may be necessary, but participation and engagement at grassroots level should be encouraged, and their role within management expanded. This approach is best described as adaptive co-management, where collaboration is encouraged between policy makers, communities and multiple levels of governance (Armitage et al., 2008), and a process of shared learning leads to adaptive decision making. Adaptive co-management is appropriate for integrated landscape management approaches with multiple objectives (Milder et al., 2014) which are suggested for the Kipembawe Division.

10.6 Next steps and policy recommendations

The next steps for the design, implementation and monitoring of a land use management strategy within the Kipembawe Division are demonstrated in Figure 10.1. Immediate action can be taken to strengthen local governance and capacity, which will enable current management efforts to improve. This could include the provision of vehicles to the Forest and Wildlife Officers to enable them to run patrols and enforce regulations on timber extraction and poaching. Funding the PFM committees to enable them to regulate utilisation within the reserves would also be beneficial. As local governance is strengthened it will increase the capacity of the local area to implement further land management plans. Environmental education and encouraging participation in current mitigation activities such as the take up of rocket burners will also be beneficial.

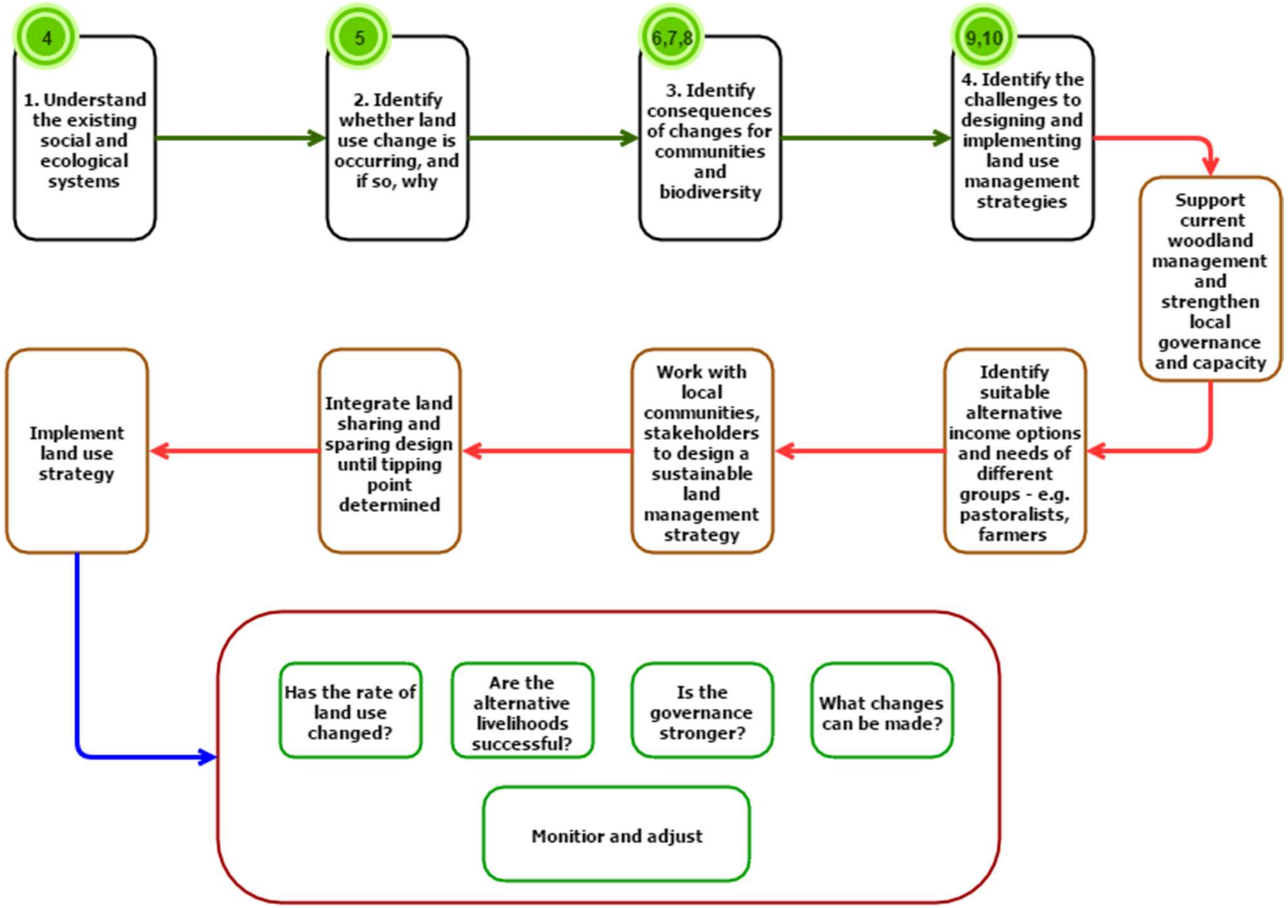

Figure 10.1: Research, design and planning for land use management strategies for the miombo woodland in Kipembawe. Boxes in black and green arrows have been completed and have been presented in this thesis. Numbers in circles represent chapters. Boxes in brown with red arrows demonstrate the next steps in research, design and implementation of a land use strategy. The maroon box with the blue arrow represents some key questions for long term monitoring and adaptive management.

Further research to ascertain the tipping point and development of alternative income options would be necessary. At the same time, community engagement and development of a land management strategy can begin. Following the implementation of the strategy constant monitoring and adaption of the programme will be required through adaptive management. Brief suggestions for policy recommendations are synthesised below.

Immediate action

- Strengthen capacity within District and Local government through the provision of funding for transport to enable patrols of forest reserves to take place
- Uphold regulations for extraction of natural resources
- Engage with the local community to develop understanding for the need for management through village meetings, focus groups and agricultural extension officers.
- Identify the aims of a land use management plan through consultation with stakeholders (e.g. biodiversity conservation, development, agricultural productivity etc.)
- Work with the Primary Cooperative Societies and tobacco companies to encourage the building of rocket burners to cure tobacco
- Work with the tobacco companies and nurseries to use less water-dependent tree species for reforestation programmes
- Work with regional and district officers to develop alternative livelihood options and secure markets
- Work with universities (e.g. the Sokoine University of Agriculture, where there is a miombo woodland facing research team) to facilitate research on tipping points

Medium term

- Design a landscape management strategy through an adaptive co-management approach, continuing to engage and work with local communities and other stakeholders in design
- Learn from current schemes in the area (‘cut a tree, plant a tree’, village land use management plans)
- Secure funding and define a long term plan for management
- Continue to strengthen local capacity and governance

Long term

- Implement the management strategy
- Monitor land use change, alternative livelihoods, deforestation rates etc.
- Monitor population growth
- Monitor biodiversity changes (butterfly and trees)
- Continue to adjust and adapt the land use strategy.

These are not exhaustive suggestions and further consultation for the design and development of a land use plan is necessary. Sustainable forest management within miombo woodlands is challenging. While five major challenges have been defined here, further challenges lie ahead in the development and design of a land management plan, where biodiversity conservation, agricultural requirements and ecosystem services must be balanced against each other.

Chapter 11

Conclusion

Chapter summary

This chapter concludes the thesis, summarising the findings and highlighting the main contributions. Further research suggestions are made that could increase the effectiveness of future land use management strategies and compliment the research presented.

11.1 Introduction

This thesis has provided new insights on rapid land use change in miombo woodland, determining the status, trends and challenges of land use change for biodiversity and ecosystem service provision. It provided a holistic, landscape level case study of the miombo woodlands in the Kipembawe Division, south-western Tanzania, using mixed methods through an exploratory, interdisciplinary approach. The thesis began by describing changes that occurred in the area post-independence, in the late 1960s and 1970s. During this period the cultivation of tobacco was encouraged, and today tobacco remains the main cash crop in Kipembawe, attracting migrants to the area to cultivate it. Tobacco cultivation was identified as the main driver of land use change through deforestation and woodland degradation as the land is cleared to plant the crop, and trees are harvested to dry the tobacco leaves. Due to the expansion of tobacco cultivation this land use change is occurring rapidly, and should it continue at the current rate the woodland in this area will disappear in just over a century.

The miombo woodlands provide over 17 provisioning ecosystem services to the local population, which are used by the majority of households because the area is remote and access to alternative products is limited. The availability of some of these products is decreasing as a result of these land use changes and increasing demand, particularly for firewood and grasses.

Changes in the water table were also evident, and this could have implications for food security in the area. Additionally the collection of these products degrade the woodland. However, although comprehensive surveys of tree and butterfly communities demonstrated declines with increasing utilisation, there was evidence of an intermediate disturbance effect, where species richness, diversity and abundance initially increased with increasing utilisation, indicating that management of the land which restricted utilisation to moderate levels may enable multiple outcomes for agriculture, ecosystem services and biodiversity conservation to be achieved. Finally, it examined how practical the implementation of such a management plan would be, by examining current programmes and capacity within the area. Programmes and policies in place today are flawed and failing, and considerable improvements in capacity and governance are required. The thesis identified five major interlinking challenges to the development of land management strategies: the impacts of a migrant-based society, poor governance, lack of alternative livelihoods, lack of knowledge about the tipping point within the miombo system, and the remoteness of the area. Despite these considerable challenges to achieving sustainable land management, local communities acknowledge that the area is becoming degraded and would be receptive to reform, if they were part of the process and could see tangible benefits both in the short and long term. With the right approach to land management in this area, it will be possible to achieve sustainable land management in the Kipembawe Division.

11.2 Knowledge contributions

This thesis has presented six empirical chapters which have fulfilled five research objectives, each providing new information:

Objective 1 (Chapter 4):

This chapter presented the first known account of the Kipembawe Division since the 1970s. It provides descriptive historical and contemporary details, particularly highlighting the influence of tobacco within this part of south-west Tanzania, which is not documented elsewhere.

Objective 2 (Chapter 5):

This chapter provides estimations of the amount of wood that is used to cure tobacco. This contributes to the literature surrounding the impact of tobacco cultivation on deforestation, broadly supporting claims of high deforestation and woodland degradation rates.

Objective 3 (Chapter 6):

This chapter determined that in contrast to studies elsewhere that household income is not the greatest influence on the use of provisioning ecosystem services within miombo woodland, but that remoteness and access to alternative products plays an important role. It also found that land use change and population increases are resulting in decreasing availability of some provisioning ecosystem services, such as firewood and water, which may lead to food insecurity.

Objective 4 (Chapters 7 and 8):

These chapters presented original empirical data on the miombo woodland tree and butterfly communities of south-western Tanzania, showing that both taxa demonstrate an intermediate disturbance effect. Chapter 7 identified the near-threatened tree species *Pterocarpus angolensis* as commercially extinct in this area, and Chapter 8 identified butterflies from the family Satyrinae as indicators of woodland degradation.

Objective 5 (Chapter 9):

This chapter assessed current environmental and land use facing programmes that are taking place within the Kipembawe Division, and identified challenges associated with governance and funding. The negative aspects of tobacco cultivation are often reported, but the benefits received by farmers and the community are not widely documented. They are reported here alongside the negative aspects to give a balanced view of the choices that tobacco farmers must make, and the challenges that must be overcome to develop and sustain alternative rather than additional incomes.

Chapter 10:

Five key barriers to land management design and implementation are presented: the lack of knowledge of tipping points for biodiversity within the miombo woodland; the lack of alternatives for curing tobacco, generating income and accessing products; high immigration; the remoteness of the area; and weak governance. Policy recommendations are made to suggest how these challenges can be addressed, and how a land management strategy could be designed and implemented.

11.3 Suggestions for further research

This thesis has provided empirical data to assist in the development of land management plans within a miombo woodland landscape in south-west Tanzania. Throughout this process several knowledge gaps have been identified where further research could aid the development and implementation of land management plans, as outlined below:

- Determination of the ‘tipping point’ within the intermediate disturbance effect – where too much disturbance results in the decrease of species richness, abundance and diversity. This information will enable land management plans to utilise woodland sustainably.

- Identifying suitable alternative livelihoods for farmers in this area is necessary. Options must be robust, and climate-proof. Suitable markets need to be available, and profits ideally need to match those gained through tobacco cultivation.

- Working with communities to encourage them to think about the future through scenario building. Evans et al (2010) used this approach to produce a community dialogue about diversifying their activities and decreasing dependency on a single product. It will also help them to understand why land management is necessary, and enable them to contribute fully to land management planning and implementation.

- A further issue that may affect land use in this area in the future is the development of roads, and infrastructure in the area. Improved access to the woodland may increase demand for charcoal, which could lead to severe woodland degradation. Predicting this, and in particular the likely timescale, would assist land management plan development.

- The impact of climate change on this area was beyond the scope of this study. However, in order for a land management plan to be resilient to climate change and sustainable for the future it is necessary to understand how climate change will affect this area, and this will guide the development of suitable alternative livelihoods.

The miombo woodland landscape within the Kipembawe Division needs to be sustainably managed in order for it to continue to support the livelihoods of the local communities and maintain biodiversity. This thesis has identified the main challenges that need to be addressed to do this, and consideration of the points outlined above will provide further information to enable a suitable strategy to be developed and implemented. While this research was based on a case study, aspects of this study are applicable to miombo woodland throughout the miombo ecoregion.

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Appendices

Appendix A: Ethics clearance

Performance, Governance and Operations
Research & Innovation Service
Charles Thackrah Building
101 Clarendon Road
Leeds LS2 9LJ Tel: 0113 343 4873

Email: j.m.blaikie@leeds.ac.uk

UNIVERSITY OF LEEDS

Eleanor Jew

PhD student

Sustainability Research Institute
School of Earth and the Environment
University of Leeds

Leeds, LS2 9JT

AREA Faculty Research Ethics Committee

University of Leeds

14 November 2012

Dear Eleanor

Title of study: **Managing miombo woodland for multiple benefits: Assessing land use options in southern Tanzania**

Ethics reference: **AREA 12-026**

I am pleased to inform you that the above research application has been reviewed by the ESSL, Environment and LUBS (AREA) Faculty Research Ethics Committee and following receipt of your response to the Committee's initial comments, I can confirm a favourable ethical opinion as of the date of this letter. The following documentation was considered:

Document	Version	Date

AREA 12-026 Ethical review response E Jew.docx	1	13/11/12
AREA 12-026 Ethical_Review_Form_ E Jew.doc	1	26/10/12
AREA 12-026 High Risk Fieldwork RA form E JEW.doc	1	26/10/12
AREA 12-026 Risk assessment form for PhD fieldwork.txt (email)	1	26/10/12
AREA 12-026 Letter to villages.doc	1	26/10/12
AREA 12-026 Consent form - workshop.doc	1	26/10/12
AREA 12-026 Consent form - Questionnaire.doc	1	26/10/12
AREA 12-026 Consent form - key informant.doc	1	26/10/12
AREA 12-026 Consent form - focus group.doc	1	26/10/12
AREA 12-026 Consent form - farm visit.doc	1	26/10/12
AREA 12-026 Confidentiality and Anonymity Agreement - translator.doc	1	26/10/12

Please notify the committee if you intend to make any amendments to the original research as submitted at date of this approval, including changes to recruitment methodology. All changes must receive ethical approval prior to implementation. The amendment form is available at

http://researchsupport.leeds.ac.uk/index.php/academic_staff/good_practice/managing_approved_projects-1/applying_for_an_amendment-1.

Please note: You are expected to keep a record of all your approved documentation, as well as documents such as sample consent forms, and other documents relating to the study. This should be kept in your study file, which should be readily available for audit purposes. You will be given a two week notice period if your project is to be audited. There is a checklist listing examples of documents to be kept which is available at

http://researchsupport.leeds.ac.uk/index.php/academic_staff/good_practice/managing_approved_projects-1/ethics_audits-1.

Yours sincerely

Jennifer Blaikie

Senior Research Ethics Administrator

Research & Innovation Service

On behalf of Dr Emma Cave

Chair, AREA Faculty Research Ethics Committee

CC: Student's supervisor(s)

Appendix B: COSTECH Research Permit

TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY (COSTECH)

Telephones: (255 - 022) 2775155 - 6, 2700745/6
Director General: (255 - 022) 2700750&2775315
Fax: (255 - 022) 2775313
Email: rclearance@costech.or.tz

Ali Hassan Mwinyi Road
P.O. Box 4302
Dar es Salaam
Tanzania

RESEARCH PERMIT

No. 2013–21-NA-2012-216 **15th January 2013**

1. Name : **Eleanor Jew**

2. Nationality : **British**

3 Title : **Managing Miombo Woodland for Multiple Benefits: Assessing Land use Options in Southwest Tanzania**

4 Research shall be confined to the following region(s): **Mbeya**

5 Permit validity: **15th January 2013 to 14th January 2014**

6. Contact /Collaborator: **Prof. Pantaleo Munishi, Department of Forest Biology, Faculty of Forestry and Nature Conservation, SUA, P.O. Box 310, Morogoro**

7. Researcher is required to submit progress report on quarterly basis and submit all Publications made after research.

M. Mushi

for:DIRECTOR GENERAL

Appendix C: Household Survey for Head of Household

Landuse and perceptions in the Kipembawe Division

A: Identification

Date:	Time: Start: Finish:
Researchers:	Notes:

B: Demographic information

Name:	Origin: Ethnic group:
Age:	Length of time in area:
Marital status: Gender:	Occupation:
Education level: **Standard 7**: *Failed* ☐ *Passed* ☐ **Form 4**: *Failed* ☐ *Passed* ☐ **Form 6** ☐ **Diploma** ☐ **Bachelor** ☐ **Masters** ☐ **PhD** ☐ **Other** ______________________________	
Number of people in household:	

TIME FRAME USED FOR 'CHANGES OVER TIME' QUESTIONS – BASED ON LENGTH OF TIME IN AREA:

30 YEARS ☐ **20 YEARS** ☐ **10 YEARS** ☐ **5 YEARS** ☐

1. *If not from this area –*

Why did you move to this area?

____

C. Farming

2. In this area, how long have you:
   a) Cultivated cash crops?______________________________
   b) Cultivated food crops?______________________________
   c) Kept cattle, sheep, pigs or goats?______________________________
   d) Cultivated vegetables for household use?______________________________

Questionnaire ID : Village : Sub-village:

3.Please describe the type of land you use:

Type of land	Acres	Ownership status
Natural forest		
Managed forest		
Seasonal floodplain		
Agricultural		
Regenerating forest		
Pasture		
Garden at house		

4.What animals do you have?

Type	Number owned	Use of livestock	Sale (S)/Own Consumption (C)
Cows-dairy			
Cows-free grazing			
Goats			
Sheep			
Pigs			
Chickens			
Ducks			
Geese			
Donkey			
Dog			
Cat			
Other			

Questionnaire ID : Village : Sub-village:

5. What crops do you grow (farm and garden)?

Crop	How often?*	Acres	This season's yield (20L bucket/kg)	Cash (C)/ Subsistence (S)/Both (B)	Good yield for your farm? (20L bucket/kg)
Maize					
Tobacco					
Rice					
Sunflower					
Sesame					
Groundnuts					
Beans					
Irish potato					
Sweet potato					
Millet					
Cassava					
Other					

*Code: Every year (1); Every other year (2); Every three years (3); Used to, don't any more (4); Want to in the future (5).

6. If you use the following fruit and vegetables, where do you get them from?

Tomatoes ☐ Pumpkin ☐ Cabbage ☐ Onions ☐
Aubergine ☐ Avocado ☐ Pineapple ☐ Watermelon ☐
Bananas ☐ Spinach ☐ Chinese leaves ☐ Baby aubergine ☐
Other____

Code: Buy (1); Grow myself (2); Gather elsewhere (3); Given for free (4); Traded for other goods (5) Don't use (6); Don't know (7)

7. Does your household have adequate food supply for the whole year?

Yes ☐ No ☐ Don't know ☐ No answer ☐

If no: Which months and why? ____

If yes: Why not?____

8. When was the last time you were unable to meet your household food needs?

Never ☐ Every year ☐ Year _______ Months _____________
Other___________________

Reason ____

Questionnaire ID : Village : Sub-village:

9. Do wild animals damage your crops?

Yes ☐ No ☐ Don't know ☐ Did not answer ☐

If yes:

When was the last time? _______________

How often does it occur? Every year ☐ Every other year ☐ Other ___________________

Crop	Animal	Amount lost per year~	Time of year	Stage in crop growth	Changed over the last ___ years?*	Reason

*Increased, decreased, stayed the same, don't know, no answer

~buckets, number of acres damaged

10. How often do you clear natural vegetation for farmland? ________________________________

How much:____

Reason:____

11. Have you planted any trees this year? How many? What species? __________________________

____

D: Tobacco

12. How long have you been growing tobacco? ______________________________________

13. Why did you decide to grow tobacco? ____

____

14. How many trees did you use to dry the tobacco harvested on your farm this season?

____

15. How do you benefit from the income you get as a result of growing tobacco?

i. ____

ii. ____

iii. ____

16. What are the challenges associated with growing tobacco?
i. ___
ii. ___
iii. ___

17. Do you think tobacco farming has any effect on the environment?
Yes ☐ No ☐ Don't know ☐ Did not answer ☐

Reason ___

___

E: Ecosystem service use *Ask if it is possible to speak to the appropriate person.*

18. What fuels do you use?

Cooking:___ Lighting ___

19. Where do you get firewood from?

Forest owned personally ☐ Other people's forest ☐ Open access forest ☐
Village managed forest ☐ Farmland owned personally ☐ Other people's farm ☐
Buy it ☐ No particular area ☐
Other___

20. How often does your household need to fetch firewood?
Every day ☐ Every other day ☐ Every four days ☐ On5ce a week ☐ Twice a week ☐
Other ___

21. How far do you walk to get firewood? (time/distance)___

22. Has this changed over the last___years?

Increased ☐ Decreased ☐ Stayed the same ☐
Don't know ☐ Did not answer question ☐

Reason___

23. Do you go to the forest for any of the following reasons?

Reason	Y/N/ N/A	HH use (H)/Sale (S)/Both (B)	Where from?*	How far do you travel? Time /km	How often?	Has availability changed over the last __years?~	Reason
Honey							
Rope							
Building poles							
Building timber							
Wood for tools							
Grasses for construction							
Grasses for animal fodder							
Wild meat							
Wild mushrooms							
Other wild vegetables							
Forest fruits							
Wild honey							
Medicinal plants or herbs							
Medicinal tree parts							
Charcoal							
Other							

*Code: Personal farm/forest (PF); Neighbours' farm/forest (NF); Open access forest (OAF); Village managed forest (VF) Specify Other

~Code: Increased (I); Decreased (D); Stayed the same (S); Don't know (DK) No answer (No ans)

Interview ID:

Village:

Sub-village

Questionnaire ID : Village : Sub-village :

24. If the forest was no longer available to provide these products how would it affect your household?

Bad for household ☐ Not affect household ☐ Good for household ☐
Don't know ☐ Did not answer ☐

Reason ____

____

____

25. What do you think the village will look like in 10 years time?

____

____

____

26. What do you think the surrounding farmland and natural landscape will look like in 10 years time?

____

____

____

Thank you very much for your time today.

Observation notes:

Roof material:
Tin roof ☐ Grasses ☐ Other ____________________

Walls:
Brick ☐ Mud and wood ☐ Concrete ☐ Other _____________

Based on what you have seen (assets, building, clothing etc) how well off does this household appear in comparison with others in the village?

Much better off ☐ Better off ☐ Average ☐
Worse off ☐ Much worse off ☐

Reason:

____

____

____

Any other comments:

____

Appendix D: Uses of tree species for medicinal reasons

Species ^Most used*Most important	Swahili Safwa	Use	Other	Present in low utilisation	Present in medium utilisation	Present in high utilisation
Acacia xanthophloea	Kisafwa – Ileunua	Firewood		Yes	Yes	Yes
**Afzelia quanzensis*	Mkola	Timber Roots as an aphrodisiac for women Treatment for infertility in men, take the roots and mix them in a clean bucket with pigs testicles and drink it		Yes	No	No
Albizia antunesiana	Kisafwa – Ipangala Kiswahili – Mpilipili	Roots for snake bite medicine Roots in house to keep snakes away Building poles – very strong – even ants and termites don’t damage it Bark made into oil and put on babies heads to harden skull Bark good for wound infections – tie bark in cloth and put over wound	Still abundant	No	Yes	Yes
Anisophyllea boehmii	Kisafwa – Nyemvi	Edible fruits for humans, birds, bushpig, baboons	Still abundant	No	Yes	No

Species ^Most used*Most important	Swahili Safwa	Use	Other	Present in low utilisation	Present in medium utilisation	Present in high utilisation
		Ash can be used as a treatment for maize – put it in a bag to stop insects				
Bobgunnia madagascariensis	Kisafwa – Inyeng'enye	Pods and fruit are poisonous to cows if they eat them and then drink water Building poles Used to smoke out bees	There are only a few, but no change Found in clay soils	Yes	Yes	Yes
Boscia salicifolia	Kisafwa – Ilongi	Medicine – aphrodisiac Edible fruits Building poles Glue from fruit Fishing nets	Increasing	No	No	Yes
Brachystegia longifolia	Kiswahili – Mnyombo	Beehives Timber Firewood Rope	No change Found in termite mounds	Yes	Yes	Yes
^**Brachystegia spiciformis*	Kisafwa – Isangala	Beehives Building poles Rope Pollinated by bees 'Best' for firewood	Still abundant	Yes	Yes	No
Burkea africana	Kisafwa – Isangala	Building poles	Still abundant	Yes	Yes	Yes

Species ^Most used*Most important	Swahili Safwa	Use	Other	Present in low utilisation	Present in medium utilisation	Present in high utilisation
Combretum collinum	Kisafwa – Ipulula	Timber Firewood Building poles Bark for teeth medicine Firewood For bees- pollinate	Still abundant	Yes	Yes	Yes
Commiphora africana	Kisafwa – Itoonto	Fencing When it is small the roots can be eaten like cassava Cooking utensils and small chairs	Rare here – only found in big forests	Yes	Yes	Yes
Diplorhynchus condylocarpon	Kisafwa – Isongasonga	Roots for medicine Glue from bark and leaves Firewood	No change, regenerates well	Yes	Yes	Yes
^**Dolichos kilimandscharicus*	Kisafwa – Iholi	Construction poles Roots- medicine for stomach ache – looks like a potato so it is boiled and mixed with porridge Fruit looks like beans and is eaten by rabbits	Still abundant Found in natural vegetation only	Not recorded		
Erythrina abyssinica	Kisafwa – Isangameni	Bark – medicine for fever in children Big trees are good for construction	Shrub Found in seasonal floodplains	Yes	Yes	No

Species ^Most used*Most important	Swahili Safwa	Use	Other	Present in low utilisation	Present in medium utilisation	Present in high utilisation
Fadogia sp.	Kiswahili – Majani ya chai (tealeaves)	Edible fruits Leaves for tea	Available in April only No change Flowering plant	No recorded		
Flacourtia indica	Kiswahili – Sinatem	Bark used as medicine for sores Building poles Tools – e.g. cooking utensils Firewood Fruit	No change Found in specific areas where there are few other trees	Yes	Yes	Yes
Gardenia ternifolia	Kisafwa – Ipetranzufu	Very hard wood, even elephants can’t damage it Firewood Building poles	Only a few, no change	Yes	No	No
Hexalobus monopetalus	Kisafwa – Linguwa Kiswahili – Mtundadanu	Edible fruits Chew bark for medicine Roots in the house keep snakes away	No change, abundant	Yes	Yes	Yes
^*Julbernardia globiflora*	Kisafwa – Izagara	Beehives Bark for rope Firewood Bees pollinate it	Still many	Yes	Yes	Yes

Species ^Most used*Most important	Swahili Safwa	Use	Other	Present in low utilisation	Present in medium utilisation	Present in high utilisation
Kigelia africana	Kisafwa – Izumbe Kiswahili	Building poles Medicine for teeth Fruit used to increase amount of blood Before maturity the sap of the fruit is used as Viagra Bark used for treatment of 10 diseases, e.g. diahorrea, mental problems		Yes	Yes	No
Lannea schimperi	Kisafwa – Ibumpu	Roots for rope for building Bark used to treat snakebite	You can cut them and plant the cuttings and they will grow Still abundant Found in seasonal floodplains	Yes	Yes	Yes
Maprounea africana	Kisafwa – Isungua	Building poles Fruit edible for people, birds and animals	Very few, but you can plant them and they will grow in the garden	Yes	Yes	No
Margaritaria discoidea	Kisafwa – Iliambuzi	Leaves are food for goats Snakes eat the fruit Firewood	Still abundant	Yes	No	No

Species ^Most used*Most important	**Swahili Safwa**	**Use**	**Other**	**Present in low utilisation**	**Present in medium utilisation**	**Present in high utilisation**
Oldfieldia dactylophylla	Kisafwa – Ihalula	Edible fruits		Yes	Yes	Yes
Osyris lanceolata (sandalwood)	Kiswahili – Mswaki	Young shoots for brushing teeth Fruits not edible	There are few, only found where there a few other trees	Not recorded		
Ozoroa insignis	Kisafwa – Mpamaha Kiswahili – Muembe pori (wild mango tree)	Medicine for diahorrea Firewood	These are hard to find, all his life they have been decreasing	Yes	Yes	No
Pericopsis angolensis	Kisafwa – Ivanga Kiswahili – Muwanga	Roots are poisonous in water Firewood	Still abundant	Yes	Yes	Yes
Prunus africana	Kisafwa – Nahawanga	Roots are a medicine for flu Building poles, roof and doors Fruit for baboons	Still abundant	Yes	No	No
Pseudolachnostylis maprouneifolia	Kisawfa - Ikete	Eaten by duiker Boards and seeds for marbles game (Bao) Building poles Roots for medicine for stomach problems, but must be mixed with *Ozoroa insignis* and *Terminalia mollis*	Still abundant	Yes	Yes	Yes

Species ^Most used*Most important	Swahili Safwa	Use	Other	Present in low utilisation	Present in medium utilisation	Present in high utilisation
Pterocarpus angolensis	Kiswahili – Mninga	Timber Building poles Furniture Medicine – bark for stomach problems Fertility for men Mend broken arms – prepare as for Mkola	Decreasing, very few It is the main tree for timber so ever since it has been used for building it has decreased, and there are still people illegally harvesting it	Yes	Yes	Yes
^*Piliostigma thonningii*	Kisafwa – Ipasapasa	Fruits look like avocados, used for eye treatment Can't use it for building or firewood – leads to conflict within the family	Found in regenerating areas	Yes	Yes	Yes
^**Rothmannia engleriana*	Kiswahili – Mtunda koroboi	Edible fruits for humans, birds, baboons Medicine for spiritual things in the home – one in each corner of the house guards against witches	Still abundant	Yes	No	No
Sclerocarya birrea		Utensils Chairs Fruit		Yes	No	No

Species ^Most used*Most important	Swahili Safwa	Use	Other	Present in low utilisation	Present in medium utilisation	Present in high utilisation
^**Securidaca longipedunculata*	Kisafwa – Iguluha	Roots used as Viagra when drunk in tea Giraffes eat the leaves Bark for soap for washing clothes Believe that if you use the tree to build a house it will cause conflict within the family – if it grows needles they must be removed	Found in regenerating forest	Yes	Yes	No
Steganotaenia araliacea	Kisafwa – Indeinde Kiswahili – Mnyonga mpembe	Bark makes a snapping sound – used for children's toys Leaves for eye medicine	Few, but no change	No	Yes	No
Strychnos cocculoides	Kiswahili – Idongadonga	Edible fruits for people, bushpigs, baboons Roots for medicine for elephantitus Leaves for medicine for a disease in fingers – sores	Still abundant Found in shrubby areas and regenerating areas	No	Yes	No
Strychnos madagascariensis	Kisafwa – Ibow	Edible fruits for people and baboons Can't climb it because it is spiky	Still abundant	Yes	Yes	No
Strychnos pungens	Kisafwa – Impiligo	Edible leaves for goats Edible fruit for people and bushpigs Building poles, doors	Still abundant	Yes	Yes	No
Syzygium sp.		Edible fruit		Yes	Yes	Yes

Species ^Most used*Most important	**Swahili Safwa**	**Use**	**Other**	**Present in low utilisation**	**Present in medium utilisation**	**Present in high utilisation**
Tamarindus indica	Kiswahili - Mkwaju	Edible fruit Young leaves can be eaten for stomach-ache	Seen in villages	Not recorded		
^**Terminalia mollis*	Kisafwa – Ikisia	Building poles Roots and leaves for medicine – stomach ache	Still abundant	Yes	Yes	Yes
Thespesia garckeana	Kisafwa – Itowa, Kiswahili – Mtobho	Edible fruits are like bubblegum Building poles for construction Making tools such as cooking utensils, hoe, axe	Found in termite mounds	Yes	Yes	No
Uapaca sp.		Edible fruit		Yes	Yes	Yes
Ximenia americana	Kisafwa – Mtunduwa	Edible fruits for humans, baboons Building poles Firewood	Still many	No	Yes	No
Zanthoxylum chalybeum	Kisafwa - Ilungulungu	Edible leaves – dried and ground and mixed with beans Roots are medicine for coughs Building poles Fishing baskets	Found on termite mounds	No	Yes	No
^*Zizphus abyssinica*	Kisafwa – Ikaangwe	Medicine for snake bite Making tools, e.g. hand hoe, spines - needles Firewood	Found in termite mounds	Yes	Yes	Yes

Appendix E: Supplementary material for Chapter 7

Table E1: Utilisation and land cover variables used to determine the level of utilisation of each site. The average value of each variable for each level was calculated (Sites: High n=2; Medium n=4; Low n=3). One way ANOVA results (df = 2 for all variables) are given to demonstrate differences between each level. Where a significant difference was demonstrated between the levels the post-hoc test Tukey HSD was performed to ascertain which levels differed. P< 0.05 indicates a significant difference.

Variable		Site utilisation level			One-way ANOVA				P-value for Tukey HSD post-hoc test		
		High	Medium	Low	Sum of Squares	Mean squares	F value	P-value	Low-High	Low-Medium	Medium - High
Approximate distance (km)	From settlement	4	5	11	88.17	44.09	2.44	0.167	-	-	-
	From road	2	4	10	108.24	54.12	5.764	0.0401	0.0534	0.0686	0.7738
Age (years)	Of agriculture	17	13	1	374.3	187.15	4,287	0.0698	-	-	-
Land use (% cover)	Agricultural area	49	21	0	2812	1406	25.05	0.00122	0.0009	0.0244	0.0131
	Regenerating miombo	20	1	0	605	302.5	10.56	0.0108	0.0146	0.982	0.0136
	Seasonal floodplain	2	8	2	70.15	35.07	3.225	0.112	-	-	-
	Open miombo	30	70	97	5499	2749.3	16.21	0.00381	0.003	0.0777	0.0261
Utilisation (%)	Cut poles and timber	29	20	3	939.2	469.6	15.35	0.00437	0.0045	0.0163	0.1915
	Cattle tracks present	13	31	3	1428	714	0.732	0.519	-	-	-
Utilisation Activity (number of incidents)	Access	46	31	6	2081	1040.3	41.34	0.00031	0.0003	0.0016	0.0274
	Agriculture-related	6	2	0	33.81	16.917	16.46	0.00366	0.0033	0.3526	0.0092
	Charcoal production area	2	0	0	6.222	3.1111	9.333	0.0144	0.021	1	0.01673
	Honey-related activity	13	26	25	279	139.49	2.114	0.202	-	-	-
	Marked trees	55	30	16	1755.6	877.8	6.197	0.0347	0.0292	0.3654	0.11578
	Non-Timber Forest Product	8	18	7	227.9	113.94	1.477	0.301	-	-	-
	Settlement - related	8	5	0	66.97	33.49	2.052	0.209	-	-	-
	Timber products	26	31	4	1327.6	663.8	5.111	0.0506	-	-	-
	Stumps	27	6	4	1871	935.5	13.49	6.28E-06	0.0000032	0.094	0.001

Table E2: Differences between tree species abundance, richness and diversity at different utilisation levels, using one-way ANOVA (df =2 for all variables). The post-hoc test Tukey HSD was performed on significant ANOVA results to determine how the levels differed. Two sites from each utilisation level were used to ensure even sampling. P< 0.05 indicates a significant difference.

	One-way ANOVA				P-values for Tukey HSD		
Tree	**Sum of Squares**	**Mean squares**	**F value**	**P-value**	**Low-High**	**Low-Medium**	**Medium - High**
Abundance	1756	878.1	1.109	0.336	-	-	-
Richness	59.3	29.67	0.854	0.431	-	-	-
Diversity	4.48	2.2417	4.094	0.0214	0.01627	0.51736	0.1935

Table E3: Frequency of occurrence of tree species per plot per utilisation level

		Frequency per utilisation plot		
Family	***Species***	**Low**	**Medium**	**High**
Mimosoideae	*Acacia gerrardii*	0.03	0.00	0
	Acacia hockii	0.08	0.00	0
	Acacia macrothyrsa	0.03	0.00	0
	Acacia sieberiana	0.08	0.00	0
	Acacia xanthophloea	0.11	0.08	0.4
	Acacia zeyheri	0.00	0.00	0.3
Fabaceae	*Afzelia quanzensis*	0.08	0.00	0
Mimosoideae	*Albizia adianthifolia*	0.08	0.00	0
	Albizia antunesiana	0.00	0.04	0.35
	Albizia glaberrima	0.00	0.02	0.2
	Albizia harveyi	0.08	0.04	0
Sapindaceae	*Allophylus africanus*	0.03	0.00	0.1
	Allophylus sp.	0.00	0.06	0
Anisophylleaceae	*Anisophyllea boehmii*	0.00	1.47	0
Annonaceae	*Annona senegalensis*	0.05	0.02	0
Phyllanthaceae	*Antidesma venosum*	0.24	0.00	0
Fabaceae	*Bauhinia petersiana*	0.68	0.00	0
Melianthaceae	*Bersama abyssinica*	0.03	0.00	0
Fabaceae	*Bobgunnia madagascariensis*	0.08	0.37	0.35
Capparaceae	*Boscia mossambicensis*	0.00	0.08	0
	Boscia salicifolia	0.00	0.00	0.05
Fabaceae	*Brachystegia boehmii*	1.46	2.06	0.25
	Brachystegia glaucescens	0.70	0.00	0
	Brachystegia longifolia	0.57	0.71	0.15
	Brachystegia manga	0.00	0.90	0
	Brachystegia spiciformis	1.16	2.04	0
	Brachystegia utilis	0.05	0.02	0
Euphorbiaceae	*Bridelia duvigneaudii*	0.03	0.00	0.7
	Bridelia micrantha	0.08	0.00	0
Fabaceae	*Burkea africana*	0.27	1.06	0.1
Rubiaceae	*Canthium sp.*	0.00	0.02	0
Rhizophoraceae	*Cassipourea mollis*	0.16	0.16	0.3
Rubiaceae	*Catunaregam spinosa*	0.32	0.10	0.9
Lamiaceae	*Clerodendrum sp.*	0.00	0.00	1.65
Combretaceae	*Combretum collinum*	0.27	0.22	0.4
	Combretum molle	0.30	0.16	0.3
	Combretum pentagonum	0.03	0.27	0.15
	Combretum zeyheri	1.86	0.14	6
Burseraceae	*Commiphora africana*	0.46	0.31	0.05
	Commiphora mossambicensis	0.32	0.02	0.05

		Frequency per utilisation plot		
Family	***Species***	**Low**	**Medium**	**High**
Araliaceae	*Cussonia arborea*	0.32	0.00	0
Fabaceae	*Dalbergia nitidula*	0.08	0.20	0.2
Fabaceae	*Dichrostachys cinerea*	0.32	0.06	0.55
Ebenaceae	*Diospyros fischeri*	0.11	0.00	0
Apocynaceae	*Diplorhynchus condylocarpon*	0.51	1.20	1.55
Streculiaceae	*Dombeya rotundifolia*	0.05	0.00	0
Meliaceae	*Ekebergia capensis*	0.00	0.06	0
Papilionoideae	*Erythrina abyssinica*	0.08	0.02	0
Proteaceae	*Faurea rochetiana*	0.24	0.08	0
Salicaceae	*Flacourtia indica*	0.24	0.06	0.15
Clusiaceae	*Garcinia huillensis*	0.00	0.04	0
Rubiaceae	*Gardenia ternifolia*	0.03	0.00	0
Malavaceae	*Grewia pachycalyx*	0.11	0.00	0
Annonaceae	*Hexalobus monopetalus*	0.19	0.49	0.6
Phyllanthaceae	*Hymenocardia acida*	0.35	1.04	1.1
Rubiaceae	*Hymenodictyon floribundum*	0.03	0.00	0
Fabaceae	*Isoberlinia angolensis*	0.51	0.27	1.95
Fabaceae	*Julbernardia globiflora*	1.62	4.84	0.95
Rubiaceae	*Keetia venosa*	0.03	0.00	0
Bignoniaceae	*Kigelia africana*	0.03	0.02	0
Anacardiaceae	*Lannea schimperi*	0.78	0.90	0.45
Fabaceae	*Lonchocarpus capassa*	0.24	0.16	0.05
Chrysobalanaceae	*Magnistipula butayei ssp. Bangweolensis*	0.27	0.16	0.35
Anacardiaceae	*Mangifera indica*	0.00	0.00	1.3
Euphorbiaceae	*Maprounea africana*	0.08	0.06	0
Phyllanthaceae	*Margaritaria discoidea*	0.14	0.00	0
Bignoniaceae	*Markhamia obtusifolia*	0.03	0.10	0.2
Celastraceae	*Maytenus mossambicensis*	0.00	0.18	0
	Maytenus senegalensis	0.03	0.02	0.05
Melastomataceae	*Memecylon flavovirens*	0.00	0.04	0
Dipterocarpaceae	*Monotes africanus*	0.51	0.16	0
	Monotes sp.	0.00	0.06	0
Ochnaceae	*Ochna mossambicensis*	0.14	0.61	0.15
	Ochna schweinfurthiana	0.22	0.39	0.3
Picrodendraceae	*Oldfieldia dactylophylla*	0.46	0.35	0.5
Fabaceae	*Ormocarpum kirkii*	0.08	0.04	0
Anacardiaceae	*Ozoroa insignis*	0.27	0.04	0
Chrysobalanaceae	*Parinari curatellifolia*	0.65	0.39	0.5
Fabaceae	*Pericopsis angolensis*	0.65	0.92	1.75
Arecaceae	*Phoenix reclinata*	0.05	0.00	0
Phyllanthaceae	*Phyllanthus sp.*	0.08	0.00	0

Family	*Species*	Frequency per utilisation plot Low	Medium	High
Ixonanthaceae	*Phyllocosmus lemaireanus*	0.03	0.71	0.05
Fabaceae	*Piliostigma thonningii*	0.16	0.18	1.45
Celastraceae	*Pleurostylia africana*	0.05	0.04	0.05
Proteaceae	*Protea sp.*	0.00	0.06	0
Rosaceae	*Prunus africana*	0.03	0.00	0
Phyllanthaceae	*Pseudolachnostylis maprouneifolia*	0.97	1.61	4.45
Ixonanthaceae	*Psorospermum febrifugum*	0.11	0.00	0
Fabaceae	*Pterocarpus angolensis*	0.51	1.08	0.6
	Pterocarpus tinctorius	0.03	0.08	0
Anacardiaceae	*Rhus anchietae*	0.08	0.00	0
Rubiaceae	*Rothmannia engleriana*	0.05	0.00	0
Oleaceae	*Schrebera trichoclada*	0.08	0.06	0.35
Anacardiaceae	*Sclerocarya birrea*	0.03	0.00	0
Polygalaceae	*Securidaca longipedunculata*	0.03	0.04	0
Fabaceae	*Senna singueana*	0.00	0.02	0
Sapotaceae	*Sideroxylon sp.*	0.00	0.04	0
Umbelliferae	*Steganotaenia araliacea*	0.00	0.02	0
Loganiaceae	*Strychnos cocculoides*	0.00	0.02	0
	Strychnos innocua	0.05	0.04	0
	Strychnos madagascariensis	0.03	0.10	0
	Strychnos potatorum	0.16	0.22	0
	Strychnos pungens	0.05	0.22	0
	Strychnos spinosa	0.16	0.02	0.1
Myrtaceae	*Syzygium cordatum*	0.59	0.00	0
	Syzygium guineense	0.30	0.18	0.05
Combretaceae	*Terminalia mollis*	0.54	0.18	0.25
	Terminalia sericea	0.43	0.02	1.6
	Terminalia stenostachya	0.54	0.00	0.35
Hibiscus	*Thespesia garckeana*	0.03	0.29	0
Rubiaceae	*Tricalysia sp.*	0.08	0.00	0
Meliaceae	*Turraea robusta*	0.00	0.14	0
Phyllanthaceae	*Uapaca kirkiana*	0.95	0.59	0
	Uapaca nitida	0.30	0.06	0.1
Verbenaceae	*Vitex doniana*	0.22	0.04	0.25
	Vitex mombassae	0.03	0.06	0
Olacaceae	*Ximenia americana*	0.00	0.41	0
	Ximenia caffra	0.05	0.04	0
Sapindaceae	*Zanha africana*	0.22	0.02	0
Rutaceae	*Zanthoxylum chalybeum*	0.00	0.08	0
Rhamnaceae	*Ziziphus abyssinica*	0.05	0.12	0.15
	Ziziphus mucronata	0.00	0.08	0

Appendix F: Supplementary material for Chapter 8

Table F1: Utilisation and land cover variables used to determine the level of utilisation of each site. The average value of each variable for each level was calculated (Sites: High n=2; Medium n=4; Low n=3). One way ANOVA results (df = 2 for all variables) are given to demonstrate differences between each level. Where a significant difference was demonstrated between the levels the post-hoc test Tukey HSD was performed to ascertain which levels differed. P< 0.05 indicates a significant difference.

		Site utilisation level			One-way ANOVA				Tukey HSD post-hoc test		
	Variable	High	Medium	Low	Sum of Squares	Mean squares	F value	P-value	Low-High	Low-Medium	Medium - High
Approximate distance (km)	From settlement	4	5	11	88.17	44.09	2.44	0.167	-	-	-
	From road	2	4	10	108.24	54.12	5.764	0.040	0.053	0.069	0.774
Age (years)	Of agriculture	17	13	1	374.3	187.15	4,287	0.070	-	-	-
Land use (% cover)	Agricultural area	49	21	0	2812	1406	25.05	0.001	0.001	0.024	0.013
	Regenerating miombo	20	1	0	605	302.5	10.56	0.011	0.015	0.982	0.014
	Seasonal floodplain	2	8	2	70.15	35.07	3.225	0.112	-	-	-
	Open miombo	30	70	97	5499	2749.3	16.21	0.004	0.003	0.078	0.026
Utilisation (%)	Cut poles and timber	29	20	3	939.2	469.6	15.35	0.004	0.005	0.016	0.192
	Cattle tracks present	13	31	3	1428	714	0.732	0.519	-	-	-
Utilisation Activity (number of incidents)	Access	46	31	6	2081	1040.3	41.34	0.000	0.000	0.002	0.027
	Agriculture-related	6	2	0	33.81	16.917	16.46	0.004	0.003	0.353	0.009
	Charcoal production area	2	0	0	6.222	3.1111	9.333	0.014	0.021	1.000	0.017
	Honey-related activity	13	26	25	279	139.49	2.114	0.202	-	-	-
	Marked trees	55	30	16	1755.6	877.8	6.197	0.035	0.029	0.365	0.116
	Non-Timber Forest Product	8	18	7	227.9	113.94	1.477	0.301	-	-	-
	Settlement - related	8	5	0	66.97	33.49	2.052	0.209	-	-	-
	Timber products	26	31	4	1327.6	663.8	5.111	0.051	-	-	-

Table F2: Differences between butterfly species abundance, richness and diversity at different utilisation levels, using one-way ANOVA (df =2 for all variables). The post-hoc test Tukey HSD was performed on significant ANOVA results to determine how the levels differed. Two sites from each utilisation level were used to ensure even sampling. P< 0.05 indicates a significant difference.

	One-way ANOVA				P-values for Tukey HSD		
Butterfly	**Sum of Squares**	**Mean squares**	**F value**	**P-value**	**Low-High**	**Low-Medium**	**Medium - High**
Abundance	4905	2452.5	33.34	8.79E-14	0	0	0.370
Richness	307.5	153.77	19.32	1.31E-08	0	<0.001	0.029
Diversity	21.49	10.75	25.61	5.55E-11	0	<0.001	0.001

Table F3: Differences between habitat levels for butterfly species abundance, richness and diversity, using one-way ANOVA (df = 7 for all categories). P< 0.05 indicates a significant difference.

	One-way ANOVA			
Butterfly	**Sum of Squares**	**Mean squares**	**F value**	**P-value**
Abundance	4903	700.4	9.256	<0.001
Richness	455	65.03	7.2	0.001
Diversity	28.39	4.056	9.134	<0.001

Table F4: P-values for the post-hoc test Tukey HSD, demonstrating how butterfly species abundance, richness and diversity differed between habitats. P< 0.05 indicates a significant difference.

	P-values for Tukey HSD		
Habitat	**Abundance**	**Richness**	**Diversity**
Disturbed miombo -Agriculture	0.051	0.033	0.055
Miombo adjacent to agriculture-Agriculture	1.000	1.000	1.000
Miombo adjacent to SFP-Agriculture	0.859	0.852	0.451
Miombo woodland-Agriculture	0.000	0.000	0.000
Regenerating miombo-Agriculture	1.000	1.000	0.984
Riverine woodland-Agriculture	1.000	0.999	0.986
Seasonal floodplain-Agriculture	1.000	0.992	0.828
Miombo adjacent to agriculture-Disturbed miombo	0.141	0.059	0.034
Miombo adjacent to SFP-Disturbed miombo	0.889	0.837	0.999
Miombo woodland-Disturbed miombo	0.638	0.993	0.776
Regenerating miombo-Disturbed miombo	0.089	0.024	0.008
Riverine woodland-Disturbed miombo	0.738	0.959	0.996
Seasonal floodplain-Disturbed miombo	0.438	0.614	0.976
Miombo adjacent to SFP-Miombo adjacent to agriculture	0.974	0.938	0.387
Miombo woodland-Miombo adjacent to agriculture	0.000	0.000	0.000
Regenerating miombo-Miombo adjacent to agriculture	0.999	0.995	0.985
Riverine woodland-Miombo adjacent to agriculture	1.000	1.000	0.983
Seasonal floodplain-Miombo adjacent to agriculture	1.000	0.999	0.791
Miombo woodland-Miombo adjacent to SFP	0.072	0.296	0.553
Regenerating miombo-Miombo adjacent to SFP	0.846	0.664	0.121
Riverine woodland-Miombo adjacent to SFP	0.993	1.000	1.000
Seasonal floodplain-Miombo adjacent to SFP	0.994	1.000	1.000
Regenerating miombo-Miombo woodland	0.000	0.001	0.000
Riverine woodland-Miombo woodland	0.236	0.825	0.865
Seasonal floodplain-Miombo woodland	0.010	0.163	0.368
Riverine woodland-Regenerating miombo	1.000	0.986	0.844
Seasonal floodplain-Regenerating miombo	1.000	0.934	0.386
Seasonal floodplain-Riverine woodland	1.000	1.000	1.000

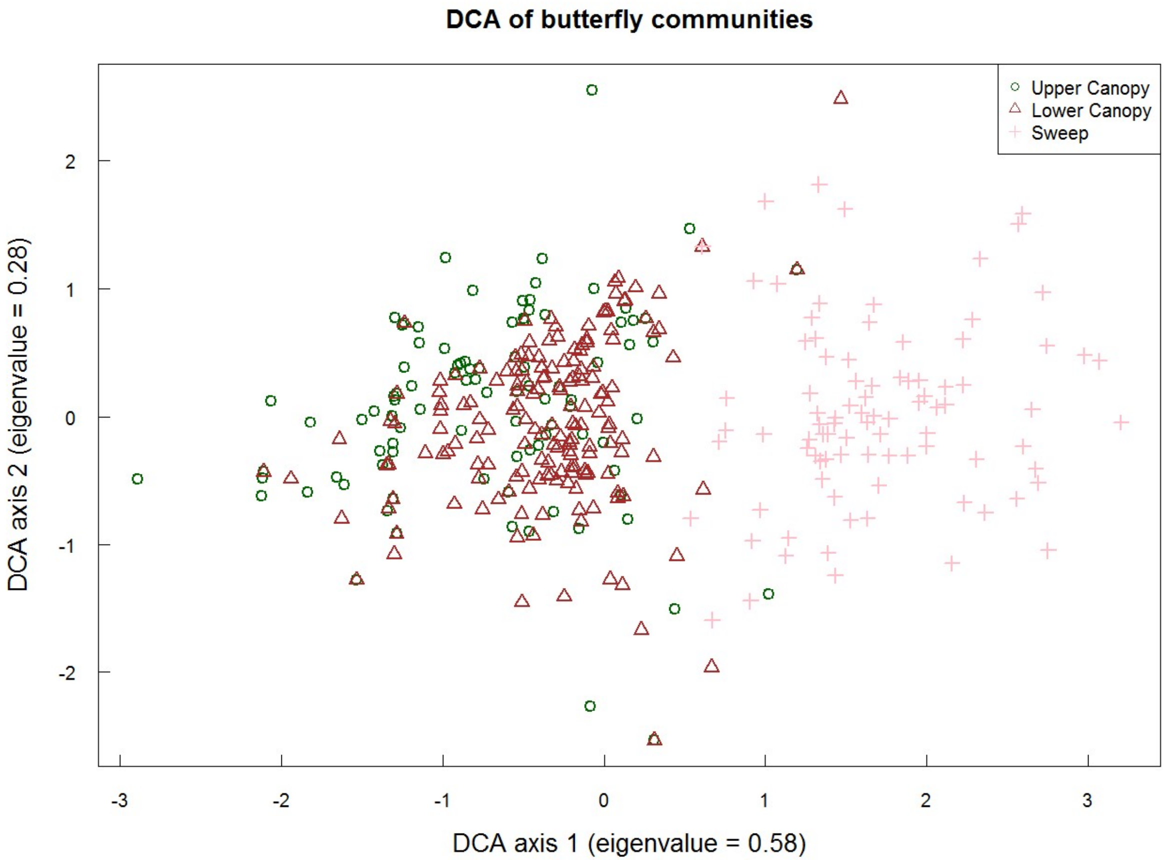

Figure F1: DCA of butterfly sampling - upper and lower canopy traps and sweep netting, showing no differences between species assemblages for upper and lower canopy traps

Table F5: Butterfly species list, detailing habitat association to demonstrate miombo woodland specialists, and distribution within Tanzania, to highlight those that are only found in Western Tanzania (Source: Kielland, 1990). Frequency of occurrence for each species at each utilisation level is given per site.

			Frequency per utilisation site		
Species	**Habitat**	**Records in Tanzania**	***High***	***Medium***	***Low***
Acada biseriata	Miombo woodland	Widely distributed throughout Tanzania	0	0.25	0.67
Acraea acrita acrita	Woodland and savanna	East and Central Tanzania	0.5	0.5	1
Acraea caldarena	Miombo woodland	Western Tanzania	0.5	0.75	0
Acraea encedon encedon	Woodland and dry habitats	Widely distributed throughout Tanzania	0	0	0.33
Acraea eponina eponina	Woodland	Widely distributed throughout Tanzania	10.5	10.25	4.33
****Acraea rahira***	Swampy areas close to riverbanks	Mpanda and Kigoma (North-west)	0	0	0.67
Acraea utengulensis	Miombo woodland	Western Tanzania	1	0.5	2
****Anthene lasti***	Lowland forest from 300-800m	Coastal areas inland to the Eastern Arc Mountains	0	0.25	0.33
Appias sabina phoebe	Woodland and forest	Widely distributed throughout Tanzania	0	1.75	0
Axiocerses amanga	Woodland and savanna	Widely distributed throughout Tanzania	0	0.25	0
Axiocerses tjoane	Woodland and savanna	Widely distributed throughout Tanzania	0	0.25	0
****Bebearia mardania***	Forest	West Africa, unconfirmed reports from Western Tanzania	0	0	0.33
Belenois calypso	Miombo woodland	Western Tanzania	0	0.25	0
Belenois creona severina	Woodland and savanna	Widely distributed throughout Tanzania	2.5	5.5	1.33
****Belenois thysa thysa***	Woodland, savanna, and forest margins	East Tanzania	0.5	12	0
Bicyclus anynana	Woodland and coastal forest	Widely distributed throughout Tanzania	3	20.5	10.33
Bicyclus campina	Woodland and forest	Southern and Western Tanzania	0.5	17.5	3
Bicyclus cooksoni	Miombo woodland and open montane grassland	Western Tanzania	0	0.25	2.33
Bicyclus ena	Woodland and dry acacia habitats	Widely distributed throughout Tanzania	5	17.5	5.33
Bicyclus safitza	All habitats	Widely distributed throughout Tanzania	5	43	41.33
****Byblia ilithyia***	Woodland, savanna and evergreen forest	Coastal areas inland to the Northern Highlands and Central Tanzania	16.5	41	202

Species	Habitat	Records in Tanzania	Frequency per utilisation site *High*	*Medium*	*Low*
Catacroptera cloanthe cloanthe	Woodland, savanna and open habitats	Widely distributed throughout Tanzania	1.5	0.25	6.67
Catopsilia florella	All habitats	Widely distributed throughout Tanzania	1	0.5	0.67
Charaxes achaemenes	Woodland and savanna	Very common in woodlands of Western Tanzania, and found in most parts of the country	1	6.75	2.67
Charaxes bohemani	Miombo woodland	Widely distributed throughout Tanzania	4.5	11.5	9.67
Charaxes brutus	Woodland and forest	Southern and Western Tanzania	0	0.25	0
Charaxes candiope candiope	Forest and riverine forest	Widely distributed throughout Tanzania	0	0.5	0.33
****Charaxes castor***	Miombo woodland	Western Tanzania	0	0	0.33
Charaxes druceanus	Open montane and riverine forests	Western Tanzania	0.5	0	0.33
Charaxes guderiana rabiensis	Miombo woodland	Most areas except the Northern Highlands	25.5	88.5	60
****Charaxes hansali baringana***	Woodland, savanna and bushland	North-eastern Tanzania	1.5	1.5	0
Charaxes howarthi	Miombo woodland	Western and Eastern Tanzania	5.5	8.75	6
Charaxes jasius	Miombo woodland	Widely distributed throughout Tanzania	0	0.75	1.67
Charaxes nichetes leoninus	Woodland and dry evergreen forest	Western Tanzania	1	1.25	2.33
****Charaxes protoclea azota***	Miombo woodland and forest	Widely distributed throughout Tanzania	0	2	1
Charaxes varanes vologeses	Woodland, open habitats, riverine thickets	Widely distributed throughout Tanzania	0.5	2.25	2
Charaxes zoolina	Dry thornbush areas	Southern, Northern and Eastern Tanzania	0	0	0.33
Chilades trochylus	Woodland and open habitat	Widely distributed throughout Tanzania	0	0	0.33
Cnodontes vansomereni	Woodland	Widely distributed throughout Tanzania	0	0.25	0
Colotis antevippe zera	Woodland and open habitat	Northern and Western Tanzania	0	1.25	0
****Colotis aurigineus***	Woodland and open habitat	Common in dry parts of the country. Not north of Mpanda	0	3	0.33
****Colotis auxo***	Woodland and savanna	Central, Northern and Western Tanzania	0	0	0.33
Colotis danae	Woodland and bushland	Kigoma, Mpanda, Rukwa river basin, Ufipa (North-west)	0	0.25	0
Colotis eris	Miombo woodland, savanna and bushland	Widely distributed throughout Tanzania	0	2.25	0
****Colotis euippe omphale***	Woodland, savanna and grassland	Widely distributed throughout Tanzania	1	6.5	0

Species	Habitat	Records in Tanzania	Frequency per utilisation site		
			High	*Medium*	*Low*
Colotis evagore	Woodland and bushland	Widely distributed throughout Tanzania	0	3.25	2.33
Colotis evenina	Woodland and bushland	Central, Northern and Western Tanzania	1.5	7.75	2
Colotis evenina xanthleuca	Woodland and bushland	Central, Northern and Western Tanzania	2	1.5	1
Colotis hildebrandti	Woodland and savanna	Mpanda to Ufipa (North-west)	0	0.5	0.67
Colotis regina	Miombo woodland	Western Tanzania	0.5	0.5	1
Crenidomimas concordia	Miombo woodland	Western Tanzania	0	5	16
Cupidopsis cissus	Woodland and savanna	Widely distributed throughout Tanzania	0.5	0	0
Danaus chrysippus	Woodland, open habitats, some forests	Widely distributed throughout Tanzania	1	1	0.67
Danaus droppius	Woodland, open habitats, some forests	Widely distributed throughout Tanzania	0	0.25	0
Dixeia pigea	Woodland and forest margins	Widely distributed throughout Tanzania	0.5	0.75	0
Euchrysops malathana	Woodland and open habitat	Widely distributed throughout Tanzania	0.5	3.75	2.67
****Euphaedra zaddachi***	Woodland, forest margins and riverine forest	Gombe to Tukuyu	0	0.25	0.67
Eurema brigitta	Woodland	Widely distributed throughout Tanzania	15.5	6	3.33
Eurema desjardansii	Woodland and forests	Widely distributed throughout Tanzania	0.5	2.75	3.33
Eurema hapale	Open marshy areas	Widely distributed throughout Tanzania	2	2.25	0.33
Eurema hecabe solifera	Woodland and grassland	Widely distributed throughout Tanzania	4.5	1.25	0.67
Eurema regularis regularis	Woodland and forest margins	Widely distributed throughout Tanzania	22	14	6.67
****Eurema senegalensis***	Evergreen forest	Found in evergreen areas throughout Tanzania	6.5	4.5	1.33
Eurytela dryope angulata	Woodland and forest	Widely distributed throughout Tanzania	0	1.5	4.33
Eurytela hiarbas	Forest	Western Tanzania	0	0	0.33
Fresna nyassae	Woodland	Western Tanzania	0	0.25	0.33
Gnophodes betsimena diversa	Woodland and forest	Widely distributed throughout Tanzania	0.5	0	0
****Gorgyra johnstoni***	Woodland, forest margins and riverine forest	Kigoma and Mpanda (North-west)	0	0.25	0
Graphium taboranus	Miombo woodlands and savanna	Southern, Central and North-west	0.5	0.25	0
Hamanumida daedalus	Woodland and open habitat	Widely distributed throughout Tanzania	4	6	14.67

			Frequency per utilisation site		
Species	**Habitat**	**Records in Tanzania**	***High***	***Medium***	***Low***
Hemiolaus caeculus dolores	Miombo woodland	Western Tanzania	0.5	0	0
Henotesia simonsii	Woodland	Western, South-central and Eastern Tanzania	0	22.25	121
Hypolycaena auricostalis	Woodland	Western Tanzania	0	0.25	0
Junonia artaxia	Miombo woodland	Western Tanzania	0.5	1	6.33
Junonia hierta	Woodland and open habitat	Widely distributed throughout Tanzania	0	1.75	1.33
Junonia natalica natalica	woodland, savanna and riverine forest	Widely distributed throughout Tanzania	2.5	1.75	5
Junonia oenone	Woodland and open habitat	Widely distributed throughout Tanzania	0.5	0.5	0
Junonia orithya madagascariensis	Miombo woodland and open habitats	Widely distributed throughout Tanzania	0.5	0	0
****Junonia touhilimasa***	Miombo woodland	Kigoma to Ufipa (North-west)	0.5	0.25	0
[a]***Leptotes sp.***			3.5	2	2.67
Melanitis leda	Woodland and forest margins	Widely distributed throughout Tanzania	0	0.25	0
Meza larea	Miombo woodland	Kigoma, Mpanda, Ufipa	0	0	0.33
Mylothris rueppellii	Woodland and forest margins	Western, Southern and Eastern Tanzania	0	0.25	0.33
Neocoenyra gregorii	Montane and forest grassland	Western Tanzania	1.5	0.25	0.67
****Neptis morosa***	Moist areas and forest edges	Bukoba Region only	0	9.5	31
Papilio demodocus demodocus	Woodland and open habitat	Widely distributed throughout Tanzania	0	0.5	0
****Pelopidas thrax***	Woodland and forest margins	Mpanda and Kigoma (North-west)	0	0.25	0
Pentila pauli nyassana	Woodland and forest margins	Throughout Tanzania, except North-east	1	0.5	0
Phalanta phalantha	Woodland, savanna, open habitat and forest margins	Widely distributed throughout Tanzania	1	0	0.33
Pinacopterix eriphia	Dry woodland	Central, Southern and Western Tanzania	0	0.5	0
Precis actia	Miombo woodland	Western Tanzania	0	3.75	5
Precis antilope	Miombo woodland	Widely distributed throughout Tanzania	0	0.5	2.33
Precis ceryne	Miombo woodland	Western Tanzania	0.5	0.25	1
Precis octavia sesamus	Woodland and savanna	Widely distributed throughout Tanzania	0	0.25	0.67

Species	Habitat	Records in Tanzania	Frequency per utilisation site		
			High	*Medium*	*Low*
Precis pelarga	Miombo woodland	Western Tanzania	0.5	4.25	1.33
****Pseudacraea poggei f carpenteri***	Miombo woodland	Mpanda and Kigoma only (North-west)	0	0	0.33
****Sevinia boisduvali***	Woodland and forest	Mpanda and North to Uganda (North-west)	0	0.5	1
****Sevinia moranti***	Woodland and forest	East Tanzania, in mountain areas	0	0	0.33
Sevinia rosa	Woodland and forest margins	Southern, Western and Eastern Tanzania	10	101.5	56.67
Teniorhinus harona	Miombo woodland	Widely distributed throughout Tanzania	0	1	0.67
Teracolus subfasciatus ducissa	Miombo woodland	Western Tanzania	0.5	1	0.67
[b]***Ypthima sp.***			6.5	4	0.67
Zizeeria knysna	Woodland and open habitat	Widely distributed throughout Tanzania	0	0.25	0
Zizula hylax	Woodland and open habitat	Widely distributed throughout Tanzania	0	0	0.33

[a]*Leptotes* can only be identified to species by examining genitalia. There are six species described in Kielland (1990), with a range of habitat and distributions.
[b]*Ypithima* can only be identified to species by examining genitalia. Eleven species are known in Tanzania Kielland (1990), with a range of habitat and distributions.
*Possible range extensions - there are no previous records of these species from this region of Tanzania.