Forest ecosystem services, rural livelihoods and carbon storage in Miombo woodland in the Copperbelt region of Zambia

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The candidate confirms that the work submitted is his 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

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In writing the above papers, I designed the research including the methodology, and analysed the data. I wrote the manuscripts and all co-authors contributed to the revisions and editing of these papers.

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Abstract

This study examines the linkage between rural livelihoods and forest ecosystem services under different land uses in Miombo forest socio-ecological systems of Zambia to understand the potential for carbon-based payment for ecosystem service schemes. The research develops and adopts an integrated research methodology in a new framework for ecosystem assessment (FESA) that combines livelihood surveys, ecological surveys and policy analysis to provide an interdisciplinary, multi-level case study analysis.

Findings show that forest provisioning ecosystem services (FPES) are vitally important to rural livelihoods as a source of food, medicine, construction material and fodder, and make the highest contribution to household income among diverse livelihood strategies. FPES provided 43.9% of the average household's income and contributed a 10% income equalisation effect among study households, as revealed by the Gini-coefficient analysis. Poorer households received a lower mean annual income from forests than did their intermediate and wealthy counterparts, but in relative terms, forest income made the greatest contribution to their total household incomes. The study indicates that wealth, rather than gender, was the key determinant of a household's engagement in the sale of FPES. Results also show that households face multiple shocks and that FPES are the most widely used coping strategy used by households facing idiosyncratic shocks such as illness, death of family members and loss of household assets which changes household consumption patterns. In terms of carbon storage, the study shows that Miombo woodlands are an important carbon store and that carbon storage can recover quickly through regeneration of cleared forests. After forest clearance for charcoal production and slash and burn agriculture, aboveground carbon stocks accumulate rapidly showing no significant differences in carbon stocks between undisturbed woodlands and ≥ 20 year old fallows. Findings however indicate low species similarities suggesting that though Miombo systems recover relatively fast in terms of carbon storage, species composition and biodiversity takes longer to recuperate.

Findings of this research show a lack of multi-stakeholder involvement in forest governance, which is hindered by the absence of legislation to ensure stakeholder participation and cost and benefit sharing mechanisms. Policy analysis show inconsistencies between Zambia's national agricultural, forestry, energy and climate change policies and national statements to multilateral environmental agreements in efforts to address forest loss. Additionally, although national statements to Rio Conventions share common ground on measures to address deforestation, they are poorly mainstreamed into national policies and broader development policies at national level. The agricultural policy's focus on expanding agricultural land by providing fiscal incentives and subsidised credit provides incentives for deforestation, indicating negative horizontal interaction with the forest policy, while the mutually supportive link through conservation farming is poorly developed. A more holistic landscape management approach would be useful to bridge sectoral divides.

A research contribution to the evidence and knowledge base for forests and rural livelihoods is made by this thesis, and empirical findings are detailed on how socio-economic differentiation affects contribution of Miombo FPES to total livelihood portfolios and household incomes. This analysis feeds into broader debates on forest conservation and development by linking FPES and livelihood strategies, which is important in designing long-term forest management strategies and providing national/international policy guidance for similar socio-economic contexts. This study further provides new understanding of the opportunity that carbon storage can bring to increasing financial gains from ecosystem services in local communities who practice slash and burn cultivation and charcoal production, once the carbon stores/changes in the recovery trajectory are established and monitoring schemes initiated.

This study makes an applied contribution to forest-based climate change mitigation initiatives such as REDD+ debates by providing a better understanding of the opportunities and challenges of its implementation in view of Miombo woodland use for livelihoods, improved ecological understanding and current policy discourses that converge in the forest sector.

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List of Acronyms and Abbreviations

AGB - Aboveground Biomass

CoP – Conference of the Parties

CSO – Central Statistics Office

DBH - Diameter at Breast Height

FAO – Food and Agriculture Organisation

FESA – Framework for Ecosystem Services Assessment

FPES - Forest provisioning Ecosystem Services

GDP - Gross Domestic Product

GHG – Greenhouse gas

GRZ – Government Republic of Zambia

IPCC - Intergovernmental Panel on Climate Change

IVI – Importance Value Index

JFM - Joint Forest Management

MA - Millennium Ecosystem Assessment

NAP - National Action Programme

NAPA - National Adaptation Programme of Action

NBSAP - National Biodiversity Strategy and Action Plan

NGO – Non-Governmental Organisation

PES - Payment for Ecosystem Services

REDD - Reduction of Emissions from Deforestation and Forest Degradation

SNDP - Sixth National Development Plan

NTFPs – Non-Timber Forest Product

UNCBD - United Nations Convention on Biological Diversity

UNCCD - United Nations Convention to Combat Desertification

UNCED - United Nations Conference on Environment and Development

UNFCCC - United Nations Framework Convention on Climate Change

Chapter 1 Introduction

1.1 Introduction

This research focuses on forest ecosystem services flows to rural livelihoods and carbon storage potential in Miombo woodlands to elucidate the potential for carbon-based payments for ecosystem services. This thesis provides a detailed case study and integrated interdisciplinary analysis of Miombo woodlands in Copperbelt Province, Zambia to inform policy and development of projects that aim to manage tropical forests by integrating reduction of greenhouse gas emissions and improved support for livelihoods. This chapter highlights trends in ecosystem management and provides an overview of forest ecosystems and Miombo woodland systems. Zambia as a case study country is introduced before the objectives of the study and its academic contribution are presented. Finally, the thesis structure is outlined and explained.

1.2 Research need and importance

Ecosystems are increasingly being recognised for their contribution of services to human well-being. Across the world, understanding ecosystems is an important subject for scientific enquiry (Cowie et al., 2011, Rounsevell et al., 2010), largely due to the recognition of the growing costs of biodiversity loss and ecosystem degradation (TEEB, 2008). There is increased interest in understanding human-environment interactions against the backdrop of climate change (IPCC, 2007) and dwindling ecosystems (about two-thirds of global ecosystems are in decline) (MA, 2005). This is particularly true for developing countries whose populations depend heavily on ecosystems for survival, and that have high rates of ecosystem degradation problems, most notably affecting drylands and especially the dryland systems of sub-saharan Africa (Middleton et al., 2011, Stringer et al., 2012a).

Globally, ecosystem services research is a rapidly growing field and is faced with the challenge of understanding the flows of ecosystem services and their links to livelihood strategies (Carpenter et al., 2009). Humans not only benefit from ecosystems but impact and shape the capacity of ecosystems to generate services (Folke et al., 2005), creating a dynamic mutual and reciprocal relationship between humans and ecosystems (Mung'ong'o, 2009) which alters the capabilities of ecosystems to continue to provide many of their services (MA, 2005). These interactions can be understood to exist within socio-ecological systems where management requires sustained and coordinated responses by policy-makers (Halliday and Glaser, 2011). This is because of the complex interlinked nature of social and ecological systems (Erb et al., 2009, Figueiredo and Pereira, 2011, Young et al., 2006), which cannot be understood if the two systems are approached independently (Figueiredo and Pereira, 2011), and where management requires sustained and coordinated responses by policy-makers.

Enhancing understanding of socio-ecological systems requires an integrated interdisciplinary, multi-level, and multi-scale case study approach which integrates social, ecological, political and economic factors (Tzoulas et al., 2007) such as provided in this research. It requires integration of different academic traditions, theories and research methods (Moss, 2000, Tzoulas et al., 2007). This research combines a local livelihood analysis using the sustainable livelihoods approach (Scoones, 1998), policy evaluation using an approach broadly based on the grounded theory (Strauss and Corbin, 1990), and ecological analysis of ecosystems to provide insights on their interactions and implications for spatially explicit socio-ecological systems.

1.2.1 Overview of tropical forest ecosystems

Forests are one of the most important terrestrial biomes. In tropical regions, forest ecosystems provide various ecosystem services that sustain rural livelihoods, making forests a means of production amongst rural people (Anderson and Grove, 1987), as well as regulation of the terrestrial carbon cycle (Chhatre and Agrawal, 2009) and conservation of biodiversity (World Bank, 2004). Forests are however being lost at alarming rates, endangering the flow of ecosystem services. The recent global forest resource report estimates the global annual deforestation rate is 13 million hectares

(FAO, 2010), the majority of which is in developing countries. Africa loses an average of 3.4 million hectares of forests annually (FAO, 2010). Deforestation accounts for 25-30% of total greenhouse gases emissions (GHGs) annually; releasing about 1.6 billion tonnes of GHGs per annum (FAO, 2006). Global climate change policy debates aimed at reducing deforestation in developing countries have intensified in the last decade as a way of mitigating the impacts of climate change (Bryan et al., 2010). There is increasing recognition that co-ordinated approaches are needed, such as through the United Nations Reduction of Emissions from Deforestation and Forest Degradation-plus (REDD+) program to protect tropical forests and enhance carbon stocks (Thompson et al., 2013). REDD+ has been developed to provide incentives for avoided deforestation and increased forest cover, which is to be achieved through payments for the ecosystem service of carbon sequestration (Angelsen et al., 2009, Blom et al., 2010). REDD+ includes policies and actions whose targets are to reduce emissions and address biodiversity conservation and climate change mitigation simultaneously (Wilson, 2010). It has the potential to bring about economic development in developing countries through transfer of payments thereby reducing poverty and boosting the capacity of people and forests to adapt to climate change (Angelsen et al., 2009, Baker et al., 2010).

Currently, momentum is growing in sub-Saharan Africa to reduce deforestation and forest degradation through various strategies under the REDD+ programme. This is considered important for reducing GHG emissions and mitigating climate change in light of projected future climate change in sub-Saharan Africa (IPCC, 2007). This requires an understanding of carbon sequestration and storage potential of forests, and the role of forests in livelihoods as REDD+ is expected to influence use of forests by local communities. As a result, there is a need for integrated case-study based research to understand how sustainable forest management and policy responses to mitigate climate change might be formulated under REDD+.

1.2.2 Overview of Miombo woodland ecosystems

Miombo woodland is the most extensive dry forest formation in Africa, with an estimated area of 270 million hectares (Frost, 1996). It exists on the Central African

Plateau within the Zambezian phytoregion, which, according to White (1983), is Africa's largest phytochorion. Miombo woodlands extend through parts of Zambia, Democratic Republic of Congo, Malawi, Mozambique, Tanzania, Angola and Zimbabwe (Figure 1.1).

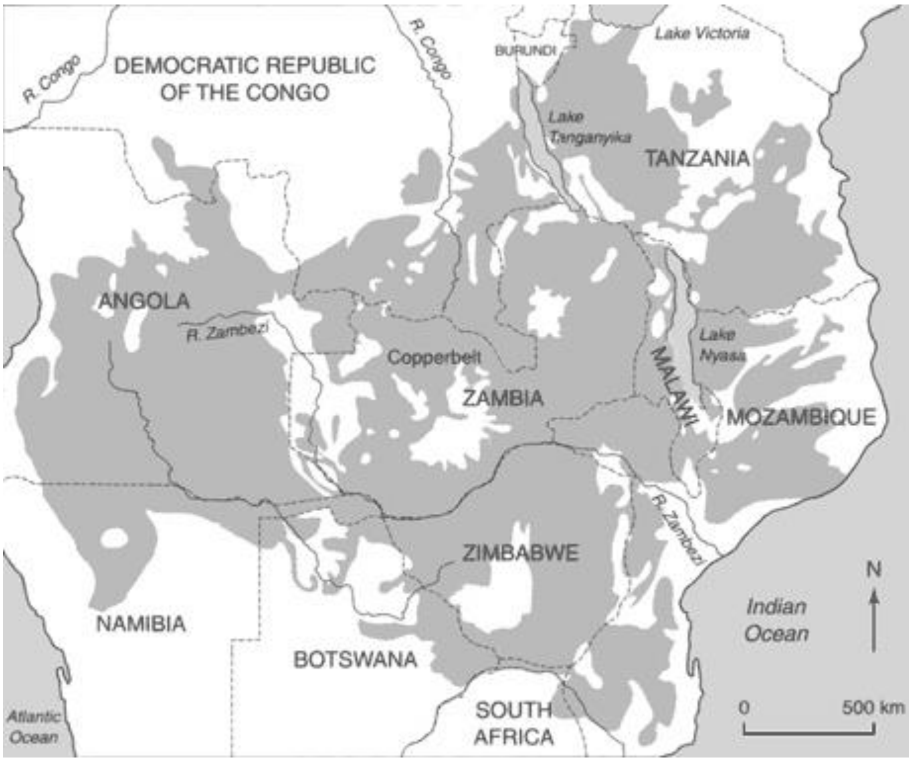

Figure 1.1- Distribution of Miombo woodlands **(**source: Desanker et al. (1997))

The Miombo system forms a transitional zone between closed rainforests and open semi-arid savannas of southern Africa (Vinya, 2010). This biome is classified into wet and dry types divided by the 1000 mm mean annual rainfall isohyets, and is dominated by tree species of the genera *Brachystegia*, *Julbernadia*, and *Isoberlinia* (White, 1983). The woodland is rich in plant diversity, with about 8500 species of higher plants of which 54% are endemic (Chirwa et al., 2008b), making the woodlands one of the world's high-biodiversity hotspots (Mittermeier et al., 2003). Miombo holds the bulk of the Earth's tropical dry forest biomass (about 43% of the world's tropical dry forests) and are one of the last remaining megafaunal assemblages (Mittermeier et al., 2003). The Miombo woodlands are a source of livelihoods for their inhabitants in a region often referred to as the 'world's most income poor region' (Fisher et al., 2011:161).

Since emerging forest management strategies are increasingly seeking to improve the conservation of forests as well as increasing the contribution of forests to livelihood improvement, a more holistic understanding of forests within the context of socio-ecological systems is vital to elucidate how social and ecological systems interact. This is particularly important for developing countries where human-environmental interactions are poorly understood, particularly in biologically diverse dry and sub-humid forest systems such as Africa's Miombo woodland systems (Bond et al., 2010). Understanding forest socio-ecological systems is vitally important in providing a more integrated understanding of forest use and management potential and to inform the emerging climate finance schemes which aim to integrate reduction of GHG emissions and improved support to livelihoods. There is a clear need for case study data such as provided in the present research to reconcile the long-term goals of economic development and forest conservation in regions with high poverty levels and biologically diverse ecosystems (Paumgarten and Shackleton, 2011), which have the intertwined challenges of poverty and forest degradation (Soltani et al., 2012).

1.3 Zambia

Zambia is a landlocked country in southern Africa lying between 8° and 18° S and 22° and 34° E (Figure 1.2). It has a population of approximately 13 million, 68.5% of which live below the income poverty line of US $1.25/day (UNDP, 2013). The country is one of the 49 least developed countries and sits in 163rd position according to the Human Development Report (UNDP, 2013).

Zambia has about 60% of its total area (752 000 km^2) covered by natural vegetation, with Miombo woodland systems being the most extensive vegetation type covering approximately 47% of the total land area. Deforestation is however rampant, occurring at a magnitude of 250,000-300,000 ha annually (Zambia Department of

Forestry and FAO, 2008), and is driven largely by clearing of forests for agricultural land and woodfuel[1] (Chidumayo, 1987b, Syampungani, 2009). In the entire Miombo eco-region, Zambia is regarded as an area of biological significance as it is rich in plant diversity and is the centre of endemism for *Brachystegia* tree species (Chirwa et al., 2008b, Rodgers et al., 1996). Additionally, Miombo woodlands in the Copperbelt region of Zambia lie on the Congo-Zambezi watershed (Chidumayo, 1987b) which is important in regulating the hydrological cycles in southern Africa. Furthermore, the forests are a source of livelihood and income for their inhabitants in a region characterised by high rural poverty (PRSP, 2002).

Owing to the importance of forests and because of high deforestation rates, Zambia has been designated as a REDD+ pilot country (see section 2.6.1) and is therefore faced with the challenge of developing forest management strategies aimed at reducing deforestation. Lessons drawn from understanding Miombo systems in this context are therefore likely to be significant to southern Africa more widely and to woodland systems globally.

[1]Woodfuel is a combination of fuelwood (unprocessed wood i.e. poles, branches, twigs) and charcoal.

Figure 1.2- Zambia showing location in southern Africa and main regions of the country (from nationsonline.org)

1.4 Aim and objectives of the study

The aim of this study is to understand the socio-ecological linkages between rural livelihoods and forest ecosystem services in the Miombo woodlands of the Copperbelt region of Zambia, and assess their carbon storage in order to establish the potential for community-based payments for ecosystem service schemes.

1.4.1 Objectives

1. To identify the key forest provisioning ecosystem services (FPES) obtained in the Copperbelt Province Miombo systems in different community cultural settings and to assess their relative contribution to local livelihoods.

    a. To identify the types and proportional contribution of FPES to total livelihood portfolios and household incomes.

b. To understand how social groups (stratified by wealth and gender) affect the use and sale of FPES.

c. To examine the use of FPES as a natural insurance against household stress and shocks.

d. To investigate forest changes (over the last 10 years) and the impacts of these changes on livelihood options.

2. To understand floristic composition, forest diversity and to quantify aboveground (AG) C stores in Copperbelt Province Miombo systems under different land management regimes.

   a. To assess floristic composition and forest diversity in undisturbed woodlands and regrowth sites after slash and burn and charcoal abandonment at various successional stages.

   b. To understand AG C stores in undisturbed areas and under different types of human disturbances (slash and burn agriculture and charcoal production).

   c. To understand changes in AG C stores at various stages along the trajectory of recovery from disturbances in 2 (b).

3. To examine policy interactions across forest, agriculture and energy sectors across governance levels, and examine the consistency between national sectoral policies and national programmes under Rio conventions.

   a. To examine how drivers of deforestation and forest degradation are discussed in different policy documents.

   b. To evaluate policy measures identified to address deforestation across policy documents and their interactions.

c. To evaluate policy implementation on the ground and elucidate on policy implementation deficits.

4. To evaluate the potential of carbon-based payment for ecosystem services in Zambian Miombo woodland systems.

   a. To understand trade-offs and complementarities between pursuing income streams from C-based payments for ecosystem services and existing livelihood activities.

   b. To examine the implications of 1), 2) and forest related policies analysed in 3, on national REDD+ architecture.

1.5 Academic and applied contribution of the research

This research provides new integrated, interdisciplinary case study evidence on the socio-ecological system within Miombo woodlands in Zambia and the potential for C-based payment for ecosystem services (PES). The research combines local livelihood analysis using the sustainable livelihoods approach, policy evaluation and ecological analysis of ecosystems to provide insights on their interaction and implications for management of Miombo socio-ecological systems.

The research makes a theoretical contribution by extending Bastian et al. (2012)'s conceptual framework for understanding fundamental relationships between social and ecological components of ecosystems. The framework for forest ecosystem services assessment (FESA) highlights dynamic factors and complex interactions within socio-ecological systems and allows for a holistic understanding of social and ecological systems and their interactions within forest socio-ecological systems. It also provides assessment of potential intervention points for improved forest ecosystem management. This framework forms the context into which the new interdisciplinary research can be placed. The framework explicitly addresses the role of policies such as Joint Forest Management in providing benefits to humans and the consequent implications for forest resources. This research provides an overarching methodological approach for interdisciplinary research which integrates methods from ecology, social science, politics and other disciplines to enhance understanding of Miombo woodland systems, which should have relevance for other global woodland systems.

Further, a contribution to the evidence and knowledge base for forests and rural livelihoods is made, and empirical findings are detailed on how socio-economic differentiation affects contribution of Miombo FPES to total livelihood portfolios and household incomes. Additionally, empirical findings are detailed on how FPES are used by rural communities as a natural insurance against stresses and shocks. This analysis feeds into broader debates on forest conservation and development by linking FPES and livelihood strategies, which is important in designing long-term forest management strategies and providing national/international policy guidance for similar socio-economic contexts.

The research contributes to global debates on land use changes aimed at restoring C and biodiversity in degraded forest ecosystems by providing empirical analysis of changes in floristic composition and AG C storage in fallows. This study provides new understanding of the opportunity that C-storage can bring to increasing financial gains from ecosystem services in local communities who practice slash & burn cultivation and charcoal production, once the AG C stores changes in the recovery trajectory are established and monitoring schemes initiated.

This research has also made an applied contribution to understanding how policies across different sectors affect forest use and management at the local scale. This research provides empirical evidence of policy interaction and implementation thereby providing insights on the extent to which forest, agriculture and energy policies interact. Finally, this study makes an applied contribution to global REDD+ debates by providing a better understanding of the opportunities and challenges of its implementation in view of Miombo woodland use in livelihoods, woodland ecology and current policy discourses that converge in the forest sector.

1.6 Definitions of key terms and concepts

Definition of terms in climate change and ecosystem services literature is often contested. In order to provide a consistent understanding of the terms used in this study, working definitions used are summarised below and applied throughout this thesis.

Deforestation and forest degradation: Deforestation is the (complete) removal of trees and the conversion from forest into other land uses such as agriculture, mining etc. Forest degradation is defined as the removal of some trees species or tree parts resulting in loss of carbon in remaining forests, where removal of trees or tree parts is not associated with a change in land use (Angelsen et al., 2009).

Direct and indirect drivers of deforestation: Direct drivers of deforestation are human activities that directly impact forest cover and loss of carbon, while indirect drivers are complex interactions of fundamental social, economic, political, cultural and technological processes that do not affect forest ecosystems directly but stimulate direct drivers (Hosonuma et al., 2012).

Ecosystem services: These are benefits people obtain from ecosystems (MA, 2005).

Livelihood: A livelihood comprises the capabilities, assets (stores, resources, claims and access) and activities required for a means of living (Chambers and Conway, 1991).

Payment for ecosystem services: A market-based environmental management approach which provides financial incentives to encourage ecosystem conservation and restoration (Milder et al., 2010).

Reduction of emissions from deforestation and forest degradation - plus (REDD+): Policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management and enhancement of forest carbon stocks in developing countries (UNFCCC, 2008).

1.7 Structure of thesis

This thesis is structured in 8 chapters. In chapter 2, relevant literature through which the study was contextualised is unpacked. The ecosystem services concept is discussed after which the key literature from rural livelihoods, ecology and policy that informed the research objectives is discussed. Chapter 3 presents an overview of the study area and the research design. The conceptual framework used to answer the research objectives is then presented and discussed. The chapter then introduces the broad methodological approaches used in the research. These methods are later discussed in detail in each corresponding results chapter. General data collection and analysis methods are also explained. Results are presented and analysed in Chapters 4 to 7. In each results chapter, specific detailed data collection and analysis methods are presented. Chapter 4 presents empirical evidence and discusses the use of FPES in rural communities for household consumption, sale and as a coping strategy against stresses and shocks. Further the influence of socio-economic differentiation on use of Miombo woodlands is presented and discussed. The impact of human disturbances on the ecology of Miombo woodland is discussed in Chapter 5. Here, results are presented and discussed on the floristic composition, species diversity and AG C storage in undisturbed Miombo woodlands and in charcoal and agriculture fallows. In Chapter 6, current policy discourses are presented and discussed. The chapter gives insight into how deforestation and forest degradation are discussed in national sectoral policies (i.e. agriculture, energy and forestry) and national commitments to international environmental conventions, and examines policy measures to reduce forest loss among analysed policy documents and their interactions. Further, local level implementation is presented and discussed. Chapter 7 examines the opportunities and challenges of REDD+ facing initiatives in Zambian Miombo. This chapter draws together the findings from chapter 4, 5 and 6 to inform REDD+ initiatives. Chapter 8 summarises the main conclusions, and suggests potential avenues for future research.

Chapter 2 Forests as socio-ecological systems: livelihood benefits, carbon sequestration and implications for deforestation

2.1 Introduction

This chapter presents and analyses the literature that informs the current study. It explores the use of forests in rural livelihoods, C-storage and policies that influence deforestation and forest degradation in Miombo woodland systems. The chapter shows mixed evidence on how wealth and gender influence forest use, while information on C-sequestration and storage under different land management regimes remains limited in Miombo woodland systems. Additionally, this review highlights that there is a paucity of studies that have attempted to understand how various environmental related policies interact and their subsequent implications for forest ecosystems in a developing country context.

This chapter first discusses theoretical perspectives on the concepts of ecosystem services and socio-ecological systems after which the use of forests in rural livelihoods is explored. Literature on C-storage and floristic composition of forests in the recovery trajectory after anthropogenic activities (e.g. Slash and burn agriculture and charcoal production) is then discussed to understand how different land uses affect forest ecology. Finally, the influence of policies on deforestation and forest degradation is presented after which the chapter concludes with a review of literature on payment for ecosystem services and REDD+. Throughout the chapter, research gaps/needs are identified which then inform the research design and methods used for this study.

2.2 Theoretical perspectives on ecosystem services and socio-ecological systems

An ecosystem is an ecological unit comprising of a combination of all living organisms and their physical environment interacting as an organisational unit (Tansley, 1935). Within an ecosystem various components "overlap, interlock and interact with one another" (Tansley, 1935:300). Ecosystems provide a range of services which are important in people's livelihoods (Sekercioglu, 2010). The Millennium Ecosystem Assessment (MA) broadly defines ecosystem services as the benefits people obtain from natural ecosystems (MA, 2005). Several definitions for ecosystem services have been advanced (e.g. Atkins et al., 2011, Costanza et al., 1997, Nasi et al., 2002) with the commonality of viewing ecosystems through the utilitarian lens (Dunn, 2010), making the benefits derived by humans central to the concept of ecosystem services (Currie, 2011). The ecosystem services concept identifies ecosystems as the fundamental basis of production (Patterson and Coelho, 2009). It acknowledges the importance of ecosystems to people: as integral for cultural and social needs, providing various products which are consumed or traded, and regulating biogeochemical cycles. The concept's main presupposition is that understanding ecosystems through a utilitarian lens has the potential to protect ecosystems and the services that flow from them (Brauman et al., 2007). It therefore becomes possible to assign ecosystems an economic value because they contribute to human well-being (Patterson and Coelho, 2009).

Applied to forest systems, ecosystem services include provisioning services (timber and non-timber forest products), regulating services (watershed functions, carbon storage and sequestration), cultural services (spiritual, recreational and religious) and supporting services, which underpin the provisioning of all ecosystem services. Ecosystem services are identified by various indicators which are quantifiable, sensitive to land management, temporally and spatially explicit and scalable (van Oudenhoven et al., 2012). Indicators for provisioning services are diverse and dependent on individual products and may include food production (kg ha^{-1}), timber harvested (m^3), number of people utilizing various wild products (percentage), number of plant species used for medicinal purposes (percentage), economic value of harvested products (monetary), etc. Regulating services indicators are also diverse and include indicators such as carbon stock (t C ha^{-1}), carbon sequestration capacity (t C ha^{-1} yr^{-1}) and evapotranspiration (m^3 ha^{-1} yr^{-1}). Indicators for cultural services may be measured by aesthetic value, number of rural/nature visitors, monetary value calculated from actual spends, travel costs or willingness to pay, presence of cultural norms, etc. (for detailed dicussions on indicators see Layke et al., 2012, MA, 2005, van Oudenhoven et al., 2012). Globally, forests are important because a large proportion of global ecosystem service flows originate within forests (Patterson and Coelho, 2009), therefore making case study research on understanding ecosystem services from forest ecosystems important.

Globally, the significance of the ecosystem services concept is now widely acknowledged in the framing of human-environment interactions by development agencies, national governments and researchers (Atkins et al., 2011, Sekercioglu, 2010). The concept is a significant structure used in assessing benefits that people derive from ecosystems and allows focus on a specific set of outputs (ecosystem service category) at the centre of interest (Patterson and Coelho, 2009). The ecosystem service concept has the potential to improve ecosystem management decisions by facilitating considerations of benefits trade-offs among alternative scenarios (Brauman et al., 2007, Kline et al., 2009), as it provides an opportunity to account for ecosystem values in making decisions concerning natural resources (Wallace, 2007).

The ecosystem services concept has been critiqued for regarding ecosystems as separate entities where society derives benefits, and that it does not pay attention to components of ecosystems that are not perceived to provide benefits to humans (Wallace, 2007). Additionally, this concept defines ecosystems by the services produced rather than their ecological structures and functioning. Ecosystem processes are viewed as merely means to an end. Focusing on managing ecosystems for identified services has the potential to negatively affect structure and functioning of ecosystems (Wallace, 2007), as for example in forest ecosystems where focussing on the ecosystem service of C sequestration has the potential to cause biodiversity loss as overall functioning of the ecosystem is overlooked in preference for a specific ecosystem service (Putz and Redford, 2009). The ecosystem services concept further focuses on current ecosystem benefits and lacks a time dimension to understand future benefits. It also does not address complex interactions between people and ecosystems and possible implications of their interaction on ecosystems (Norgaard, 2010). It has been argued that the ecosystem concept is "blinding us to the complexity of the challenges we actually face" (Norgaard, 2010:1226). Ecosystem management often raises political and ethical considerations (Brauman et al., 2007) and therefore cannot be analysed using an approach that largely focuses on the economic value of ecosystems services to inform management options. In many ecosystems including African drylands, economic value of ecosystem services "may not be easily traceable through functioning markets or may not show up in markets" (Costanza et al., 1997:257).

According to Cook and Spray (2012:95) "integration of social and scientific knowledge remains an unresolved challenge to ecosystem services-based governance." Norgaard (2010) has highlighted the importance of institutions in ecosystem management and therefore the need to add social dimensions to the existing ecological-economic biased conceptualisation of ecosystem services. Understanding nature as providing various services for human wellbeing is insufficient to resolve the problem of environmental degradation. According to Brauman et al. (2007:68), current environmental problems have "accentuated the need to move beyond simple recognition of human dependence on the environment and create more sustainable interaction." This invariably needs interdisciplinary research to build a knowledge base oriented around socio-ecological systems and the services derived from the ecosystems in which they exist (Steffen, 2009).

A socio-ecological system can be defined as a "bio-geophysical unit with its associated social factors and institutions, which are complex and delimitated by spatial and functional boundaries surrounding particular ecosystems and their problem context" (Glaser et al., 2008: 77). Cook and Spray (2012) have argued that poor ecosystem management ensues from a poor understanding of natural environments that does not take into consideration social factors in ecosystem management. The integration of knowledge from both the social and natural sciences is important to ensure sustainable ecosystem management. In an analysis of interdisciplinary research for managing ecosystem services, Steffen (2009:1301) argued that "without improved knowledge of the dynamics of socio-ecological systems, it's almost impossible to design appropriate management tools or even the adaptive intervention experiments needed to inform policy and management."

Socio-ecological system literature acknowledges society and ecosystems as being interdependent as opposed to the ecosystem services concept which views ecosystems as merely providing benefits to humans. It recognises ecosystems as being dynamic and that changes are partly due to interactions between social and ecological components (Berkes and Folke, 1998). The conceptualisation of the social in socio-ecological systems implies a broader and more explicit understanding of both benefits to humans and institutional structures that impact on human-environment interactions. This concept is however narrow in regards to classification of various benefits obtained from ecosystems as it focuses on system dynamics and system stability (Folke, 2006, Folke et al., 2002). This study provides a case study based attempt of incorporating ecosystem services-based identification of benefits i.e. provisioning, cultural, regulating and supporting services, with a socio-ecological systems approach that has the potential to enhance ecosystem management. It is envisaged that an integration of these two approaches could improve management decisions by holistically focusing on various ecosystem service categories while understanding socio-ecological interactions and providing insights on the implications of these dynamic interactions on social and ecological components in ecosystems to inform future management strategies.

2.3 Miombo woodlands and rural livelihoods

Forest ecosystems provide various products that underpin many rural livelihood strategies (Shackleton and Shackleton, 2004). These are collectively referred to as provisioning services, which are “services supplying tangible goods, finite though renewable, that can be appropriated by people, quantified and traded” (Maass et al., 2005:7). Since the value of vegetation to rural livelihoods is socially constructed and contested (Kepe, 2008), direct–use value of Forest Provisioning Ecosystem Services (FPES) is a key determinant of their value to livelihoods for household consumption and as a source of income (Mamo et al., 2007, Shackleton and Shackleton, 2006, Sunderlin et al., 2005, Tesfaye et al., 2011). Miombo woodlands provide FPES to millions of rural inhabitants. They are a source of foods such as mushrooms (Syampungani et al., 2009), edible insects (Mbata et al., 2002), indigenous fruits (Kalaba et al., 2010, Leakey and Akinnifesi, 2008), seeds, wild vegetables, honey and oils (Shackleton and Gumbo, 2010). The woodlands are also a source of traditional medicine for primary health care (Chirwa et al., 2008b), and poles, fibres and other materials used for constructing houses and barns (Clarke et al., 1996).

Woodfuel (firewood and charcoal) from Miombo woodlands is an important energy source, providing over 75% of total energy needs for both urban and rural dwellers in Zambia (Malimbwi et al., 2010). To local people, “Miombo woodlands are a pharmacy, a supermarket, a building supply store and a grazing resource” (Dewees et al., 2010:61).

2.3.1 Socio-economic factors determining use

Despite the use of Miombo products being widely reported, how socio-economic factors such as wealth and gender of household head in Miombo socio-ecological systems affects use and sale of FPES remains understudied. In natural resources management, complexity and heterogeneity of communities is often overlooked by researchers (Blom et al., 2010), as little attention is paid to socio-economic differentiation in local communities and its implications for forest use. Local communities are often assumed to be homogenous entities possessing common characteristics (Klein et al., 2007, Neumann, 1997). According to Blom et al (2010), understanding community complexities is critical for the success of forest management initiatives such as REDD+, given that the initiative will be implemented in various institutional and cultural settings. Understanding how use and sale of FPES is differentiated by socio-economic factors such as wealth and gender is essential in understanding people’s reliance on forest ecosystems and their contribution to livelihoods (Heubach et al., 2011, Shackleton et al., 2007). Furthermore, knowledge on socio-economic differentiation in forest use is vital to avoid marginalisation of various social groups and to guide the development of local management strategies (Shackleton and Shackleton, 2006).

From the relatively few empirical studies that have investigated how some socio-economic factors (such as wealth and gender) affect forest use, the evidence is mixed. Wealthy households have been reported as consuming more forest products than poorer households in Zimbabwe (Cavendish, 2000) and Nepal (Malla et al., 2003), while in contrast, studies in South Africa have reported wealth as not significantly influencing consumption of forest products (Paumgarten and Shackleton, 2009, Shackleton and Shackleton, 2006). In terms of household income, middle and wealthy households have been reported to earn more income from sale of FPES in Cameroon (Ambrose-Oji, 2003) and Democratic Republic of Congo (de Merode et al., 2004), while a study in Dixie village of South Africa reported household wealth as not influencing sale of FPES (Paumgarten and Shackleton, 2009). These reported differences are influenced by various factors such as access rights that local people of different wealth classes have to forest resources, land ownership and local institutions regulating use.

Findings on the influence of gender of household head on use and sale of FPES are also mixed. Female headed households have been reported to rely more on forest products in Cameroon (Fonjong, 2008) and southern Ethiopia (Yemiru et al., 2010), while in South Africa, studies report the influence of gender as negligible (Cocks et al., 2008, Paumgarten and Shackleton, 2009). In light of the above, it is evident that the use and sale of FPES in relation to household wealth and head of household gender varies across different case studies, and further empirical studies (such as provided in this thesis) are required to explore these relationships and inform local policies and programmes.

2.3.2 Rural livelihoods, vulnerability and coping mechanisms

Rural households are vulnerable to a wide range of shocks and stresses which affect their livelihood assets and options (Debela et al., 2012, Scoones, 1998). Shocks are sudden events that have negative impacts on livelihoods while stresses are predictable events such as seasonal shortages that affect livelihoods (Chambers and Conway, 1992). Households experience different frequencies and types of idiosyncratic shocks (such as death, sicknesses, loss of property) and covariate shocks (e.g. droughts, flooding, outbreaks of human and livestock diseases) (McSweeney, 2004, Paumgarten and Shackleton, 2011). Rural households seldom have access to formal insurance institutions to help them cope with stresses and shocks (Debela et al., 2012).

To cope with these stresses and shocks, households use various strategies such as selling productive assets, kinship, engaging in off-farm employment, or reducing the frequency and amount of consumption (Debela et al., 2012, Dercon, 2002). Others increase extraction of forest resources for consumption especially among very poor households (Debela et al., 2012). The coping capacity of households is determined by a number of factors such as the nature and intensity of the shock (Pattanayak and Sills, 2001), local environmental endowments (Takasaki et al., 2004), and household socio-economic factors (Pattanayak and Sills, 2001, Turner et al., 2003). Although households use a variety of strategies to cope with idiosyncratic shocks (Heemskerk et al., 2004, Maxwell et al., 1999, Paumgarten and Shackleton, 2011), these strategies are often inadequate to cope with extreme covariate shocks (Dercon, 2002, Heemskerk et al., 2004). High frequency and intensity of shocks coupled with inadequate household coping strategies is a common poverty trap for many rural households (Carter and Barrett, 2006, Zimmerman and Carter, 2003).

A recent study reports that rising levels of human vulnerability to multiple stressors are increasing rural people's dependence on ecosystem services to respond (Shackleton and Shackleton, 2012). Households' use of forests to cope with household stresses and shocks, and how socio-economic factors influence coping decisions however remains understudied due to limited empirical studies (Paumgarten and Shackleton, 2011). As global interest in understanding forest socio-ecological systems to inform forest management increases, it is imperative that use of forests is understood beyond consumption and sale of goods to include their use among rural households as a natural insurance against stresses and shocks, to provide a more holistic insight into forest use and to inform management practices.

This section has provided literature on social components of socio-ecological system. It has shown the importance of forest ecosystems in rural livelihoods and how socio-economic factors influence use and sale of forest products. Literature on the vulnerability of rural households to various stresses and shocks is presented and coping mechanisms discussed. The following section focuses on the ecological component examining C-storage and changes in C-stocks and biodiversity after anthropogenic disturbances.

2.4 Aboveground carbon storage, sequestration and forest recovery

Forests are one of the most important terrestrial biomes contributing immensely to carbon (C) sequestration and storage, and regulating other climate related cycles (Gibbs et al., 2007, Nasi et al., 2002). There is growing interest in understanding the capacity of forest ecosystems to sequester and store C in developing countries (Milne et al., 2013), which is fundamental in quantifying the contribution of trees to climate mitigation because they indicate the amount of C that can be offset (Ditt *et al.*, 2010). As such, forests have great potential to provide financial resources through C-based payment for ecosystem services (PES) (Baker et al., 2010), but their functions as dynamic C-pools in biogeochemical cycles remains uncertain (Schongart et al., 2008).

The C cycle in Miombo and other tropical dry forests is comparatively understudied (Bombelli et al., 2009, Williams et al., 2008). There are very few empirical studies that have attempted to estimate carbon stocks in Miombo woodland and in African drylands as a whole (Gibbs et al., 2007, Grace et al., 2006, Williams et al., 2008). In southern Africa, there is relatively scarce knowledge of growth rates and wood biomass in natural woodlands due to the focus on fast growing exotic plantations which have been prioritized by governments (Grundy, 1995), thereby making the total carbon stores in woodlands uncertain (Bryan et al., 2010).

As regards to the amount of C stored in forests, studies have reported higher C stores in Africa's tropical rainforests ranging from 202 Mg C ha^{-1} (Lewis et al., 2009) to 350 Mg C ha^{-1} (Munishi and Shear, 2004), compared to other forest types such as the tropical woodlands of Mozambique with 19 Mg C ha^{-1} (Williams et al., 2008) and Tanzania with 23.3 Mg C ha^{-1} (Shirima et al., 2011) and 19.1 Mg C ha^{-1} (Munishi et al., 2010). Although tropical rainforests have been reported as C-dense (Malhi and Grace, 2000), the vast areas covered by tropical dry forests shows that they store substantial amounts of C. The total Earth's surface comprises 11.7% tropical rainforests compared with 18.8% for tropical dry forests (Grace et al., 2006), therefore underscoring the importance of tropical dry forests in the global C-cycle.

2.4.1 C-stores and forest recovery

Slash and burn agriculture and charcoal production are the major causes of forest loss in tropical dry forests (Stromgaard, 1987; Chidumayo, 1991; Malambo *et al.*, 2008), and have been linked to huge losses of C and biodiversity in forest systems (Kotto-Same *et al.*, 1997). Increased human populations in Zambia[2] and generally across the Miombo woodlands (Dewees et al., 2010) has led to massive conversion of woodland into agriculture based land-use systems (Chirwa et al., 2008b). Traditional shifting cultivation has seen fallow periods reduce, which has largely been caused by inadequate land to support the practice (Chidumayo and Kwibisa, 2003). Additionally, the increase in population has increased energy needs and intensified the pressure on woodlands as a source of fuelwood and charcoal, which are prominent commercial enterprises in areas which are close to major cities and main roads (Mwampamba, 2007). However, studies have shown that after clear-felling for either slash and burn agriculture or charcoal production, in recovery Miombo has greater regeneration ability (Chidumayo, 1994). This recovery has been attributed to roots of Miombo tree species being well developed to allow rapid coppicing after felling, fires or attack by defoliators (Malimbwi et al., 1994). The root system acts as a stress tolerant adaptation for Miombo trees and a reserve for recovery (Malimbwi et al., 1994). Despite this recovery in some areas, forest cover overall is declining due to continuous perturbations. There is however potential for more areas to recover with appropriate management strategies and financial incentives.

Globally, there are increasing demands for land use changes aimed at restoring C and biodiversity in degraded forest ecosystems (Chazdon, 2008). How land use affects forest recovery and C stores in the recovery trajectory remains understudied (Mwampamba and Schwartz, 2011). Estimating carbon stocks is a global challenge that needs to be addressed in woodlands (Bryan et al., 2010). Understanding C stores, the rates and extent to which forests recover from disturbances and how C stores change in this recovery trajectory has important implications for emerging C-

[2] Zambia's total population has increased by more than 100% (i.e. from 5,661,801 to 13,046,508) in the last 3 decades (CSO, 2011).

based PES schemes (Mwampamba and Schwartz, 2011). These schemes are taking centre stage in United Nations Framework Convention on Climate Change (UNFCCC) climate negotiations for post-2012, after the expiry of the Kyoto Protocol commitment period. Quantifying C under different land use scenarios will help in making future land use decisions to ensure optimal land use benefits (Ditt et al., 2010). This research has the potential to provide insights into how recovery of fallow fields from the main drivers of forest loss (charcoal production and slash and burn agriculture) can be used in the emerging C markets as a way of maximizing rural people's benefits from ecosystems, hence potentially reinforcing forest conservation and sustainable management (Schongart et al., 2008). This is especially the case in developing countries, which have high poverty levels and where people's livelihoods often depend on forest resources.

2.4.2 Floristic composition and species diversity in forest recovery

Vegetation structure and floristic compositional changes in forest recovery has been discussed mainly in post-slash and burn agriculture abandonment sites in tropical rainforests (Guariguata *et al.*, 1997; Ferreira *et al.*, 1999; Denslow *et al.*, 2000), with only a few studies in African woodlands (Williams *et al.*, 2008; Syampungani *et al.*, 2010), though floristic composition in regrowth sites remains contested by ecologists. Some studies e.g Stromgaard, 1985; Kappelle *et al.*, 1996; Syampungani, 2009 have reported the presence of tree species usually dominant in old-growth woodlands on young (i.e. < 10 years-old) slash and burn regrowth sites, while others have reported absence of old-growth dominant species in regrowth of the same age (Saldarriaga *et al.*, 1988; Williams *et al.*, 2008). Furthermore, some studies have suggested it takes centuries for forests to return to primary forest species composition and argue that forests may not return to their original composition after severe disturbances (Jacobs *et al.*, 1988; Meng *et al.*, 2011).

In comparing species richness between old-growth forests and recovering sites in central Panama, Denslow and Guzman (2000) reported no differences in species richness between young regrowth sites and old-growth when seedlings were considered. In the Miombo of southern Africa, Williams *et al.* (2008) found tree species richness increased asymptotically with the age of fallow, while Syampungani (2009) reported increased species richness with increasing age of recovery, comparable to old-growth. After slash and burn agriculture abandonment, fire-tolerant tree species have been reported to dominate the early stages of recovery, as fire is important in breaking seed coat imposed dormancy (Orwa et al., 2009, Stromgaard, 1984).

Among the factors affecting forest vegetation recovery and subsequent floristic composition are the proximity of propagule sources and intensity of land use preceding abandonment (Connell and Slatyer, 1977, Guariguata and Ostertag, 2001, Peters, 1994, Saldarriaga et al., 1988), biology of tree species, and climate and edaphic factors (Guariguata and Ostertag, 2001). Furthermore, floristic composition in recovering forests has been reported to be affected by methodological approaches used. For example, Saldarriaga et al. (1988) in a study in Colombia and Venezuela found that it took 40 years for species richness of regrowth with diameter at breast height (DBH) >10 cm to be similar with the primary forest, and only 10 years if DBH > 1 cm. Similar observations were obtained in Costa Rica comparing 16-18 year regrowth sites and primary forests (Guariguata et al., 1997).

An integrated understanding of C storage, and the structural and floristic composition of trees in succession stages, is important in understanding forest restoration processes and in designing forest management strategies for different forest disturbance regimes (Gutiérrez *et al.*, 2012). Forest restoration has the potential to increase the contribution of forest resources to rural livelihoods, and conserve biodiversity, which is fundamental to the provisioning of ecosystem services. This is both timely and important due to global interest among policy makers on C-based PES as a way of incentivizing reductions in carbon loss from deforestation and degradation (Baker *et al.*, 2010; Stringer et al., 2012a), and conservation of biodiversity (Putz and Redford, 2009, Sasaki and Putz, 2009).

This section has presented literature on ecological components of forest socio-ecological systems. It has identified research gaps in the current understanding of both C stores and the structural and floristic composition of regrowth sites after slash and burn and charcoal production. The following section highlights interaction among policies and implications on forests. The discussion of policies is limited to those that directly address the agricultural and energy sectors which are the main drivers of deforestation and forest degradation.

2.5 Influences of policies on deforestation and forest degradation

There is increasing international demand by policymakers focussed on REDD+ for developing countries to conserve forests in the face of pressure from agriculture and energy demands. The continued high rates of forest loss in Zambia (see section 1.3) raises concerns about the effectiveness of various policies and strategies that intersect in the forest sector, their interactions and their implications for forest resources. This is because policies and laws play an essential role in human-environmental interaction by providing guidance on priorities and practices of countries (Bryant, 1992), and can be one of the major factors driving ecosystem degradation when they are designed and implemented poorly (Rasul et al., 2011). The Millennium Ecosystem Assessment report highlights the urgent need to reverse the degradation of ecosystems through substantial changes to policies, institutions and practices (MA, 2005), since functioning of many forest ecosystems could be restored once appropriate action is taken (Nasi et al., 2002).

At a national level, studies have reported that forest management is hindered by inappropriate policies (Colchester et al., 2006) and the marginalization of the forest sector, particularly with regard to low financing when compared to other sectors such as agriculture (Dewees et al., 2010). Further, most national policies are not coherent and are inconsistent, with some national agricultural policies providing incentives for agricultural land expansion in forest frontiers (Bunker, 1982, Guimaraes, 1989). Some governments have failed to manage forest resources due to the negative influence of other policies outside the forest sector such as agriculture and energy, which directly or indirectly affect the forest sector, and have subtle competition among themselves (Kaimowitz, 2003). Most past forest sectoral policies have followed the ‘protectionist paradigm’ (Kusters et al., 2006), where policies and laws restrict access of local people to protected areas (Ghimire and Pimbert, 1997, Syampungani et al., 2009) and do not recognise the role of traditional leadership in natural resources management (Virtanen, 2002). These policies gives rise to illegal forestry activities which are often unsustainable and threaten forests (Kaimowitz, 2003). This is because the protectionist approach is only effective if strongly enforced, while lack of monitoring and enforcement increases illegal activities because it creates a de facto open access resource. At the international level, forests are increasingly dominating global policy debates under various UN conventions which Zambia has ratified (see section 6.1.1).

Research has highlighted that policies influence human-environment interaction and trigger land use changes (Angelsen et al., 2009, Bryant, 1992, Chhatre and Agrawal, 2009, Keleman et al., 2010, Liu et al., 2007). Sectoral policies are affected by the integration of various policies which interact and influence each other's effectiveness (Oberthür and Gehring, 2006a, Alig et al., 2010). This challenges traditional policy analysis approaches in which policies are analysed vertically on a single-sector basis (Söderberg, 2008). In the case of deforestation and forest degradation, most drivers of forest loss are outside the forest sector, and therefore policy analysis requires a cross-sectoral approach (Lenschow, 2002, Sand, 1992), to provide new insights (Hewitt, 2009). It has recently been observed that to effectively address deforestation and forest degradation policies must go beyond the forest sector to include other policies, to mitigate non-forest drivers of deforestation and degradation (see Angelsen et al., 2009, Kalame et al., 2010, Keleman et al., 2010). Integrated thinking in public policy with respect to forest policy has seldom been extensively explored by academics and policymakers (Urwin and Jordan), particularly in a developing country context.

2.5.1 Unpacking policy interactions

There is growing interest among policymakers and scholars in understanding how policies influence each other's effectiveness, and the ensuing challenges and opportunities for environmental governance (Oberthür and Gehring, 2006b, Stokke, 2009). Research on policy interaction has mostly been devoted to assessing interactions between international policies (Jordan, 1999, Rosendal, 2001, Stokke, 2001, Young, 2002, Young et al., 1999), which according to Rosendal (2001) has been driven by an upsurge in trans-boundary environmental problems as well as the formulation of large numbers of international institutions to meet these challenges. Evidence from the literature has dispelled long held assumptions that institutions exist in isolation from others (Rittberger and Mayer, 1993).

Policy interaction is a causal relationship between two policies in which one policy exerts influence on the other either intentionally or unintentionally (Oberthür and Gehring, 2006a). Two policies are said to interact when decisions made under one policy (source policy) affect the effectiveness of another policy (target policy). In their pioneering research on conceptual foundations of institutional interaction, Oberthür and Gehring (2006a) assert that establishing policy interaction requires a detailed understanding of the source policy which they also refer to as the independent variable, examining its components or decisions from which influence originates, and understanding the target policy (or dependant variable), paying specific attention to its components subjected to influences that emanate from the source policy. Policy interaction results in a cause-effect relationship between the target and the source institution which results in a specific effect, and therefore analysing policy interaction requires disaggregating complex interactions into single source and target policy decisions (Oberthür and Gehring, 2006a). Two policies may be involved in several cases of interaction as some policy goals may be in conflict while yet others may have a synergetic relationship. In the context of this study, the forest policy is the target policy which may be influenced by the source policies i.e. energy and agricultural policies resulting in deforestation and forest degradation. The influence of policies runs uni-directionally from the source to the target policy (Oberthür and Gehring, 2006a).

Policy interaction can occur both horizontally and vertically. Horizontal policy interaction is the interplay between policies at the same level of governance (e.g. national or regional policies), while vertical interaction occurs between policies at different spatial scales of governance (Young, 2002). Policy interactions are an important variable in understanding effectiveness of policies (Cowie et al., 2007) and their coordination to "strive for the same target through mutually supportive policies and strategies" (Söderberg, 2008:384). This paradigm acknowledges the complexity of policy domains and the need to provide policy coherence to ensure sustainable development.

Policy interaction among sectors can take various forms. A typology to understand policy interaction has been presented by Oberthür and Gehring (2006a). It is made up of three interactions. The first is a negative interaction or conflict, where a policy constrains or undermines the effectiveness of measures of another policy to achieve its objectives. The second interaction is a positive or synergetic interplay, where the policy direction of one policy is supported by measures originating from another policy (Oberthür and Gehring, 2006a), displaying mutual policy goals as well as efforts to reach them (Söderberg, 2008). The last policy interaction is neutral, where the policy objectives and goals do not affect the goals and objectives of another policy. Understanding policy interaction is important in providing insights on how policy options interact (both synergies and conflicts) in order to create synergies and enhance policy effectiveness (Niang-Diop and Bosch, 2005).

2.5.2 Unpacking policy implementation

Policy implementation is "the carrying out of a basic policy decision" (Sabatier and Mazmanian, 1980:540), which involves translating policy decisions into on-the-ground actions, often supported by statutes. Policies consist of outputs (laws, regulations and organisations created to address a policy problem) and policy outcomes (practical management actions stipulated by outputs to address the problem) (Jordan, 1999, Leventon and Antypas, 2012). Central to implementation analysis is identifying factors which affect the implementation of policy goals (Sabatier and Mazmanian, 1980). Implementation deficits or gaps occur when there exists "shortfalls between the goals embodied in particular directives and their practical effects" (Jordan, 1999:72). A policy deficit arises either from the failure to meet delineated policy goals or the failure by policy goals to sufficiently tackle policy problems (Jordan, 1999, Leventon and Antypas, 2012). Policy implementation has been viewed as a key problem in environmental governance (Leventon and Antypas, 2012). Implementation deficits have been conceptualised into four categories (Table 2.1). Type A deficits emerge when there are no policy outputs to address a defined problem, while type B emerges when management actions do not correspond with policy goals. Types C and D are caused by insufficient policy outputs or outcomes to respond to the policy problem. Types B and D originate in the policy-making process, and reflect lack of understanding of the policy problem (Hill, 1997, Jordan, 1999). This framework is useful in understanding the effectiveness of policy measures to address policy problems (i.e. deforestation in this study) and explain the nature of implementation deficits.

Table 2.1- Policy implementation typologies

Failure	Impact on	
	Policy output	Policy outcome
Orientation of policy goals	A. There are no policy measures to address deforestation and forest degradation	B. The actions dictated do not match policy goals to address deforestation and forest degradation
Orientation to policy problem	C. Insufficient policy output to address deforestation and forest degradation	D. The actions are insufficient to address deforestation and forest degradation

Modified from Leventon and Antypas (2012) and Jordan (1999)

If emerging policy initiatives in forest management targeted by REDD+ are to be effective, it is imperative to understand policy interactions across forestry, agriculture and energy sectors, and their consistency with national programmes under Rio conventions. This requires an examination of how drivers of deforestation and forest degradation are discussed in different policy documents, an evaluation of policy measures identified to address deforestation across policy documents and their interactions, and an examination of policy implementation on the ground. This is vital to provide insights on the extent to which forest, agriculture and energy policies interact, and to make policy recommendations both nationally and more widely in sub-Saharan Africa where agriculture and charcoal production are the main drivers of forest loss.

2.6 Payment for ecosystem services (PES)

In the last decade, there has been increasing global awareness among policy makers on the use of payment for ecosystem services (PES) for incentivising particular kinds of environmental management (Baker et al., 2010, Wilson, 2010, Wunder, 2008) and as a way of reducing degradation. Excessive demand for ecosystem services is diminishing the capacity of ecosystems to provide services hence the growing concern for sustainable utilization (Rasul et al., 2011). PES is a market-based environmental management approach that provides incentives to encourage ecosystem conservation and restoration (Milder et al., 2010). It therefore rewards and compensates for sound ecosystem management either directly through cash payments or indirectly through benefits earned from eco-certified products (Milder et al., 2010). According to the Centre of International Forestry Research (CIFOR)'s applied concept, PES is a voluntary transaction where well-defined environmental services are being bought by an environmental service buyer from an environmental service provider, if and only if environmental provision is secured (see Wunder, 2008).

PES is a mechanism for translating non-market value of the environment into financial incentives (Engel et al., 2008). It is relatively new to Africa, as most PES projects have been conducted in Latin America (Corbera et al., 2009, Pagiola, 2008, Pagiola et al., 2005, Pagiola et al., 2007). PES has the potential to provide tangible benefits linked to protection of ecosystems (Swart, 2003), and hence make conservation more attractive by providing incentives (Engel et al., 2008). According to Nasi et al., (2002), the reason why deforestation and forest degradation are prevalent is because local people are provided with financial incentives to degrade and deforest, and they are not necessarily an act of recklessness. Woodland conversion through shifting cultivation and charcoal production provides higher benefits to households than conservation, at least in the short-term (Bond et al., 2010).

PES schemes demand a transformation in the perception of what constitutes productive land in developing countries, where land tenure is uncertain and retention of land is often based on land cultivation or evidence of economic use (Zimba, 2003). According to Wunder (2008), there is need to create local recognition that land set aside for conservation has tangible economic value and is productive. This is particularly true for forests, which capture and store carbon and regulate various environmental cycles (Sugden et al., 2008).

2.6.1 Reduction of emissions from deforestation and forest degradation

The 21st century is faced with the challenge of climate change, which is caused by the increasing concentration of greenhouse gases emanating from anthropogenic activities (IPCC, 2007). High deforestation rates have led to the recognition of the need to reduce C emissions from deforestation and forest degradation as a way of mitigating the impacts of climate change (Bryan et al., 2010). At the global level, policy discussions on financial payments for reducing GHGs emissions have emerged in the last few decades. Currently, carbon markets exist as regulatory compliance (formal) or voluntary (informal) markets.

The Kyoto Protocol of 1997 provides for purchasing of GHG emission reduction credits under regulatory markets. Forest conservation and management projects were however excluded from carbon credit-generating activity in the Kyoto Protocol (Blom et al., 2010), because of the complexity of measuring carbon stored in forests and the lack of certainty, even if measured, of whether the carbon will remain (Gibbs et al., 2007). The omission of forests gave rise to the formation of an intergovernmental organisation by developing nations called the Coalition for Rainforest Nations (CfRN) to advocate for amendments to the Kyoto Protocol to include forest carbon trading on international markets as a way of providing incentives to protect tropical forests (Laurance, 2007). In response to unprecedented evidence of global warming, the UNFCCC during the conference of the parties (COP-13) of 2007 in Bali, adopted the 'Bali action plan' to ensure a reduction in emissions from deforestation and forest degradation (REDD). The initial focus of REDD was to provide incentives for reduced emissions (Mazzei et al., 2010). Over the years, REDD has evolved into REDD+ as it has been realised that there is need for more than isolated actions to reduce emissions and to increase the flow of ecosystem services (Patterson and Coelho, 2009).

REDD+ has become popular in global debates on forest management and poverty in developing countries. Proponents of the initiative view it as a win-win for both conservation and poverty reduction, as the initiative involves polluters from developed countries channelling money to developing countries to protect carbon stocks (Nature, 2011). This is on the premise that C retained from protection through REDD+ is above what could be obtained by afforestation and reforestation (Grace et al., 2006). C–based PES has the potential to reduce carbon emissions, sustainably managing ecosystems and enhance livelihoods (whose income generating activities are usually seasonal) (Baker et al., 2010).

The implementation of REDD+ faces challenges that are common to all forest management strategies in developing countries. Inherent problems include land ownership, which according to Angelsen (2009) is often unclear or contested, inadequate institutions and restrictive legislation (Colchester et al., 2006). The success of REDD+ largely depends on significant incentives for forest management, providing revenue streams that are more than the revenue flows of competing economic activities such as agriculture and charcoal production (Hajek et al., 2011).

Many forest management initiatives in the past have failed to achieve the desired results, as evidenced by continued high deforestation rates (Angelsen et al., 2009, Kanowski et al., 2010). Sunderlin and Atmadja (2009) stress the need to avoid making the same mistakes. Experiences from previous forest management initiatives and other environmental related management initiatives are important in informing strategies for REDD+ implementation (Angelsen et al., 2009, Bond et al., 2010, Kanowski et al., 2010). Several forest management strategies have been practiced ranging from the protectionist to more participatory approaches, but forest loss remains alarming therefore there is a pressing need for insights in forest management to reduce deforestation and forest degradation at local scales. Past conservation lessons are essential tools for efficient and effective design of REDD+ (Blom et al., 2010). An understanding of forest use in livelihoods, C-stores and policies, are important in providing insights for REDD+ strategies owing to the fact that success of forest management interventions depends on the design, strategic context and implementation at local level (Hajek et al., 2011).

The UN-REDD programme has selected 14 pilot countries, including Zambia, to receive funding to prepare for the REDD+ Readiness process through UN-REDD National Programmes, in order to assess if payment and capacity support can provide incentives for reducing emissions and maintain other forest ecosystem services.

2.7 Chapter summary

This chapter has presented multidisciplinary literature that sets the context of this study. It has identified the key research needs important to inform forest management. In particular, the chapter has highlighted the need for understanding socio-economic factors influencing use of FPES in rural livelihoods, changes in floristic composition and C storage in forest recovery, and how policies interact among different sectors, and subsequent impacts on Miombo woodland systems. It is clear from the literature that responding to current debates on forest management aimed at reducing GHG emissions and improving the contribution of forests to livelihoods requires a multidisciplinary approach. This needs a holistic understanding of forest uses by local communities, policy contexts and C storage capacity of forest ecosystems to inform emerging community-based PES schemes. Such a holistic understanding of forest ecosystems within the socio-ecological context is important in providing empirical evidence important in designing long-term forest management strategies and providing national/international policy guidance for similar socio-economic contexts. In the next chapter, the conceptual framework used to explore the research objectives will be discussed and research methods introduced.

Chapter 3 Research design and methodology

3.1 Introduction

This chapter introduces the research design and methods employed in this study. The first section introduces the study area, after which the integrated conceptual framework used during this research process is presented. A brief overview of the research methods used to address the research objectives is then presented explaining the various methods used in this integrated interdisciplinary, multi-level, and multi-scale case study based approach. Finally, researcher positionality and ethical considerations are explored to give insight on the context under which this study was conducted.

3.2 Study area

This case study research was conducted in Copperbelt Province of Zambia (Figure 3.1), which is located between latitudes 12^{o} 20’ and 13^{o}50’ south and longitudes 26^{o}40’ and 29^{o}15**’** east and covers a total surface area of 31,014 km^2. The average altitude of the region is 1200 m above sea level, and its geology is characterised by granite and granite gneiss, basement schist and lower Katanga rock systems (Syampungani et al., 2010b). The province is a high rainfall area, receiving an average annual rainfall of 1200 mm, and experiences three weather seasons that are distinguished based on rainfall and temperature, namely: hot dry (September–November), rainy season (December–March) and cold dry (April-August) (Chidumayo, 1997). The average temperature ranges from 17°C in the cold dry season to 37°C in the hot dry season. In terms of natural vegetation, Miombo woodland systems (see section 1.2.2), represents 90% of the Copperbelt Province’s total vegetation (GRZ, 1998b).

The Copperbelt Province derives its name from the copper ore deposits in the area, which were discovered in the early 1900s. Mining started in the early 1930s and fuelled the migration of people from different parts of Zambia into Copperbelt Province, owing to the job opportunities provided by the mining industry. The economic boom in the area gave rise to a sharp increase in population, establishing it as the second most densely populated province in Zambia (62.5 persons / km^2) which is almost four times the average national population density (17.3 persons/km^2) (CSO, 2011). In the Copperbelt, forest dependent communities on the outskirts of mining towns are ethnically heterogeneous and dynamic (due to migration propelled by economic booms and busts in the mining industry). In the early 1990s, the Government of the Republic of Zambia liberalized its economy and embarked on structural changes in the development pattern from public to private investments, leading to privatization of all the copper mining companies. This led to the retrenchment of workers both in mining and other related sectors (PRSP, 2002). The decline in the mining industry in Copperbelt Province has led to high unemployment levels in urban areas, forcing people to migrate to rural areas on the outskirts of mining towns in search of agricultural land and natural resources with which to earn a living (Kaoma, 2004), thus exacerbating existing pressures on forest resources (PRSP, 2002). These people directly depend on the forest as a source of agricultural land and as a source of cheaper and readily available energy in the form of charcoal and firewood (Shitima, 2005).

3.3 Site selection

This study employed purposive sampling as a general approach in identifying study sites (Curtis et al., 2000). This method is appropriate in selecting a sample on the basis of knowledge, its elements and the purpose of the study (Babbie, 2005). In this research, two main attributes were considered for site selection. Firstly, to provide empirical data on use of FPES in rural livelihoods (Objective 1) study sites were purposefully selected on the basis of their ecological setting, evidence of use of Miombo agro-ecosystems, similarities in socio-economic activities and livelihood activities, and differences in legal status of the forests, location and local institutional contexts (Table 3.1). Secondly, sites were selected that had identified undisturbed Miombo woodlands and regrowth from slash and burn agriculture and charcoal production to provide insight in C storage, floristic composition and forest diversity (objective 2).

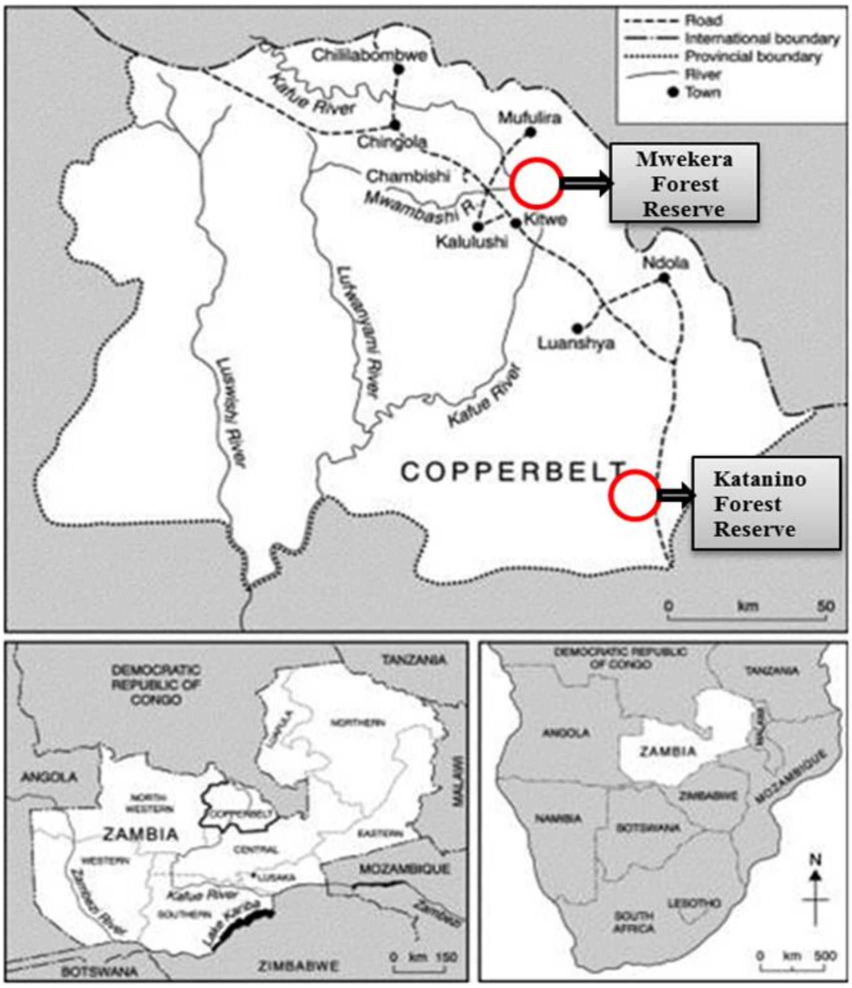

Figure 3.1- Location of study sites (modified from von der Heyden and New (2004))

The two study sites selected were Mwekera and Katanino Forest Reserves (Figure 3.1). The villages in the two sites represent the two main rural village types of Zambia's Copperbelt region: rural peri-urban and rural traditional villages. This classification is based on the distance of the village from urban centres, which is over 40 km for rural traditional and within 40 km for peri-urban villages (Blake et al., 1997, Simon et al., 2004). Rural traditional villages tend to be situated within a customary land tenure system while peri-urban villages are located on state land (Phillips et al., 1999).

Table 3.1- Site characteristics

Site characteristics	**Katanino Site**	**Mwekera Site**
District	Masaiti rural	Kitwe City
Location of site	13˚ 36′ S and 28˚ 42′ E; elevation 1300 m above sea level	12˚ 49′ S and 28˚ 22′ E; elevation 1295 m above sea level
Legal status of forest[3]	Joint Forest Management	National Forest Reserve
Local institutional administration	Customary	State
Cultural context	Rural traditional	Peri-urban
Average household size	5.3 ± 2.3	6.6 ± 3.7
Head of household gender	Male-headed = 66.1%, Female-headed = 33.9%	Male-headed = 78.6% Female-headed = 21.4%
Number of households	512	483
Ethnic groups	15 ethnic groups. The *Lamba* are the most dominant ethnic group (61.9%). Other major groups include the *Bemba* (15.3%) and the *Lala* (6.8%), and 16% of residents belong to 13 other ethnic groups.	19 ethnic groups. There is no dominant group. The majority groups are the *Bemba* (22.2%), *Lunda* (12.9%), *Lamba* (9.5%), *Luvale* (8.7%), and *Ushi* (7.9%), while 38.8% of residents belong to 14 other ethnic groups.
Distance to the nearest urban markets	75 km	20 km
Vegetation type	Miombo woodlands	Miombo woodlands
Livelihood activities	Farming, charcoal production, livestock	Farming, charcoal production

Source (GRZ, 1998b, Kaoma, 2004, Shitima, 2005, Zimba, 2003)

Katanino is located 75km from the nearest urban town (Ndola) and lies on the main road connecting Copperbelt Province and Lusaka. The villages are dominated by the

[3] Despite differences in legal status of forests, forest use is effectively open access

people of the Lamba tribe, who are the indigenous inhabitants of Copperbelt Province (Mitchell and Barnes, 1950). The tribe is matrilineal, in marriage a husband moves to the wife's village and land ownership is linked to the marriage (Mitchell and Barnes, 1950). Female landholding is therefore common among the Lambas. In Katanino, the villages are under the authority of traditional chiefs, who are responsible for land allocation and general leadership. In these rural villages, the residents are more attached to their traditions and beliefs than those of peri-urban villages (Simon et al., 2004).

Mwekera is located about 20 km from Kitwe city and is comprised of mainly peri-urban villages. In these villages, ethnicities are more diverse due to the mix of tribes in urban areas that feed these villages (Zimba, 2003, Kaoma, 2004). Village leadership is vested in a chairperson, who belongs to the currently ruling political party. These villages were previously held under traditional authority but urbanisation undermined the role of traditional chiefs (Zimba, 2003). Further the gazetting of Mwekera forest as a National Forest Reserve led to the exclusion of local people from forest use and management. The government manages forests on behalf of citizens and therefore has decision making powers over all forest management aspects. It excludes any stakeholder participation and does not stipulate any rights for forest dwelling communities. The ownership of all trees in Zambia (both on customary and state land) is vested in the Republican President (GRZ, 1973).

The targeting of these two case study sites provided a wide sample of institutional administrations, market accessibility, and socio-economic criteria, allowing for a better determination of the structures and processes that govern access to and use of forest resources and their consequent impacts on the livelihoods of residents.

Bwengo and Kashitu villages were selected as case study villages in Katanino, while Misaka and Twesheko villages were selected in Mwekera. These villages were adjacent to the Forest Reserves, and all of their households were within 5 km of the forest edge. Further, the selected villages were comparable in village size and population, accessible by road during data collection and the people were willing to engage in the research.

3.4 Forest ecosystem services conceptual framework

There have been growing calls for a better understanding of the interactions in socio-ecological systems (Atkins et al., 2011, Carpenter et al., 2009, Mung'ong'o, 2009, Sekercioglu, 2010). Understanding the interactions between ecosystems and rural people, including current and potential benefits for livelihoods, requires a multi-disciplinary conceptual framework as a guide for integrated research methods and analysis. Conceptual frameworks have been used by researchers, policy makers and governments to get a thorough understanding of a number of complex issues, among them poverty and environment, and links between ecosystems and social systems (Parkes et al., 2003). Conceptual frameworks present information in a logical manner, capturing the essential elements of systems (Midgley, 2007).

A number of studies have constructed conceptual frameworks for analysing socio–ecological systems (Bastian et al., 2012, MA, 2005, Parkes et al., 2003, Rounsevell et al., 2010). However a conceptual framework to ensure analysis of interactions between ecosystems and rural livelihoods at a local-level is still lacking. Some of the frameworks already proposed, e.g. the Millennium Ecosystem Assessment services framework, are linear and hence incapable of capturing complex nonlinear interactions (Folke et al., 2005), while other frameworks focus solely on effects of environmental change (Rounsevell et al., 2010). The analysis of various components of socio-ecological systems requires a more holistic approach (Figueiredo and Pereira, 2011, Whitfield and Reed, 2012) with a need for a non-linear framework to explore the dynamic interaction between social and ecological systems (Carpenter et al., 2009).

Managing forest socio-ecological systems comes with a number of challenges, among them (i) understanding how ecological components and processes are linked to people’s livelihoods, (ii) systematically analysing and comprehensively addressing direct and underlying drivers of ecosystem degradation (FAO, 2012), (iii) understanding the key areas for interventions within an ecosystem for sustainable management, and (iv) developing a dynamic conceptual outline for the analysis of socio-ecological systems adopting an integrated landscape approach. Climate change calls for a need to provide a framework for sound decision making in socio-ecological systems (Burgess et al., 2010).

In this research, a new framework for ecosystem services assessment (FESA) is developed and applied to provide insight in understanding fundamental interactions between social and ecological components of forest socio-ecological systems. This framework has been modified from Bastian et al.'s framework on ecosystem properties, potentials, and services (Bastian et al., 2012) that was constructed to understand the dependence of human society on ecosystems (Figure 3.2). Modifications are suggested here because firstly, the initial framework is not explicit on drivers of ecosystem loss and does not distinguish between direct and indirect drivers of ecosystem loss. Understanding direct and indirect drivers of ecosystem changes is essential in addressing ecosystem management (Kamelarczyk, 2009, MA, 2003, Rounsevell et al., 2010). Secondly, it is not explicit in linking ecosystem functioning and ecosystem services as it lacks transforming structures between the ecosystem and people. Transforming structures mediate the use of resources by people (see section 3.3.3). Thirdly, it lacks intervention points in forest socio-ecological system management, which are critical for informing sustainable interventions in ecosystem management. In view of these discussed limitations, this study has extended and modified the framework further to make it applicable to this research (refer to Figure 3.3).

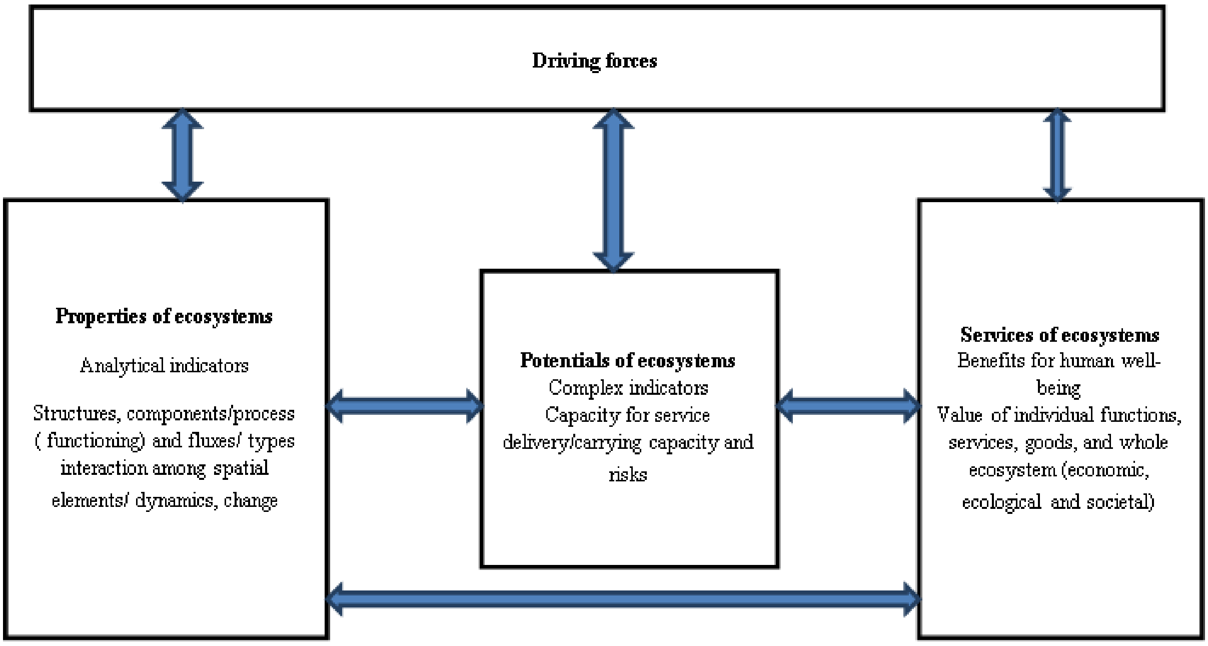

Figure 3.2- Ecosystem, properties, potentials framework (source Bastian et al., (2012)).

3.5 Framework for ecosystem assessment (FESA)

The framework for ecosystem assessment (FESA) shows how the ecosystem functioning relates to the social system and the steps through which ecosystem services become benefits. Forests are fundamental ecosystems that by their functionality provide services, which through transformative structures provide benefits to people. This framework introduces new novel elements of relevance for assessing ecosystems services use and management. It combines some elements from the sustainable livelihoods analysis framework (Scoones, 1998), Millennium ecosystem assessment framework (MA, 2005) and the framework for ecosystem services provision (Rounsevell et al., 2010). FESA integrates multiple uses and interaction within the ecosystem, and provides a holistic investigation of relationships and connections that exists between and within the ecosystem. This is important in evaluating ecosystem services in a more comprehensive way.

FESA consists of six main components or pillars which constitute its theoretical foundations. These are ecosystem properties, potential ecosystem services, transforming structures and processes, actual ecosystem services, drivers (direct and indirect) and intervention points for forest socio-ecological systems management (Figure 3.3).

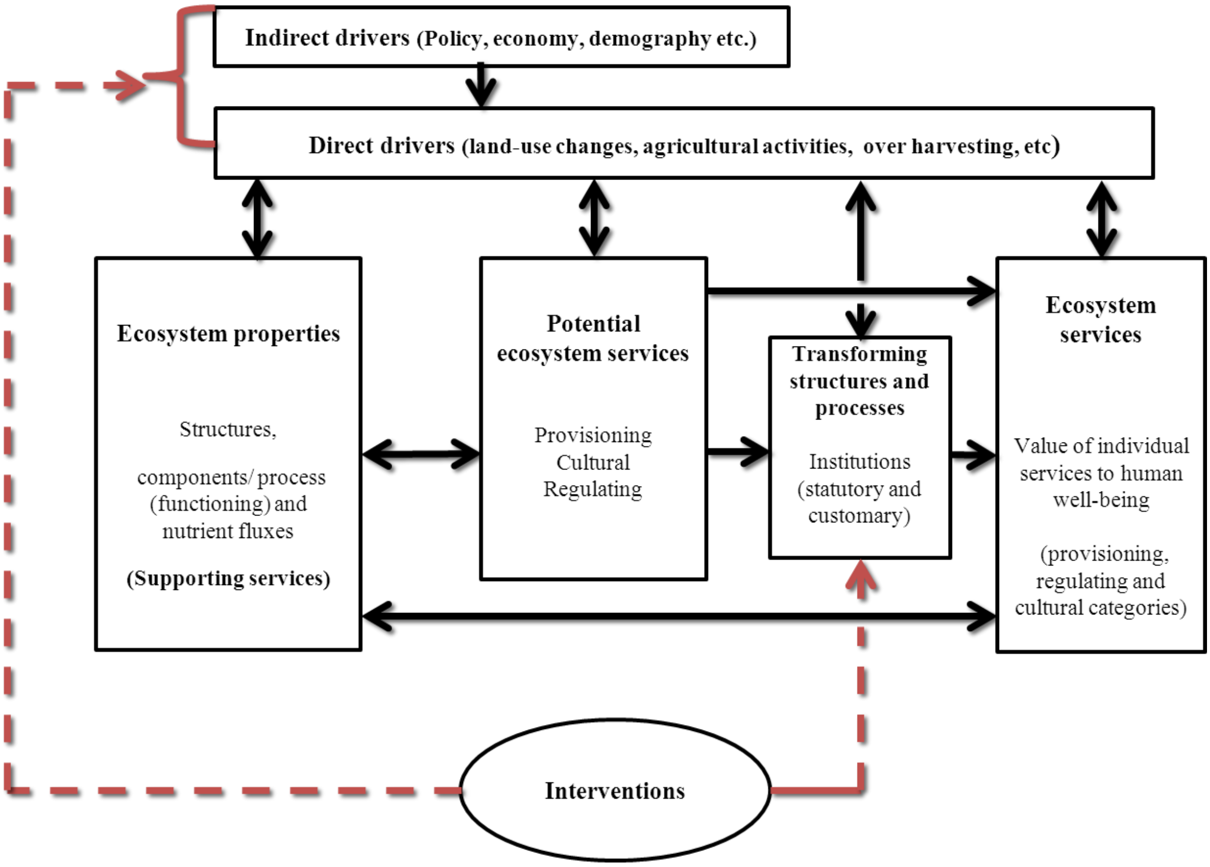

Figure 3.3- Conceptual framework for ecosystem services assessment

3.5.1 Ecosystem properties

Ecosystem properties are defined as "the size, biodiversity, stability, degree of organization, internal exchanges of materials and energy among different pools, and other properties that characterize an ecosystem" (MA, 2005:211). Ecosystem properties underpin the ecosystems' capacity to provide ecosystem services and are the fundamental basis of production (Patterson and Coelho, 2009). These ecosystem properties are the fundamental environmental cycles including water, carbon and nitrogen (Nasi et al., 2002, van Oudenhoven et al., 2012), energy flows and various other complex interactions, all of which are necessary for determining and maintaining function and structure of ecosystems (Johnson et al., 2002, van Oudenhoven et al., 2012, Walker, 1995). Central to ecosystem energy flows and consequently biological productivity is net primary productivity (NPP), which is the amount of biomass produced per unit of time (Erb et al., 2009). Ecosystem properties are fundamental for human well-being as all the services flowing from an ecosystem depend on the functioning of an ecosystem (Sekercioglu, 2010). This pillar is purely ecological, though it is the basis of benefits needed for well-being (Bastian et al., 2012). Ecosystem properties are assessed using natural science methods while the functioning of ecosystems produces potential ecosystem services.

3.5.2 Potential ecosystem services

Potential ecosystem services are the latently available services representing the possible services that an ecosystem can provide for human well-being (Bastian et al., 2012). Potential services flow from biophysical processes and including them allows ecosystems to be viewed from the perspective of potential uses for humans. The flow of ecosystem services is determined by ecological constraints and ecosystem status (Brown et al., 2008). According to Bastian et al. (2012) ecosystems provide service potential by their functioning. The potential services are provisioning, cultural, regulating and supporting. In ecosystem management, the potential services provide valuable information for possible uses and therefore guides in developing future management strategies. Methodologically, analysis of previous literature on forest use provides an opportunity to explore the possible uses, and to compare the actual ecosystem services used against potential ecosystem services in the socio–ecological system.

3.5.3 Transforming structures and processes

Transforming structures and processes mediate access of ecosystem services by people. These may exist as institutions and organisations (formal and informal), culture, power relations and legislation, including bylaws, which mediate the use of ecosystems. In FESA, transforming structures and processes form a link between potential ecosystem services and ecosystem services utilised by people. The significance of transforming structures in people’s access to natural capital has been highlighted by the sustainable livelihood framework (Scoones, 1998). In socio-ecological systems, resource access regulations (statutory or customary) determine the contributions of ecosystems to human well-being (Whitfield and Reed, 2012). Atkins et al. (2011) argue that potential ecosystem services and benefits are not synonymous, an ecosystem potential may exist, but local people may not benefit from its existence, and therefore an analysis of transforming structures elucidates barriers and restrictions on the use of resources (Scoones, 1998). According to Brown et al. (2008), access to resources in ecosystems are mediated by a number of factors including gender, market and technology. Local users of ecosystems are often marginalized by institutional and procedural barriers such as restriction on access to some ecosystem benefits (Whitfield and Reed, 2012).

For potential ecosystem services to be available for human well-being, services can be divided into those that do not need structures and processes to access, such as clean air, which are passively-obtained (van Oudenhoven et al., 2012) and the actively-obtained services that are often mediated by markets (Costanza, 2000) or by transforming structures, such as global carbon sequestration (which requires structures to provide monetary benefits at local level).

3.5.4 Ecosystem services

The last pillar depicts the benefits provided by ecosystems to humans: ‘ecosystem services’ (MA, 2005). They are “components of nature directly enjoyed, consumed, or used to yield human well-being” (Boyd and Banzhaf, 2007: 619). Ecosystem services can either be actively or passively used potential ecosystem services and are spatially and temporally explicit. Ecosystem services are anthropocentric, reflecting local people’s perception of ecosystem service contribution to their livelihoods in various socio-ecological settings (Brown et al., 2008). Benefits determine humans’ perception of the value of the ecosystem. The perception of value has the potential to influence policy and management decision making for different products and services in socio-ecological systems (van Oudenhoven et al., 2012, Whitfield and Reed, 2012). The different types of benefits also have their corresponding environmental, economic and social costs, and therefore environmental decisions require weighting of the various available benefits against their cost (Costanza, 2003).

3.5.5 Drivers of ecosystem change

Drivers are natural or human-induced factors that cause ecosystem change (Carpenter et al., 2009, Nelson et al., 2006). Ecosystems are subjected to changes caused by direct and indirect drivers. Direct drivers are biological, physical or chemical processes that influence ecosystem conditions directly (Nelson et al., 2006), which act on the biophysical component of socio-ecological systems and impose constraints on the capacity of the system to produce benefits (Young et al., 2006). Impacts of direct drivers on ecosystems can be measured by parameters such as changes in land cover/land use, species removals, harvest and resource consumption (MA, 2005).

Indirect drivers are factors that do not affect the ecosystem directly but stimulate direct drivers (Carpenter et al., 2009). Among the main indirect drivers are policy, economic, socio-economic and socio-political influences. Policy influences land management decisions, which ultimately influences (both positively and negatively) the provision of ecosystem services (Ceschia et al., 2010, van Oudenhoven et al., 2012). Markets have also been identified as indirect drivers of ecosystem degradation (Geist and Lambin, 2004) because people's perceptions of economic incentives often become more important than sustainability considerations in ecosystem management (Whitfield and Reed, 2012). Addressing indirect drivers is essential in identifying root causes of ecosystem degradation. Further, ecosystem properties, potential services and ecosystem services have an impact on drivers of ecosystem change (Bastian et al., 2012). The use of ecosystems by humans can trigger changes in ecosystem productivity, resulting in positive or negative impacts on ecological processes and function (ecosystem properties pillar) (van Oudenhoven et al., 2012, Veldkamp and Fresco, 1996).

3.6 Introduction to methods

Empirical data in this research was collected between November 2011 and May 2012. This study employed a mixed methods approach based around the FESA framework (Figure 3.3) to address each of the research objectives (Table 3.2). These methods were used to understand various aspects of Miombo forest socio-ecological systems, generating both qualitative and quantitative data (Figure 3.4).

Table 3.2- Links between research tools or methods and research objectives

Research tool or method	**Research objectives**			
	FPES use in rural livelihoods (Objective 1)	Vegetation and AG C storage (Objective 2)	Policy interactions and implementation (Object 3)	Potential of C-based PES (Objective 4)
Expert interviews			X	
Focus group	X			
Household questionnaires	X			
Key informants	X		X	
Oral history		X		
Policy analysis			X	
Transect walk	X	X		
Vegetation survey		X		

X indicates where a research method has been used for a particular objective.

This study employed different sampling methods which were dependent on the research methods and data needed. Household questionnaires employed stratified random sampling where households were stratified by wealth (see Babbie and Mouton, 2001, Creswell, 1998), giving a total sample of 244 households. Key informants were identified using purposive sampling (Babbie, 1995), while expert interviews employed a combination of purposive and snowball sampling (Babbie, 2005, Patton, 1990). The vegetation survey employed double stratified random sampling for regrowth plots and systematic sampling for mature woodland (see section 5.2), giving a total sample of 82 plots (i.e. 24 (50 m x 50 m plots) and 58 (10 m x 20 m plots)).

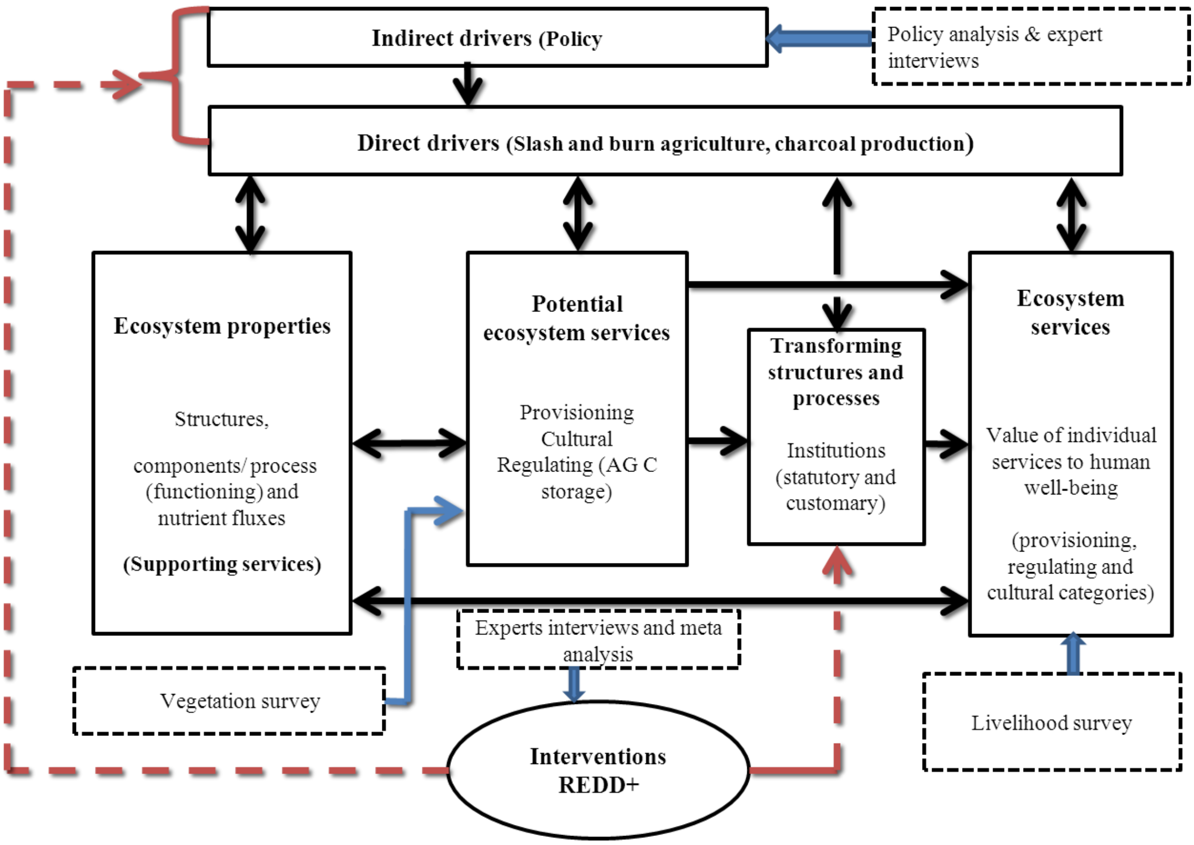

Figure 3.4- Conceptual framework with integrated research methods

3.6.1 Objective 1: Contribution of provisioning services to rural livelihoods

Livelihood and resource use surveys were conducted in each of the study villages to assess the contribution of FPES to local livelihoods using household questionnaires (section 4.2.3) and participatory tools which included transect walks (section 4.2.1), focus group meetings (section 4.2.2) and in-depth interviews with key informants (section 4.2.4). These methods provided an opportunity for rural people to share their knowledge and experiences (Chambers, 1994a). Participatory tools are useful in collecting data from a variety of people including the marginalized and illiterate (Bond and Mukherjee, 2002) and provide reliable knowledge that is developed through iterative and interactive processes (Campbell, 2002). These methods are important in opening up discussions in rural communities (Slocum et al., 1995), and when done with groups, can reveal an over-lapping spread of knowledge which is wider than that of one member (Chambers, 1994b). Participatory methods have emerged over the past few decades into a leading paradigm within the social and environmental sciences (Chambers, 1990, Chambers, 1994c, Kindon et al., 2007, Sallu et al., 2008), and are increasingly becoming popular in environmental research. This is because local communities are often the primary users of ecosystems and are knowledgeable about the ecosystem services in their area (Folke et al., 2005). For many ecosystem services, there is no clear indicator for the value of services to people due to the non-existence of markets for many services (Carpenter et al., 2009), while where markets exists for a few products, market prices do not reflect society's true valuation of benefits (Atkins et al., 2011). Understanding the social value of non-marketed ecosystem services therefore depends on the ways services are used in local livelihoods (Carpenter et al., 2009).

This study used a plurality of methods in understanding the contribution of FPES to rural livelihoods due to the fact that learning through these plural investigations allows for verification of information gathered i.e. triangulation. Triangulation provides for comparison of data among different sources of information thereby improving the validity and reliability of information (see Hindelang et al., 1979).

3.6.2 Objective 2: Vegetation and aboveground carbon storage

This study used vegetation surveys to understand AG C storage, floristic composition, and forest diversity. Vegetation surveys are a widely used method in quantitative investigation of plant communities (McVean and Ratcliffe, 1962, Nakamura et al., 2012, Ross et al., 2012). Vegetation surveys are an important ecological and biodiversity tool, essential in understanding ecosystems under different land use management (Chytrý et al., 2011). In this study, vegetation surveys were conducted using vegetation plots (Figure 3.5) (see section 5.2 for details on survey design, sample plot location and field measurements) within which various tree parameters were recorded on a vegetation recording field proforma (see Appendix 1) which was designed for easy input into SPSS for analysis.

Figure 3.5- Researcher measuring tree diameter in Mwekera Forest Reserve, Kitwe

3.6.3 Objective 3: Policy interaction and implementation

Expert interviews were conducted to elucidate expert opinions and insights on policy influence over forest resources (Dorussen et al., 2005). This method explores the opinions of different experts, which is important in understanding policy implementation (Opdenakker, 2006, Sheng et al., 2009). This study combined expert interviews with policy analysis of selected policy documents (see section 6.2).

3.7 Positionality and ethical considerations

Positionality in research refers to the social position taken by the researcher in relation to people interviewed in the research process and is influenced by several factors, among them education, gender and social class (Merriam et al., 2001). Positionality of the researcher is important in conducting research especially in rural areas (Mather, 1996, Twyman et al., 1999). A thoughtful consideration of positionality of the researcher is important in research involving human subjects as it has the potential to influence responses (Mather, 1996), making the collected data unreliable (Twyman et al., 1999). In this research, the researcher introduced himself as a member of staff from the local University (i.e. Copperbelt University) pursuing further studies at the University of Leeds. The association of the researcher with the two Universities was important in local peoples' perception of the researcher as an academic interested in generating knowledge for academic purposes. The researcher informed the village leaders that he was an independent researcher despite gaining access to the case study villages through the government Forest Department in Katanino study sites and the Ministry of Agriculture in Mwekera study site. The local people's trust in the independence of the researcher was enhanced during data collection as the researcher visited villages for an extended period of time and was not accompanied by government officials. Further logistics in Katanino made the independence of the researcher definite, by spending some nights in the village at a village primary school. To address positionality in the study villages, careful thought was given to the dress code and appearance of the researcher and the research assistants by wearing culturally appropriate outfits. Research assistants were briefed on the importance of positionality in the research and the researcher was able to observe the research assistants complete household questionnaires during the pilot phase to advise on a number of issues, among them how research assistants explained their positionality in the research process to respondents. The researcher and the research assistants engaged in the research process were familiar with cultural contexts in the study villages. Interviews at village level were conducted in either in *Lamba* or *Bemba* languages which the researcher and research assistants were fluent with and therefore prevented misinterpretation, which is common when translation is involved (Spivak, 2012).

Ethical considerations were made during data collection involving human research subjects. This was important in ensuring the research was conducted in a humane and non-exploitative way (Guillemin and Gillam, 2004), reducing the risk of harm to participants that might arise from dishonesty or deception by the researcher (Denscombe, 2010). Participants were informed that participation was voluntary. Informed consent was used to inform prospective participants about the research and what participation would involve, so that they were able to exercise free will on whether or not to participate (Guillemin and Gillam, 2004). Informed consent was obtained verbally, and participants were made aware of the anonymity of the responses. Participants were also made aware that all information collected during the course of research would be kept strictly confidential and that the results would be published in academic publications. The research protocol of this study was approved by the Research Ethics Committee of the University of Leeds (Approval Reference Number 11-008).

3.8 Conclusion

This chapter has outlined the research design and the conceptual framework developed to address the research objectives. A new FESA framework has been developed to enable holistic understanding of fundamental relationships between social and ecological components of forest socio-ecological systems, and provide potential intervention points for improved forest ecosystem management. The chapter has further introduced the integrated methods used to address the research objective, setting the research in a holistic perspective, integrating different methods, different data and research strategies. These methods will be developed in the subsequent chapters that address specific research objectives. This chapter has further discussed the positionality of the researcher during the research process and ethical considerations that can impact on the reliability of data collected. The remainder of the chapters will present and discuss the results obtained in this study.

Chapter 4 Contribution of forest provisioning ecosystem services to rural livelihoods in the Miombo woodlands of Zambia[4]

Abstract

This Chapter examines the contribution of forest provisioning ecosystem services (FPES) to rural households in Zambia's Miombo woodlands. Data was obtained using focus groups meetings, in-depth interviews, and interviews of households. The results show that FPES are vitally important in providing food, medicine, fodder, and construction materials to rural livelihoods. FPES provided 43.9% of the average household's income and contributed a 10% income equalisation effect among households. Poorer households received a lower mean annual income from forests than did their intermediate and wealthy counterparts, but in relative terms, forest income made the greatest contribution to the total household incomes of poor households. The study indicates that wealth, rather than gender, was the key determinant of a household's engagement in the sale of FPES. The results have further shown that households face multiple shocks and that FPES are the most widely used coping strategy used by households facing idiosyncratic shocks. Consequently in designing forest management strategies aimed at reconciling forest conservation and rural development, it is vitally important that use of FPES in rural livelihoods and community differentiation in the use and sale of FPES is better understood to reconcile goals of poverty reduction and forest conservation.

4.1 Introduction

Forests ecosystems provides various products that underpin many rural livelihood strategies (Shackleton et al., 2007). Despite the use of FPES being widely reported (see section 2.3), how socio-economic factors such as wealth and gender of

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[4] This chapter is developed from published journal articles of Kalaba, F. K., Quinn, C. H., Dougill, A. J. (2013). Contribution of forest provisioning ecosystem services to rural livelihoods in the Miombo woodlands of Zambia. *Population and Environment*, 35, 159-182, and Kalaba, F. K., Quinn, C. H., Dougill, A. J. (2013). The role of forest provisioning ecosystem services in coping with household stresses and shocks in Miombo woodlands, Zambia. *Ecosystem Services*, 5, 143-148.

household head affects use and sale of forest products remain understudied (see section 2.3.1). Further, the use of forest products by households to cope with household stresses and shocks is poorly researched (see section 2.3.2).

This Chapter examines the contribution of FPES to rural households in Zambia's Miombo woodlands. It first provides a detailed research design and methodology employed to examine use of FPES in the study area. The chapter then provides a detailed analysis of the types of FPES used, their contribution to livelihoods portfolios and household incomes and the effect of wealth and gender on use and sale of FPES. Furthermore, this chapter provides empirical evidence of the use of FPES as a natural insurance against stresses and shocks after which the changes in forest cover and consequent impact of these changes on livelihood options are presented.

4.2 Research design and methods

Primary data on the contribution of FPES to livelihoods was analysed using plural methods (see section 3.6.1). The following section describes in detail the methods used in data collection.

4.2.1 Transect walks and observation

Transect walks are an important participatory tool in familiarizing the researcher with the study area. Transect walks through study villages (i.e. one transect walk in each study village) with village leaders (n = 2-3) were important in understanding the agro-ecological zones in the villages and getting an in-depth account on their uses, management and associated perceived problems from the participating villagers (Mukherjee, 1993 , Binns et al., 1997). Village leaders were asked questions regarding past shocks and coping strategies employed in the village, changes in forest cover and demand for forest products. The researcher made observations during this process as he engaged in social situations in which the research aims were concealed or not principally the point of the encounter (Ackroyd and Hughes, 1992). Firstly, village leaders explained the various land uses encountered including forest fallows, which proved useful in identifying vegetation plots for the ecological survey. Secondly, transect walks were also important in starting the process of rapport building with local people as a walk with leaders provided evidence that the researcher was officially welcomed in the villages. Being seen with elders had potential negative impact on local peoples' perception of the researcher by associating him with the village leadership, hence being skeptical when answering questions for fear that their responses may be reported the village leadership. This was avoided by making people aware of the researcher's positionality and ethical considerations (see section 3.5).

4.2.2 Focus group meetings

Focus group meetings were conducted in villages to explore forest resource use at local level. These meetings followed a topic guide (appendix 2) which discussed local institutions and structures that shape use of forests and management at village level, influences of gender and wealth on use of FPES, changes in the availability of forest products and subsequent impacts on livelihood options (see appendix 2). The interactions among participants in these meetings is important in generating data (Kitzinger and Barbour, 1999). This is because focus group meetings have the potential to illuminate things about local issues that may be elusive in other survey techniques and help in understanding people's experiences and concerns (Kitzinger and Barbour, 1999, Waterton and Wynne, 1999). They give an opportunity for discussions on epistemological assumptions about the subject matter (Waterton and Wynne, 1999).

Four focus group meetings were held (one in each village) with 10-15 participants, which included males and female participants belonging to different wealth profiles and involved in different forest uses (such as charcoal production, honey collection) These participants were selected based on evidence of their knowledge on forest use and management collected during the household survey. Focus group meetings started with participants constructing a timeline of livelihood activities and forest uses and major recollected events in village history with dates[5]. Binns et al. (1997)

[5] To provide dates of events, participants used the name of the past Zambian Republican Presidents' period of reign and other natural events

found timelines to be a useful icebreaker and this was also found to be the case in this study. Focus group meetings have several weaknesses, including the potential dominance of powerful individuals and groups in group discussions (Kothari and Cooke, 2001). This was overcome in this research by encouraging all participants to talk and providing opportunities for each member to share their experiences. There was a tendency by the participants in focus group meetings to divert discussions to other issues such as government failure to distribute farming inputs or other issues beyond the scope of this research. Campbell (2002) has highlighted the challenge of managing group interviews in line with research goals and creating consensus as a common limitation of focus group meetings. This was overcome in this research by constantly reminding the participants of the key discussion questions that were relevant to the research. Focus group meetings were facilitated by the researcher and were recorded using a digital voice recorder and were listened to repeatedly, and then transcribed for qualitative analysis.

4.2.3 Household questionnaire surveys

Structured household questionnaires were used to collect primary data on FPES use and livelihood strategies of households. This data collection method is widely used in rural research (Chambers, 1983). Questionnaires allow the translation of theoretical ideas informing the research into questions and statements (Ackroyd and Hughes, 1992). Household questionnaires were completed using face-to-face interviews, which though being more expensive in terms of research costs than internet, postal or telephone interviews is the only feasible way of administering household questionnaires in rural areas due to technological challenges. Completing questionnaires using face-to-face interviews provides an opportunity for the researcher to probe beneath the surface to get more depth to the information that is obtained and offers some immediate means of validating data as the researcher can sense if he is being given false information in the interviews by cross-checking responses (Denscombe, 2010). Household surveys have an advantage of high response rates since the researcher is allowed his interpersonal skills to encourage potential respondents to take part in the survey (Denscombe, 2010).

Household questionnaires provided links between FPES and livelihood strategies and the impact of forest changes on livelihoods. Questionnaires developed by CIFOR's poverty environment network (PEN) project (CIFOR, 2007) were adapted and expanded to suit the objectives of this study (appendix 3). These questionnaires have been widely used in developing countries to collect data on people's dependence on natural resources[6]. The design of the PEN questionnaires has been largely informed by the sustainable livelihood framework, which has been critiqued as ignoring temporal changes in rural livelihoods (Scoones, 2009). This study therefore addressed temporal changes using key informant interviews (see section 4.2.4) and focus group meetings (see section 4.2.2).

The sampling frame was the list of all households in each village. To capture the various categories of households in the household survey, households were stratified by wealth (Jumbe et al., 2009, Tschakert et al., 2007). In each village, several leaders (n = 3-5) were asked to assign the households into locally appropriate wealth categories. Previous studies have indicated that rural people are better able to assess the relative wealth and well-being of their communities than 'outsiders' (Hill, 1986). Earlier work has also revealed that rankings are more accurate when three informants (as a team) rank households according to established criteria (Silverman, 1966). The criteria for assigning households into wealth categories are livestock ownership, house size and style, including roofing material and the quality of assets owned, and the ability of a household to pay for school fees. Households were then randomly selected from different categories. This is important in obtaining precise, statistical descriptions of large populations (Babbie, 2005). A total of 244 households (i.e. 118 and 126 households in Katanino and Mwekera sites respectively) took part in the household survey representing 25 % sampling intensity, which is higher than the 20 % recommend by similar studies (Adhikari et al., 2004, Hetherington, 1975). The sampling unit in the household survey was the household, while the unit of observation was the head of household.

[6] www.cifor.org/pen

These questionnaires lasted an average of 50 minutes per household, and were conducted in the local vernaculars (*Lamba* and *Bemba*), in which the researchers were conversant. The questionnaire included sections covering livelihood activities, household stresses and shocks, and the consumption and sale of FPES. Data on the income generated from the sale of FPES were representative of cash income from the previous 12 months as reported by the household. In this study, household income for the livelihood activities were self-reported values by households for net benefits (income reduced by production costs), with the exemption of own- labour costs, due to the challenge of costing own-labour costs in rural areas of Africa (Heubach et al., 2011). The reliability of forest income data was enhanced by the short recall time, and the fact that most of the forest products are sold in the rainy season when the fieldwork was conducted.

4.2.4 Key informants interviews

In-depth interviews were carried out with 15 key informants (7 and 8 in Mwekera and Katanino respectively). This data collection method is important in gathering detailed data from people who have experience or expertise to provide valuable insights on the research topic (Denscombe, 2010). Key informants provided oral history narratives which explored temporal dynamics of forest use and livelihood activities, and provided insight on cultural and religious beliefs associated with forests. Further, the researchers asked about local peoples' access to forest resources, past shocks and coping strategies, rules regulating resource use, penalties for those who break the rules, and conflicts among forest users. In-depth interviews with key informants allowed for discussions about sensitive issues such as conflicts among various forest users and the influence of religious and cultural beliefs on forest use (Marshall, 1996, Tremblay, 1957). This is because discussions about such sensitive topics have the potential of fuelling conflicts among people holding different beliefs within the community if discussed in group meetings. Key informants were village leaders and other elderly males and females. These residents were knowledgeable about forest use and were among the oldest living members of their respective villages; they were therefore able to provide information regarding the changes in forest use over time. The average age of the key informants was 68 years. These interviews were recorded using a voice recorder and then translated and transcribed.

4.2.5 Satellite images

Satellite images were used to observe changes in forest cover. Satellite images were compared with forest cover reported by local people in focus group meetings (Mwitwa et al., 2012, Robertson, 1984). In this research, a time series of LANDSAT images were setup showing deforestation at different intervals (1989, 2002, 2005 and 2009). The time series was selected based on the availability of images for the study area.

4.3 Data analysis

Quantitative data were analyzed using Statistical Package for the Social Sciences (SPSS) 19. Since household questionnaires consisted of both closed and open ended questions, open ended questions were coded to reduce the wide variety of characteristics of information to a more limited set of attributes composing a variable (Babbie and Mouton, 2001). The numeric codes were then entered into SPSS 19 for analysis. The main statistical analyses conducted were frequency analysis and descriptive statistics. The chi-square test for independence was used to determine the associations between categorical variables, while the Z-test was used to compare the significant differences between proportions. The Gini-coefficient was computed to explore the total per capita income and the distribution effects of forest incomes in reducing income inequality among households (Yao, 1999).

$$G = \sum_{f=1}^{F} W_{\mathrm{f}}\ C_{\mathrm{f}}$$

Where G is the Gini coefficient, F is the total number of source incomes, W_f is the share of source f in total income, while C_f is the concentration ratio of source f.
Gini-coefficient values range from 0 to 1 (0 indicates an exactly equal income distribution among households, while 1 indicates maximum inequality).

Qualitative data analysis began with transcribing of interviews. The researcher did not transcribe the whole interviews, but only the sections consisting of key parts of the discussions (Cameron, 2000). Themes that occurred frequently across the interviews were developed by using a grounded theory approach (Strauss and Corbin, 1990) where categories emerged from the interview data.

4.4 Results

4.4.1 Composition of households, gender and wealth differentiation

The average household size was six members. The distribution of head of household gender showed that 72.5 % (n=177) were males and 27.5 % (n=67) were female. The sampled households consisted of 49.2 % poor households, 34 % intermediate, and 16.8% wealthy households. No significant association was observed between head of household gender and the wealth status of the household ($\chi^2 = 4.09$; $p > 0.05$).

4.4.2 The use of Forest Provisioning Ecosystem Services

A high dependence on provisioning forest ecosystem services was observed across wealth groups and different head of household genders. A range of services were used on a daily basis for home consumption as part of the households' livelihood portfolios. The main categories of resources used were foods, fuelwood, medicines and construction materials. Overall, 89.8 % of households obtained various foods from the forest ecosystem. After stratifying households by wealth and gender, no relationship was detected between household consumption of forest foods and either household wealth (Table 4.1) or head of household gender (Table 4.2). The households used more than one category of food product, with the majority of households engaged in the collection of wild fruits (88.9 %), mushrooms (71.7%), indigenous vegetables (43.4 %), edible roots (17.2 %) and honey (10.2 %). Other foods collected for household consumption included caterpillars and tubers.

Almost a quarter of the sampled households (24.6 %) used the forest as a source of fodder, primarily for cattle and goats. A significant relationship was observed between the use of fodder and household wealth category (Table 4.1). A significantly higher proportion of wealthy households used forests for fodder than did poor households at both study sites (i.e., Katanino: Z = 2.73; $p < 0.05$ and Mwekera: Z = 3.47; $p < 0.05$). Further analysis indicated that a higher proportion of intermediate households in Mwekera used fodder than did poor households (Z =3.71; $p < 0.05$). No significant differences in fodder use were detected between wealthy and intermediate households at both study sites. The tree species that were considered most palatable for cattle were *Baphia bequaertii*, *Dalbergia nitudula* and *Parinari curatellifolia*. Other species used for fodder included *Julbernardia paniculata* and *Diplorhynchus condylocarpon*.

Table 4.1- Proportions of households (%) that use various FPES as stratified by household wealth (n=244)

		Katanino site				**Mwekera site**			
Forest use	**Overall** (n=244)	Wealth category			χ^2	Wealth category			χ^2
		Poor (n=64)	intermediate (n=39)	Wealthy (n=15)		Poor (n=56)	intermediate (n=44)	Wealthy (n=26)	
Food	89.8	95.3	89.7	93.3	0.5	85.7	93.7	84.6	1.7
Medicine	66.0	76.6	82.1	93.3	2.3	55.4	56.8	38.6	2.1
Fodder	24.6	18.8	33.3	53.3	7.5*	5.4	34.1	34.6	15.8*
Fuelwood	90.2	100.0	97.4	100.0	3.1	85.7	79.5	76.9	2.2
Construction	87.3	98.4	94.9	100.0	1.6	91.1	75.0	50.0	15.4*

*Significant at 0.05

The Miombo woodlands are an important source for domestic energy and construction materials. Overall, 90.2 % of households used firewood from the study area for cooking and heating, while 87.3 % of households used forest provisioning services as sources of construction material (i.e., poles and fibre). The trees that provide building poles for houses and barns are *Pterocarpus angolensis*, *Pericopsis angolensis* and *Swartzia madagascariensis*, as these species are durable and are not easily attacked by termites, borers or wood-decaying fungi. Other trees, such as

Anisophyllea boehmii, *Uapaca kirkiana* and *Parinari curatellifolia*, are used for roofing material, as they are also repellent and/or toxic to termites and other wood-eating insects. A relationship between household wealth status and use of construction material was observed in Mwekera (Table 4.1), where the use of provisioning services for construction was significantly higher in poor households than in their intermediate and wealthy counterparts ($Z = 2.18$; $p < 0.05$ and $Z = 3.99$; $p < 0.05$, respectively). Furthermore, a significant association was also detected between the use of FPES for construction purposes and head of household gender (Table 4.2). The proportion of households using these construction materials is significantly greater for male headed households ($Z = 2.47$; $p < 0.05$).

Table 4.2- Proportions of households (%) that use various FPES stratified by head of household gender (n=244)

		Katanino site			**Mwekera site**		
Forest use	**Overall** (n=244)	Head of household gender		χ^2	Head of household gender		χ^2
		Males (n=78)	Females (n=40)		Males (n=99)	Females (n=27)	
Food	89.8	92.3	95.0	0.6	91.9	74.1	0.3
Medicine	66.0	83.3	75.0	1.1	55.5	44.4	0.9
Fodder	24.6	31.2	22.5	1.1	22.2	18.5	0.2
Fuelwood	90.2	98.7	100.0	0.0	84.8	70.4	0.0
Construction	87.3	97.4	97.5	0.0	82.8	59.3	6.3*

*Significant at 0.05

Two-thirds of households reported the use of forests as a source of medicine. Within both study sites, no significant relationship was observed between a household's use of trees for medicinal purposes and either its wealth (Table 4.1) or the gender of its head (Table 4.2). A significantly greater proportion of the households in Katanino (80.5 %) used forests as a source of medicine than those in Mwekera (53.2 %) (Z = 4.63; $p < 0.05$).

Households use a number of different tree species for the treatment of various ailments. During the in-depth interviews, several respondents mentioned that people belonging to certain religious groups are often not allowed to use traditional medicines and are encouraged to rely on Western medicine. These groups impose religious sanctions (e.g., expulsion from the group) on those who admit to using traditional medicines. The 10 most common tree species used by the households in the study area are summarised in Table 4.3.

Table 4.3 - Ten most preferred tree species for medicinal purposes (n=161)

Tree species scientific name	Local name	Percentage of households	Tree part(s) used	Ailment(s) treated
Cassia abbeviata	Musokansoka	74.5	Bark/roots	Bilharzia, skin ailments, diarrhoea, cough, malaria
Julbernadia paniculata	Mutondo	24.2	Bark	Diarrhoea, headache
Pseudolachnostylis maprouneifolia	Musalya	18.0	Bark	Diarrhoea
Uapaca kirkiana	Musuku	17.4	Roots/bark	Cough, diarrhoea
Parinari curatellifolia	Mupundu	16.8	Bark/roots	Diarrhoea
Oldfieldia dactylophylla	Lundawampanga	13.7	Bark	Fever, diarrhoea
Syzygium guineense	Musafwa	15.5	Bark	Eye infections, cough, diarrhoea
Diplorhynchus condylocarpon	Mwenge	14.3	Bark/roots	Cough, fever
Zanthoxylum chalybeum	Pupwe	12.4	Root	Cough, diarrhoea
Piliostigma thonningii	Mufumbe	12.4	Leaves	Cough

4.4.3 Income portfolios of households and their relative contributions

The economic portfolios of the households in this study are diverse and include crop and livestock production, sale of forest products, remittances and on/off farm activities (Figure 4.1). The pooled results from the two study sites show that forests contribute 43.9 % of average annual household income. Income from crop production was the second most important contributor at 42.0 %. On/off farm activities, remittances and livestock accounted for 7.6 %, 3.8 % and 2.7 % of annual income, respectively.

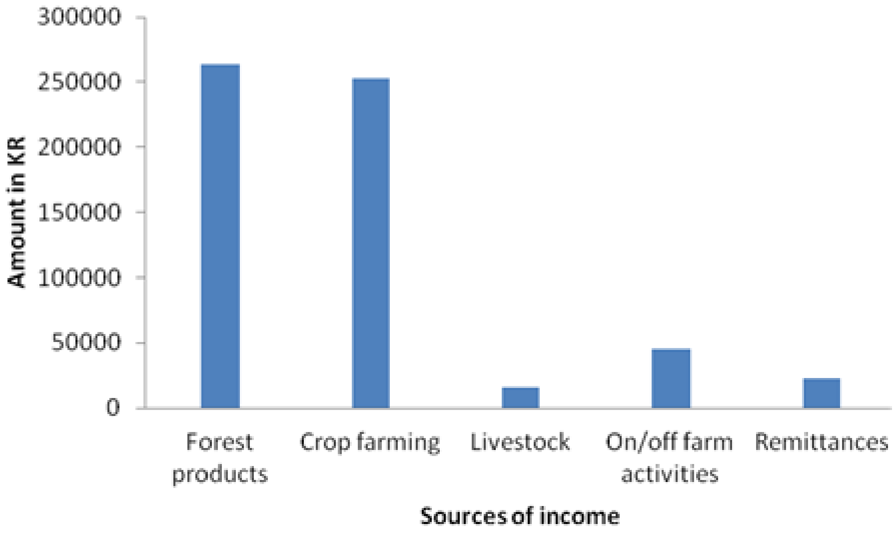

Figure 4.1- Sources of annual household income and their contributions in KR[7]

The calculated Gini-coefficient was 0.51 for total household income, and the exclusion of forest income increased the Gini-coefficient by 10 % (0.61), indicating that forest income contributes to income equalisation among households.

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[7] KR (Kwacha rebased) is the local currency in Zambia. The exchange rate with one USD was KR 5.1 during data collection. The Zambian government rebased the currency after the researchers had collected data, and the collected figures were therefore divided by the currency rebasing factor of 1000 prior to data analysis.

4.4.4 Contribution of income from FPES to total household incomes

Household incomes from the sale of FPES ranged from KR 10.0 to KR 15000.0 annually, with a mean of KR 1834.0. When analysed by study site, the mean annual income from FPES was higher in Mwekera (KR 2140.70) than in Katanino (KR 1512.4). Households sell various provisioning services (half of the sampled households sold more than one product) that contribute to the rural economy, using different FPES to diversify their overall economic portfolios. Among FPES, charcoal constitutes the largest proportion (63.5%) of forest income, followed by mushrooms (13.6%). The average contribution of firewood to forest income was 9.9 %, and wild fruits and thatching grass contributed 5.5% and 3.1% to forest income, respectively. Wild vegetables and honey accounted for 2.0% and 1.5% of forest income, respectively.

The pooled results show that 69.3% of all households derive some income from the sale of various FPES. The highest proportion of households engaged in charcoal trading, followed by the sale of mushrooms, wild fruits and thatching grass (Figure 4.2). Relatively fewer households engaged in the sale of handicrafts, reed mats and a traditional non-alcoholic beverage called *Munkoyo*, which is made from the roots of *Rhynchosia venulosa*.

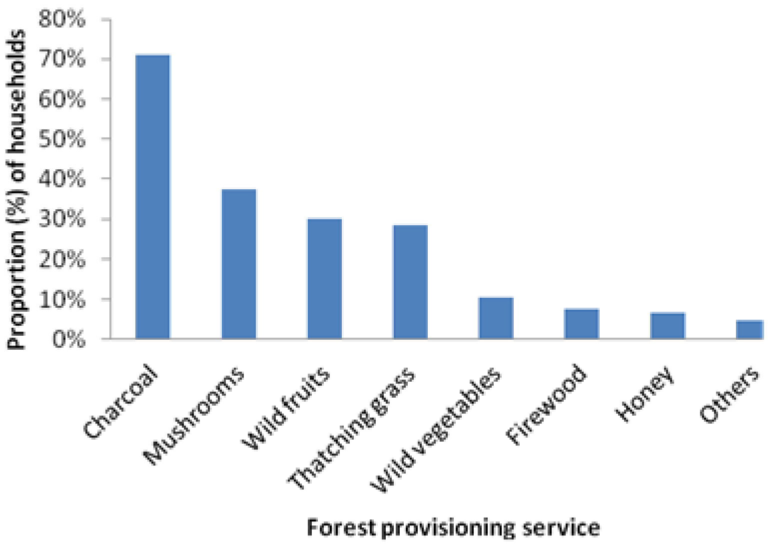

Figure 4.2- Proportions of households (%) selling different FPES (n=169)

Charcoal was shown to be the highest contributor to annual income for participating households in both Katanino (KR 1524.8) and Mwekera (KR 1920.4) (Figure 4.3).

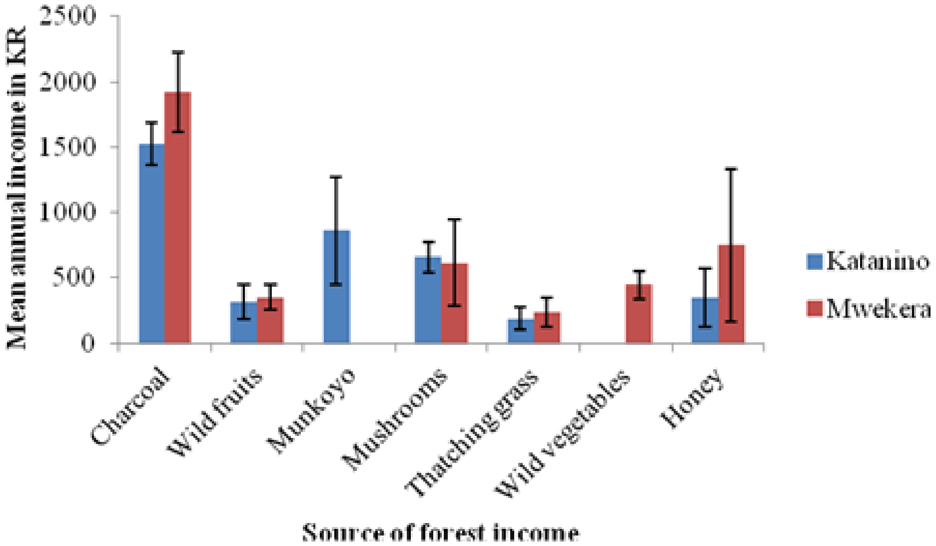

Figure 4.3- Mean annual income from different FPES for participating households and standard error bars

The charcoal produced in the villages is primarily exported to urban markets (Figure 4.4).

Figure 4.4 - Bags of charcoal in Katanino awaiting transportation to Lusaka

Wild mushrooms are a delicacy which are usually sold along the main roads (Figure 4.5) or taken to urban markets as far away as Lusaka (approximately 300 km from the study area). A barter system is occasionally observed in which forest products are exchanged for clothes or foodstuffs imported by urban-based middlemen.

Figure 4.5 - Wild mushrooms (*Termitomyces titanicus*) being sold at a roadside market in Katanino

4.4.4.1 Inter-site comparison of households selling FPES

A comparison of the sales of provisioning services between the two study sites revealed that households in Mwekera sold a significantly greater proportion of mushrooms (Z = 2.94; $p < 0.05$) and wild fruits (Z = 6.51; $p < 0.05$) than those in Katanino. Differences in the sales of charcoal, honey, thatching grass and handicrafts were not significant between the two study sites. Furthermore, the sale of firewood and indigenous vegetables was only observed in Mwekera, while the sale of *Munkoyo* was only observed in Katanino (see Table 4.4).

4.4.4.2 FPES incomes and wealth status of households

The average incomes derived from the forest by poor, intermediate and wealthy households were KR 1620.1, 2009.7 and 2340.8, respectively. In relative terms, these amounts represented contributions of 55.5 %, 48.7 % and 19.8 % of total annual household income, respectively. No significant association were detected between the sale of FPES and household wealth status in Katanino (Table 4.4). Wealthy, intermediate and poor households all engaged in the sale of FPES. The results from Mwekera indicated that the wealth status of households had a significant influence on their involvement in mushroom selling (Table 4.4).

A significantly greater proportion of poor households engaged in the mushroom trade than that of wealthy households ($Z = 2.72$; $p < 0.05$). When asked whether any members of his household sold mushrooms, a wealthy male head of household in Mwekera responded;

"Why should any member of my household wake up early at 4am in the morning to go and collect mushrooms while I have cows in my kraal that need to be milked?"
(Local resident, Mwekera site)

Mushroom sales were also significantly greater in intermediate households than in wealthy households ($Z = 2.62$; $p < 0.05$), while no difference was observed between poor and intermediate households.

Table 4.4- Proportion of households (%) selling different FPES stratified by household wealth

		Katanino site				Mwekera site			
Products sold	**Overall** (n=244)	Wealth category			χ^2	Wealth category			χ^2
		Poor (n=64)	intermediate (n=39	Wealthy (n=15)		Poor (n=56)	intermediate (n=44)	Wealthy (n=26)	
Charcoal	45.1	51.6	60.0	33.3	2.9	41.1	45.5	19.2	5.1
Wild fruits	21.3	6.5	2.6	6.7	1.2	48.2	29.5	19.2	7.6*
Handicrafts	2.4	6.5	0.0	0.0	0.8	0.0	0.0	3.8	3.9
Wild vegetables	6.5	0.0	0.0	0.0	-	5.4	13.6	7.7	2.2
Thatching grass	20.5	21.9	17.9	6.7	1.5	30.4	22.7	0.0	9.7*
Mushrooms	27.0	25.0	15.4	6.7	1.7	46.4	27.3	15.4	8.6*
Munkoyo	2.9	7.8	2.6	0.0	0.9	0.0	0.0	0.0	-
Honey	6.1	4.7	7.7	6.7	4.9	3.6	6.8	7.7	0.8
Firewood	3.2	0.0	0.0	0.0	-	7.1	6.8	3.8	-

*****Significant at 0.05

The results further revealed a significant relationship between the wealth status of households and sales of wild fruits and thatching grass (Table 4.4). A comparison between poor and wealthy households revealed that a significantly greater proportion of poor households sold wild fruits ($Z = 2.50$; $p < 0.05$), while wealthy households did not engage in the sale of thatching grass. There was no significant relationship between sale of charcoal and wealth categories of households (Table 4.4).

4.4.4.3 FPES incomes and gender

The mean FPES income stratified by head of household gender was KR 1970.6 and KR 1452.7 for male- and female headed households, respectively. FPES income contributed 44.4 % and 41.8 % of total annual household income for male- and female headed households, respectively. The results from Katanino indicate a significant association between head of household gender and involvement in the sale of mushrooms (Table 4.5), with a significantly greater proportion of female-headed households engaging in the sale of mushrooms (Z = 2.19; $p < 0.05$). There were no significant associations between head of household gender and the sale of other FPES, although a relatively higher proportion of female headed households sold thatching grass and *Munkoyo* while male headed households were more likely to sell charcoal and honey (Table 4.5).

In Mwekera, no significant relationship was observed between the proportion of households that engage in the sale FPES and head of household gender, with the exception of charcoal (Table 4.5), which was sold by a significantly greater proportion of male headed households (Z = 3.26; $p < 0.05$). A relatively higher proportion of female headed households dominated the sales of mushrooms, wild fruits and thatching grass, although these differences were not significant. According to all of the focus groups, women and children dominated the collection and sale of mushrooms, vegetables and fruits within households, while men dominated honey collection and charcoal production.

Table 4.5- Proportion of households (%) selling different FPES stratified by gender

		Katanino site			Mwekera site		
Products sold	**Overall (n=244)**	Gender of household head		χ^2	Gender of household head		χ^2
		Males (n=78)	Females (n=40)		Males (n=99)	Females (n=27)	
Charcoal	45.1	56.4	42.5	2.8	45.5	11.1	10.6*
Wild fruits	21.3	5.1	5.0	0.0	34.3	40.7	0.3
Handicrafts	2.4	3.8	2.5	0.5	1	0.0	-
Wild vegetables	6.5	0.0	0.0	-	9.1	7.4	0.1
Thatching grass	20.5	15.4	25.0	0.9	20.2	25.9	0.4
Mushrooms	27.0	14.1	30.0	4.7*	31.3	40.7	0.7
Munkoyo	2.9	3.8	7.5	3.1	0.0	0.0	-
Honey	6.1	7.7	2.5	2.1	6.1	3.7	0.2
Firewood	3.2	0.0	0.0	-	8.1	0.0	-

*Significant at 0.05

4.4.5 Prevalence of seasonal household food stresses

Almost half of the sampled households (48 %) reported food shortages several months per year as maize stocks (staple food) were depleted before the next harvest season. When stratified by study site, the results show that the proportion of households experiencing food stress was not significantly different between the sites though it was relatively higher in Katanino (53.4 %) than Mwekera (41.6 %). Food shortages were mainly experienced between November and April. Food deficits differed depending on wealth status. There was a significant difference between wealth classes ($\chi^2 = 28.7$; $p < 0.05$) with poorer households experiencing food shortages often over extended periods, while there was no difference observed as a result of gender of household head (χ^2 = 2.8; p > 0.05). During seasonal food shortages, 45.3% of respondents reported charcoal sales as the main coping strategy, while piecework (35 %), remittances (9.4 %), sale of mushrooms (5 %) and sale of livestock (2%) were also reported. When asked about what households do during food shortages, one male local key informant in Mwekera said;

"When you run out of food in the household, the axe hits the tree" (Key informant, Mwekera site)

4.4.6 Prevalence and nature of shocks

Households in the study area faced various shocks. In the 2 years prior to this study, households faced a variety of shocks, with some households experiencing more than one type of shock. This led to major income shortfalls and unexpected expenditure. The largest proportion of households reported human health shocks, i.e. serious illnesses (41 %), while loss of income due to weddings[8] and other costly social events was experienced by the smallest proportion of households (2.5 %). Other reported shocks were crop failure (30.7%), death of household member (19.7 %), major loss of assets through theft (9.8%), and loss of livestock (8.6 %). All the identified shocks were experienced by both male and female headed households and across all the household wealth classes (Table 4.6).

[8] Weddings may be considered as shocks owing to the extended family support systems in the study area. Households are expected to provide financial support to extended family members at short notice.

Table 4.6- Proportion of households (%) experiencing idiosyncratic shocks stratified by household wealth and gender of household head

Shock	Overall (n=244)	Wealth category			χ^2	Gender of household head		χ^2
		Poor (n=120)	Intermediate (n=83)	Wealthy (n=41)		Male (n=177)	Female (n=67)	
Crop failure	30.7	33.3	28.9	26.8	0.8	33.3	23.9	2.0
Serious illness	41.0	48.3	31.3	39.0	5.9	41.8	38.8	0.2
Death/funeral expenses	19.7	16.7	19.3	29.3	3.1	19.2	20.9	0.1
Major asset losses	9.8	11.7	8.4	7.3	0.9	11.3	6.0	1.6
livestock loss	8.6	10.8	4.8	9.6	2.3	7.9	10.4	0.4
Weddings and social events	2.5	0.8	3.6	4.9	2.8	1.7	4.5	1.6

The proportion of households experiencing various idiosyncratic shocks was comparable between the two study sites (Figure 4.6).

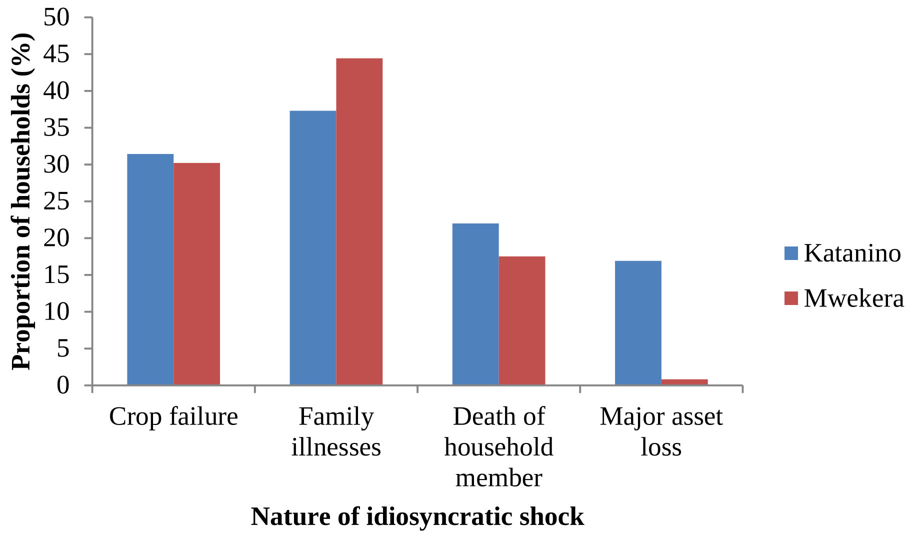

Figure 4.6- Proportion of households (%) experiencing various shocks stratified by study sites.

The focus group meetings reported various covariate shocks over the last 30 year period. These were (1) natural shocks such as severe drought in 1991/1992, and 2004/2005 farming seasons and floods 2006/2007, (2) economic shocks in urban areas leading to village in-migration and more competition for natural resources, (3) political changes in 1992, which was followed by changes in economic and agriculture policy that resulted in the abolishment of agricultural subsidies that the majority of rural people relied upon, and (4) human health shocks such as the outbreak of cholera in 1992/1993 which claimed hundreds of lives in Copperbelt province.

4.4.7 Coping with household income shocks

The results of this study indicate that households used diverse strategies to respond to household income shocks (Figure 4.7). The coping strategies employed by the greatest proportion of households were the sale of forest products (33 %), followed by *piecework*[9] (21 %) and monetary or in-kind support from kinship networks (20

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[9] Casual off farm labour usually of an agriculture nature done on *ad hoc* basis, payment is either in cash or in-kind

%). Others sold agricultural products, used their savings, sold food meant for household consumption or received assistance from churches (see Figure 4.7). Faith-based organisations (churches) offer help especially in times of bereavement. When stratified by study site, the use of FPES was comparable between the Katanino (30.6 %) and Mwekera sites (35.6 %).

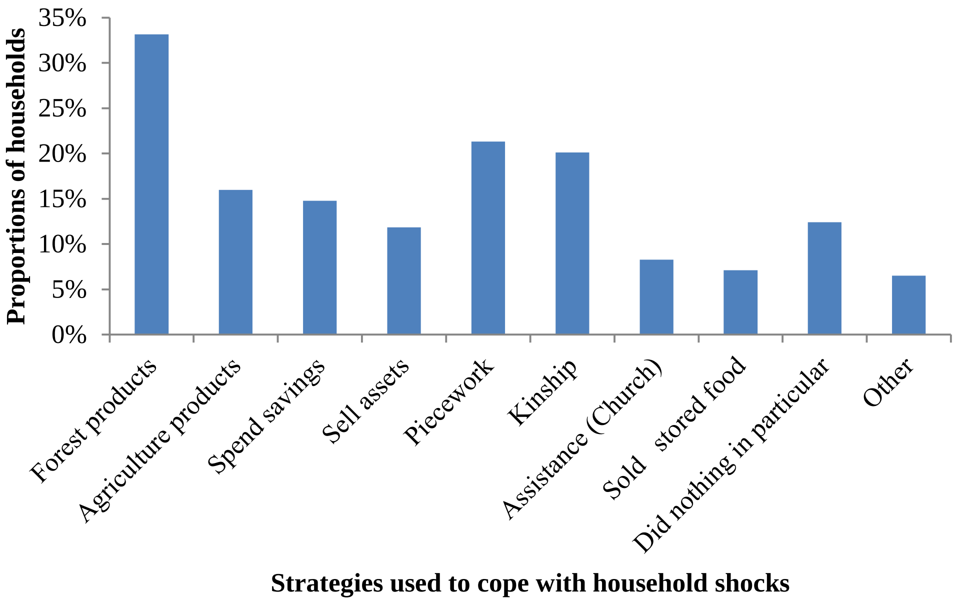

Figure 4.7- Proportion of households (%) that employed coping strategies in response to income shocks (n=169).

According to focus group meetings and in-depth interviews, during severe drought periods (i.e. 1991/1992 and 2004/2005), most households survived by increasing the consumption of wild foods, carrying out piecework and increasing charcoal production. A female interviewee in Kashitu village recalled the drought of 1991/1992 by saying;

> *"That drought was terrible, we lost self-respect, what helped us survive were the Mupundu fruits, we made thick porridge which was consumed by both children and adults."* (Key informant, Katanino site)

The fruits of *Parinari curatellifolia* (Mupundu) were preferred by many people as they were said to be filling.

4.4.8 Socio-economic determinants of coping strategies

There were no significant associations between household wealth status and use of FPES as a coping strategy, although a relatively higher proportion of poor and intermediate households used FPES to cope with household shocks (Table 4.7). A significantly higher proportion of poor households ‘did nothing in particular’ in responding to income shocks such as death of livestock. There were no significant associations between household wealth status and use of kinship connections as a copying strategy, although a relatively higher proportion of wealthy-households reported using kinship in coping with idiosyncratic shocks. A higher proportion of poor households received assistance from the church. With respect to gender, there was no significant association between use of forest products and gender although in a relatively higher proportion of male-headed households used forests as a coping strategy (Table 4.7). The results further show that a higher proportion of female-head households received assistance from faith based organisations and through kingship than their male counterparts (Table 4.7).

Table 4.7- Proportion of households (%) that employed coping strategies in response to shocks

Coping strategy	Overall (n=169)	Wealth category			χ^2	Gender of household head		χ^2
		poor (n=85)	Intermediate (n=53)	Wealthy (n=31)		Male- (n=126)	Female- (n=43)	
Forest product	33.1	35.3	35.8	22.6	1.9	35.7	25.6	1.5
Agriculture products	16.0	20.0	9.4	16.1	2.7	19.8	6.9	5.5*
Spend savings	14.8	11.8	17.0	19.4	1.3	16.7	9.3	1.4
Piecework	21.3	22.4	24.5	12.9	1.7	20.6	23.3	0.1
Assistance from Church	8.3	14.1	1.9	3.2	0.4	5.6	16.3	2.1
Kinship	20.1	18.8	18.9	25.8	0.8	17.5	27.9	2.7
Sell assets	11.8	9.4	17.0	9.7	2.0	12.7	9.3	0.4
Sold stored food	7.1	7.1	3.8	12.9	2.5	8.7	2.3	2.0
Nothing in particular	12.4	18.8	3.8	9.7	7.1*	10.3	18.6	2.0

*Significant at 0.05

4.4.9 Perception of deforestation and forest degradation

Residents in the study areas were aware of changes in forest cover, and subsequent decline of availability of some forest products. At household level, there was a perceived decline in the availability of wild fruits (83.4%) and mushrooms (95.3%). A female key informant from Mwekera explained the changes in availability of forest products by saying;

> *"Nowadays you cannot find mushroom rotting in the forest, long time ago, we used to find rotten mushroom. It is now impossible because the harvesting rates are very high both males and females engage in mushroom extraction, and are sometimes hired to harvest by traders who come from urban areas."* (Key informant, Mwekera site)

According to a male local key informant in Mwekera, some mushroom species have become rare;

> "*We no longer collect some mushroom species such as Tente (Termitomyces titanicus) due to forest clearance which has caused ecological disturbances*." (Key informant, Mwekera site)

Further, households no longer easily find tree species such as *Pericopsis angolensis* and *Pterocarpus angolensis* needed for construction materials and therefore have to walk long distances or use less preferred species. In terms of accessing medicinal trees, all focus group meetings mentioned that it is increasingly becoming difficult to find preferred medicinal trees such as *Cassia abbreviata*.

A focus group meeting in Mwekera site revealed that there is increasing pressure on forests for firewood for industrial use in the mining industry for smelting copper (Figure 4.8). The meeting further revealed that cutting of trees for firewood is dominated by young men.

Figure 4.8 - Trees cut for firewood and a truck loading for industrial use

This is a fast method of getting an income for youths. In-depth interview and focus group meetings cited charcoal production as responsible for high rates of forest cover loss. During data collection, it was observed that trees are also felled for purposes of extracting fibre used in charcoal packaging (Figure 4.9).

Figure 4.9- Tree cut for fibre used in charcoal packaging and charcoal bags with 'heads'

Extraction of wood products was not perceived by households to drive forest cover loss. In the study area, in-depth interviews revealed that wood products for construction materials (poles and timber) and carvings are selectively harvested depending on the desired specific attributes of the tree.

The village timelines show that changes in forest cover became visible to the local people in the early 1990s. The trend has been continuing to grow due to increasing demand for forest products. Satellite images of the study area confirmed local people's report of high rates of forest cover loss in the early 1990s (see Figure 4.10)

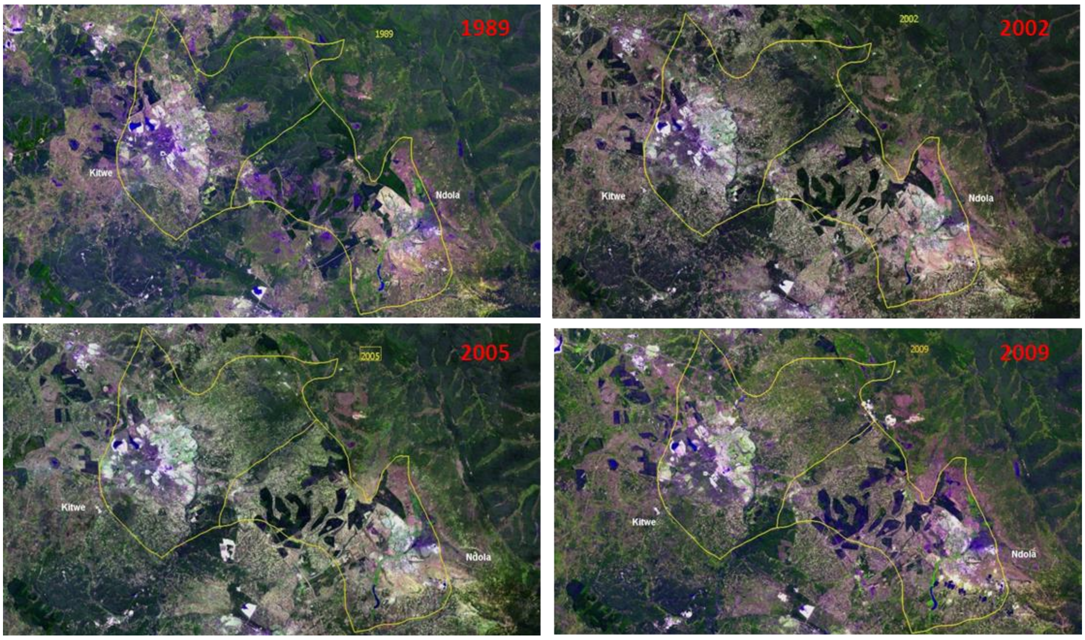

Figure 4.10 - Changes in forest cover in Kitwe and Ndola districts

4.4.10 Impact of deforestation and forest degradation on livelihoods

All focus group meetings and in-depth interviews reported the change in forest cover as reducing households' incomes and livelihood options due to limited alternative local livelihood options. Deforestation has led to households lose revenue which was once realised from sale of mushrooms and fruits. A female key informant in Mwekera revealed that:

> *"In the 1980s we used to load trucks with Musuku (Uapaca kirkiana) fruits and mushrooms to sell to Kitwe and Lusaka, now few trees have remained due to many people targeting them for charcoal and firewood."*(Key informant, Mwekera site)

Some households have resorted to buying mushrooms which they previously used to harvest. In-depth interviews further revealed that decrease in forest cover has further reduced livelihood options available. Previously, more people engaged in the sale of forest products (in increased quantities) which opened up more opportunities for livelihood diversification. According to a male key informant in Mwekera, the decrease in forest cover has moved the bees further away and they no longer harvest honey for sale.

"*We used to harvest large quantities of honey to sell, but we don't have enough bees anymore, they have gone far away due to the cutting down of trees. Now we only harvest small quantities of honey which is just for household consumption.*" (Key informant, Mwekera site)

Due to the increasingly long distances to harvest sites for scarce FPES, productive time which could have otherwise been used for other livelihood activities is spent walking long distances to harvest forest products.

4.4.11 Local institutional structure and impact on forest use and management

Mwekera site

The management of Mwekera National Forest Reserve follows a conventional conservation approach which excludes communities from managing the forests. There are no local institutions that engage communities in active forest management. This is because the forests are managed centrally by central government through the Forest Department.

Despite statutory regulations which assume to protect the forest as pristine, human activities were observed in the forest. Illegal collection of forest products was rampant; extensive areas of the forest are depleted. There is no government control on access to the forests which has led to diminishing of forest cover. During the study, charcoal kilns were found within the forest reserves (Figure 4.11).

Figure 4.11- Charcoal kilns in Mwekera National Forest Reserve

In villages surrounding Mwekera, there are no traditional institutions that regulate forest use and management. Further, no protecting of trees for a particular environmental or cultural service exists. The lack of traditional institutions and diversity of ethnic tribes has led to the erosion of cultural norms and practices that regulate forest use. A male key informant revealed that;

> *"When I first migrated to this village, I was observing the customary rules on harvesting of forest products such as fruit trees which I used to practice where I came from. I stopped when I realised the other people here were not following any rules, we have different beliefs and taboos in our ethnic groups which makes it difficult to observe them in these mixed ethnic communities."*(Key informant, Mwekera site)

Local people obtain products from the forests without any consent from the forest department despite the law demanding permits and licences to harvest forest products. Some people from urban areas also harvest forest products, including cutting down trees in order to sell firewood to urban industries. Since forest use is statutorily illegal, local people have not engaged in institutionalised (customary institutions) use of forest resources. Legally, local people are illegal settlers and do not have title to their land. The uncertainty of land tenure has made local people lose the ability to enforce exclusion rights (e.g. encroachment from outsiders). A male key informant in Mwekera highlighted that:

> *"We live around the Forest Reserve and we know the people who cut trees but we however do not have the authority to stop them."* (Key informant, Mwekera site)

The exclusions of local people from forest management has curtailed the development of local rules and norms regarding forest use as forests are seen as the government's 'property.'

Katanino site

In Katanino, community rules exist on forest use and management. These customary rules have been used to regulate forest resource use way before its establishment as a pilot Joint Forest Management (JFM) area under the Provincial Forestry Action Plan (PFAP) in 2000. When asked whether rules on forest management exist in the villages, a male key informant respondent in Katanino responded,

> *"Our forefathers instructed us to protect the forest; we had rules regarding forest use even before JFM was implemented."*(Key informant, Katanino site)

The rules prevent cutting of trees on any land except for agricultural expansion. Key informants highlighted that customary rules exist for protecting water catchment and burial sites. Additionally, fruit trees are retained on agricultural land and cutting of fruit trees for firewood or charcoal is forbidden. Sanctions are imposed on those found breaking the community rules following the village conflict resolution structure (Figure 4.12). Offenders are first reported by the complainant (any member of the community) to the village headman who often consults a group of village elders. If not resolved, the case is then taken to the traditional councillor who then refers the case to the traditional Chief for punishment. Persistence in breaking the rules could result in being banished from the chiefdom.

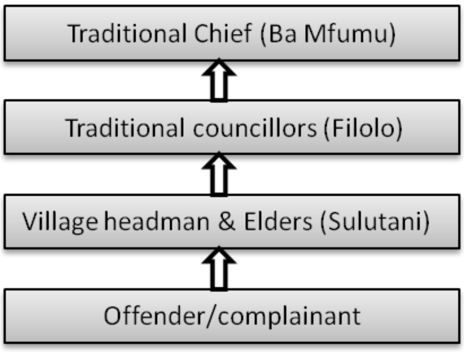

Figure 4.12- Traditional leadership structures in Katanino site

The establishment of JFM in an already established customary system in Katanino brought a different formal institutional structure which contradicts the local leadership establishment (Figure 4.13). This structure consists of the village resource management committees (VRMC) comprising representation from village headmen, forest resource guards and a representative of each forest user group (such as charcoal producer, honey collectors, mushrooms, etc.). The VRMC reports to the forest management committee (FMC), which consists of representatives of the local chief, forest department, each VRMC and the district council. FMC further reports to the district development coordinating committee (DDCC) which is a technical advisory committee comprising heads of various government units in the district and NGOs. The DDCC is mandated to coordinate all programmes in the district and has several sub-committees among the environment and natural resources sub-committee. In this structure, decision making is retained by the government. Under JFM, the local chief(s) lack a direct legally recognised role in forest management, though they send a representative to the forest management committee. Customary rules regulating forest use (e.g. no cutting of fruit trees, conserving of trees along streams) have been integrated in statutory rules under JFM. There are however conflicts between customary and JFM rules. Firstly JFM developed artificial forest user groups to regulate, monitor and issue permits for the use of specific forest product such as mushroom, honey, fruits. Customarily, people harvest multiple products and are not defined by user groups. There is a conflict in resource ownership after the introduction of JFM.

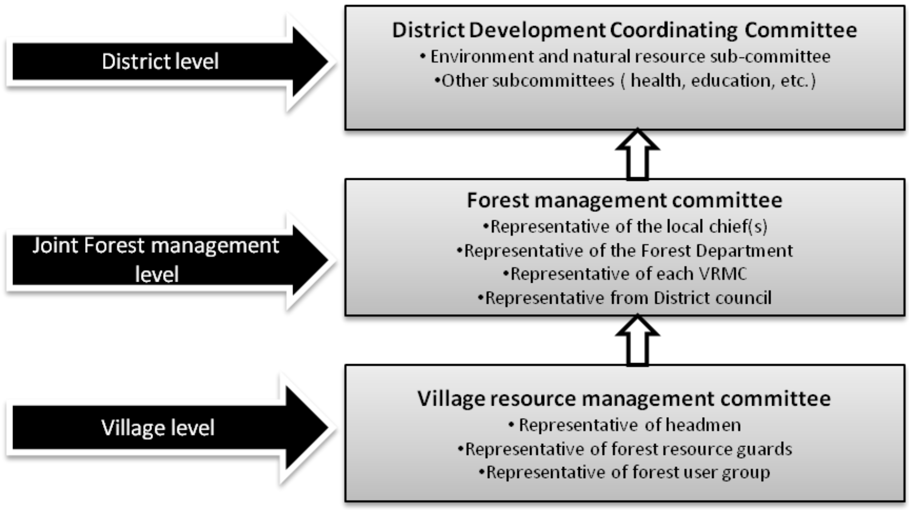

Figure 4.13- Structure of Joint Forest Management in Katanino

In Katanino, JFM seems to have slowed deforestation. Despite the ending of JFM pilot project in 2006, forest guards are still active in forest protection (though reported reductions in the frequency forest patrols) and reporting those found cutting trees to the traditional leadership. A male forest guard highlighted that:

"We are not motivated to protect the forest. We don't receive any money for the work we do. In the forest we risk our lives from snakes. Further, people who come to harvest trees illegally have axes and chain saws which they threaten us with."(JFM Forest guard, Katanino site)

4.5 Discussion

4.5.1 The use of FPES

Miombo woodlands provide an array of benefits to rural livelihoods (Chirwa et al., 2008b, Dewees et al., 2010, Kalaba et al., 2009b). This study demonstrates the high consumption of FPES for food, medicinal, fodder and construction purposes in households across both wealth classes and head of household gender. To the local people, "Miombo woodlands are a pharmacy, a supermarket, a building supply store and a grazing resource" (Dewees et al., 2010:61). Households that employ FPES for direct household consumption save cash resources which would have otherwise been used to purchase the products (Shackleton and Shackleton, 2004). The use of the forest for medicinal purposes was more prominent in Katanino than in Mwekera. This difference may be caused by Mwekera's greater proximity to Western health facilities, which reduces the village's reliance on trees for the treatment of various ailments. Furthermore, the number of residents using medicinal plants may actually be higher than reported due to the failure of study participants to disclose their use: A number of residents belong to religious groups that forbid the use of traditional medicine because of its perceived association with witchcraft. The imposition of religious sanctions on users of traditional medicines has also been reported in rural communities in the South African savanna (Shackleton et al., 2007).

4.5.1.1 Household wealth status and consumption of FPES

In terms of wealth differentiation and the household consumption of FPES, the study showed that at both sites, a significantly greater proportion of wealthy households used the forest as a source of fodder. These findings are in agreement with an earlier study in India, which indicated that because the wealth of rural households is largely associated with livestock ownership, wealthy households make considerably more use of the forest as a source of fodder (Davidar et al., 2008). The wealth status of households was also significantly associated with the use of the forest as a source of construction material in Mwekera. This association is likely due to the ability of wealthy households to purchase exotic poles from nearby plantations and sawmills in Kitwe city. In a study of the Dyala district of South Africa, Paumgarten and Shackleton (2009) found that only a small proportion of households used the indigenous forest as a source of construction material due to the ready availability of poles from surrounding plantations. In the present study, the large proportion of households observed to use FPES in their livelihoods across the wealth strata provided evidence of the importance of FPES to rural livelihoods regardless of the wealth status of households. Although previous research on rural livelihoods has reported the use of forest products as high among wealthy (Cavendish, 2000, de Merode et al., 2004), intermediate (Ambrose-Oji, 2003) and poor (Twine et al., 2003) households, this study shows that the proportions of households engaging in the collection and use of FPES are comparable across wealth classes. The magnitude of forest product consumption in these households is likely to be influenced by other household factors such as household size and the age distribution of household members.

4.5.1.2 Gender and consumption of FPES

Clear gender roles in FPES extraction were observed within households. Women dominate the collection of mushrooms, fruits and thatching grass, while men dominate honey collection, charcoal production and the felling of trees for firewood, as has been widely reported (Alelign et al., 2011, Chirwa et al., 2008b, Kideghesho and Msuya, 2010, Kiptot and Franzel, 2012, Shackleton and Shackleton, 2004). However, the present study indicates no significance difference in the consumption of FPES between different head of household genders, in contrast with previous findings in other agroecosystems such as the tropical rainforests in the Usarambara mountains in Tanzania (Kideghesho and Msuya, 2010), the Afromontane forests in north-western Ethiopia (Alelign et al., 2011) and the tropical dry forests of Nigeria (Gbadegesin, 1996). The study findings do, however coincide with those of Paumgarten and Shackleton (2009), who reported negligible gender effects on forest use in South Africa. Despite the lack of significant differences in the use of FPES between male- and female-headed households, the gender-specific collection and use of provisioning services within households was observed. In male headed households, women (either wives or adult female household members) engage in female dominated activities and vice versa for adult men in female-headed households. In most of the previous literature, female-headed households are associated more with female dominated activities, with little consideration given to households as units composed of different genders (Kideghesho and Msuya, 2010, Kiptot and Franzel, 2012). Furthermore, the age of household members plays a role in defining the livelihood activities of these members. Labour-demanding activities such as charcoal production are more common among young men, and similar observations have been made regarding labour-intensive timber harvesting in Tanzania (Kideghesho and Msuya, 2010). These activities are distributed within the household as a unit, whether it is male or female headed.

4.5.2 Contribution of FPES to household income

Income from the sale of FPES is an important contributor to overall household income for rural residents (Fisher, 2004, Kamanga et al., 2009, Mamo et al., 2007). Households in the study area were shown to combine a number of income streams, using multiple sources of income to diversify their livelihoods, as was consistent with existing literature on rural livelihoods (Belcher et al., 2005, Ellis, 2000, Sunderlin et al., 2005). Income from FPES was shown to be the most important source of household income, accounting for a substantial amount (43.9%) of the annual income of the study area. However, forest incomes have been poorly documented in national poverty and rural development strategies (PRSP, 2002, Tesfaye et al., 2011). The contribution of forest income observed in the study area is comparable with that of studies in Ethiopia (Mamo et al., 2007) and Zimbabwe (Cavendish, 2000), in which forest income contributed 39% and 35% to total income, respectively. The extraction of FPES requires minimal skills and technology, making it an attractive income opportunity for rural households (Heubach et al., 2011).

The mean income from FPES was higher in Mwekera than Katanino, likely because of the former village’s greater access to urban markets. In both study sites, charcoal was the main source of forest income. In Zambia, woodfuel (i.e., charcoal and firewood) is the main source of energy for approximately 85% of urban households (Central Statistics Office, 2005), most likely due to its low cost in comparison with that of alternate energy sources, high electricity tariffs and the unreliability of the electricity supply.

Inter-site comparisons of the households selling FPES indicated that more households in Mwekera were engaged in the sale of mushrooms, wild fruits and wild vegetables. These fresh products respire and eventually undergo senescence (the breakdown of cells and cell components) after harvest, which reduces their quality and shelf life and leads to post-harvest losses (Pardo et al., 2001). These effects are compounded by poor storage environments and distance to markets, which subject the fresh products to further transportation-related mechanical damages. These losses are likely to be reduced with distance to markets, explaining why villages near urban markets are more involved in the sale of fresh products (i.e., mushrooms, wild vegetables and wild fruits).

4.5.2.1 FPES income and wealth categories

The results of this study show that FPES contribute a larger proportion of the total annual household income of poor households than that of intermediate and wealthy households. The relative contributions of FPES to household income varied across the wealth strata, with means of KR 2340.3, 2009.7 and 1620.1 for wealthy, intermediate and poor households, respectively. However, the proportional contribution of FPES income to total household income was highest among poor households (55.5 %). This study indicates that although wealthy households obtain higher mean household incomes from FPES than do their poorer counterparts, poorer households are more dependent on FPES as a source of income, likely due to their overall more limited income streams (Shackleton and Shackleton, 2006). In a study in the Shindi ward of Zimbabwe, Cavendish (2000) reported that forest income contributed more to the total income of poor households (40%) than that of their wealthy counterparts (29%), while in the Dendi district of Ethiopia, Mamo et al. (2007) reported that forest income represented 59% and 34% of the total income for poor and wealthy households, respectively. The high contribution of forest income to poor households and the Gini-coefficient observed in this study provide evidence of the importance of FPES to the reduction in income inequality among rural households, a result in agreement with those of previous studies (Kamanga et al., 2009, Mamo et al., 2007). Forest income therefore plays an important role in the amelioration of poverty among rural households (Reddy and Chakravarty, 1999)**.** Similar patterns have been confirmed in the Bale highlands of southern Sudan (Yemiru et al., 2010), in Malawi (Fisher, 2004) and in northern Ethiopia (Babulo et al., 2008). With respect to the proportions of households engaged in the sale of FPES, a significantly greater proportion of poor households in Mwekera sold wild fruits, mushrooms and thatching grass. This observation can be attributed to the preference of wealthy households to engage in the sale of more income-rewarding products such as charcoal production (see section 4.4.4.2).

4.5.2.2 FPES incomes and gender

This study indicated that head of household gender was not a significant determinant of a household's engagement in the sale of FPES. These findings contradict those of other studies (McSweeney, 2004, Yemiru et al., 2010), which have reported that female-headed households are more engaged in the sale of forest products than male-headed households. Although females dominated selling as an activity, no differences occurred at household level, as households contain both male and female members who participate in these activities. These findings are in contrast to those of previous research (Babulo et al., 2008, McSweeney, 2004), which reported that female-headed households are more engaged in the sale of forest products. The gender difference observed for charcoal production in this study may be attributable to its physical demands; charcoal production is traditionally practiced by males, and fewer female-headed households participate in the activity as it is dependent on the presence of males in their households. The wealth of households was the main determinant of their engagement in the sale of FPES.

4.5.3 Household food stresses and coping strategies

Rural households in Miombo woodland regions experience food shortages between November and April. Seasonal food deficits are an inherent feature of rural people's livelihoods that are dependent on rain-fed agriculture, as reported in Malawi (Kamanga et al., 2009), Zimbabwe and Mozambique (Akinnifesi et al., 2004). In the study area, crop farming is predominately rain-fed and harvested food stocks are usually depleted before the next harvest season, making households vulnerable to food deficits. Households therefore diversify their livelihoods by producing charcoal and undertaking off-farm activities to reduce their vulnerability. Despite studies such as Ellis (2000) reporting households diversifying livelihood strategies in response to seasonal shortages, the role of forests have not been explicitly reported, which may impact rural development and poverty reduction strategies. The results of this study show that charcoal production is the most important strategy used to meet food shortages. Although households consume forest foods during times of household food deficit as reported by earlier studies (Akinnifesi et al., 2004, Chirwa et al., 2008a), the foods only supplement income from charcoal production. This therefore shows that the income from charcoal is important to buy food such as maize and that this is more important than consumption of forest foods in times of seasonal food deficits.

4.5.4 Coping with household income shocks

Findings of this study show that FPES are also important for coping with household shocks. A third of households sold FPES to offset costs resulting from household income shocks. Households use diverse strategies to respond to household income shocks. This study has found use of FPES as the most dominant coping strategy in contrast to kinship which has been reported in other studies (e.g. Heemskerk et al., 2004, McSweeney, 2004, Paumgarten and Shackleton, 2011). The high dependency on kinship may be attributed to the fact that the above studies were conducted in more economically prosperous study areas than Zambia i.e. Latin America and South Africa respectively. The high unemployment levels in Zambia compounded by lack of social support systems may have exacerbated the reliance on FPES.

The present study indicates a higher dependence on forests for coping with income shocks among poor and intermediate households, probably due to their limited financial capacity, making forests an important economic buffer in adverse times and a source of household income diversification (Debela et al., 2012, Pattanayak and Sills, 2001, Vedeld et al., 2007). This matches the findings of a recent study in Uganda that observed that though use of forest products may sometimes be labour intensive (e.g. charcoal production), they provide the only opportunity for poorer households to generate income to cope with shocks (Debela et al., 2012). Rural households in developing countries rarely have enough resources available to cope with shocks, and lack access to social-support systems or public safety-nets, which even when present are often weak (Heemskerk et al., 2004).

Income from sale of forest products helps to offset the financial costs resulting from household idiosyncratic income shocks such as livestock loss, major loss of household assets, and prolonged illness. To cover sudden expenses such as funeral or medical expenses, households do not often cope by selling forest products, but by either using other strategies such as borrowing money from neighbours and friends, and later use forest income to pay off the incurred debt (McSweeney, 2004, Pattanayak and Sills, 2001). According to Paumgarten and Shackleton (2011), poorer households have fewer options for coping with shocks and stresses, and have low agricultural capacity (Debela et al., 2012) and therefore increase the use and sale of forest products, which do not require any capital outlay. This makes forests the "ultimate form of self-insurance" (McSweeney, 2004:17).

4.5.5 Socio-economic (wealth and gender) determinants of coping strategies

Among poor households, the sale of forest products acts as an economic option for households experiencing income shocks (McSweeney, 2004). A greater proportion of wealthy households used kinship compared to other wealth classes. This contradicts the findings of a study in South Africa that highlighted that poorer households relied more on kinship than wealthy households (Paumgarten and Shackleton, 2011). This is probably due to the comparatively stronger economy of South Africa and higher employment rates, hence enabling men from across wealth classes to migrate to work in urban areas and send remittances to their families in rural areas. In this study, most wealthy households had relatives in urban areas that provided them with financial assistance during income shocks, while poor households seldom received financial assistance from urban areas. Poor households seemed to have low social capital. With respect to gender, the higher proportion of male-headed households engaging in forest use may be attributed to the fact that charcoal is the most common forest product produced and sold to cope with stresses and shocks and charcoal production is a male dominated activity.

4.5.6 Impact of deforestation and forest degradation on livelihoods

Deforestation and forest degradation is reducing household forest income therefore weakening economic safety nets, thus exacerbating rural poverty and threatening rural livelihoods. Other studies have reported that deforestation causes nutritional deficiencies in forest dependent communities due to scarcity of forest foods, or obtaining of less preferred foods (Bandyopadhyay et al., 2011) and loss of household income (Kamanga et al., 2009). This reduces both household income and food security.

In the study area, deforestation and degradation further reduces the availability of medicinal trees such as *C. abbreviata* whose roots and barks are used for treating a plethora of diseases. These findings coincide with earlier studies by Shanley and Luz (2003) in eastern Amazonia where highly sought after medicinal trees have become scarce; many of which did not have botanical substitutes. Forest degradation is further increasing people's vulnerability to stresses and shocks. Since forests offer an important coping strategy to household income shocks especially among poorer households, deforestation is hampering the coping strategies of households. Loss of forests requires significant changes to livelihoods in order to cope and adapt (Shackleton et al., 2007), therefore deforestation is a threat to rural livelihoods that have limited alternative livelihood options.

4.5.7 Local management institutions and impact on forest management

Findings from Katanino reveal the practice of cultural rules for forest use. Beliefs and social ties under the traditional administration system help to enforce local rules. This is because norms exist in specific social settings, compelling individuals to act in a certain way and often punishing non-compliance (Krasner, 1983). This creates a standard of appropriate behaviour which gives rise to reciprocal expectations about social behaviour in a community which determines people's interests and conduct (Dimitrov, 2005). Strong social ties that exist in native communities promote checks and balances on behaviour: the connections within the community restrain bad behaviour and hence it is less likely that people will break the rules, norms and regulations on forest protection (Keleman et al., 2010, Wunder, 2001). It is clear that norms and customary practices are facing increasing economic, commercial and demographic pressures.

In Mwekera, the absence of local rules in forest management may be attributed to the weakened traditional institutions due to the migration of people from different cultural and institutional backgrounds due to mining activities, compounded by lack of formal recognition of traditional institutions in forest management, as customary rights are often considered inferior to statutory ones (Quinn et al., 2007). Further, the migration of people of different ethnic groups into the villages has reduced adherence to taboos due to differences in cultural beliefs among different ethnic groups. Posner (1997) suggests that adherence to norms is affected by peer-pressure and other factors such as feeling of guilt. Since norms on use of forests prescribe behaviour, enforcements and sanctions elicit compliance (Hønneland, 1999, Sutinen and Kuperan, 1999), but norms easily erode in the absence of reciprocal behaviour and cooperation within communities (Ramcilovic-Suominen and Hansen, 2012). Norms and taboo adherence is sometimes affected by changes in people's cognition regarding the supernatural, education, Christianity, and local desire for commercial benefits from the forests.

4.6 Conclusion

This chapter has provided insights into the relative importance of FPES to rural livelihoods in Miombo woodlands in different local institutional contexts at the Zambian study sites, as well as the differentiation of the use and sale of forest products in relation to household wealth and head of household gender. FPES contribute substantially to rural livelihood portfolios across household wealth strata and regardless of head of household gender. This research has observed a wider variation in the contribution of income from the sale of FPES to total household income due to wealth strata than to head of household gender. The results indicated that the sale of forest products is determined by contextual factors such as proximity to markets and the nature of the products (e.g. shelf-life). The wealth status of households significantly influenced the sale of less-income-rewarding forest products such as thatching grass. This chapter has shown that FPES are an important coping strategy for households facing stresses and shocks, and that deforestation and forest degradation is negatively affecting rural households. The chapter has further shown how different local management system impact on forest use and management.

The next chapter investigates how the main forest uses discussed in the present chapter impact on Miombo woodland systems and subsequent forest recovery after woodland disturbances.

Chapter 5 Floristic composition, forest diversity and carbon storage under different land management regimes[10]

Abstract

This chapter provides an integrated understanding of aboveground (AG) C storage, structural and floristic composition in charcoal and agriculture fallows in Miombo woodland systems of Zambia. Data were collected through ecological surveys; measuring tree diameters and assessing species composition. Undisturbed Miombo stored 39.6 Mg C ha^{-1} AG, while after clearance, C stocks accumulated at 0.98 and 1.42 Mg C ha^{-1} yr^{-1} in agriculture and charcoal fallows respectively. There were no significant differences in C stocks between woodlands and ≥ 20 year old fallows, implying that in terms of AG C storage, woodlands sufficiently recover after 20 years. Stem densities were significantly higher in charcoal than agriculture fallows but the difference decreased with increase in fallow age. Importance values (IVI) of tree species show low presence of less fire resistant tree species in the initial regrowth of post agriculture fallows. Findings indicate low species similarities between woodlands and fallows, suggesting that though Miombo systems recover relatively fast in terms of species diversity and C storage, species composition takes longer to recuperate. The findings show that agriculture and charcoal fallows hold enormous management potential for emerging C-based payments for ecosystem services. Forest management should consider managing fallows for C sequestration and biodiversity restoration through natural succession in Miombo systems. In view of the uncertainty of species recovery, mature Miombo woodlands should be conserved for continued ecosystem functioning and supply of ecosystem services.

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[10] This chapter is developed from a published journal article of Kalaba, F. K., Quinn, C. H., Dougill, A. J., Vinya, R. (2013). Floristic composition, species diversity and carbon storage in charcoal and agriculture fallows and management implications in Miombo woodlands of Zambia. *Forest Ecology and Management*, 304, 99-109.

5.1 Introduction

Forest ecosystems have enormous potential to contribute to mitigating climate change through enhancing C storage in forest ecosystems and reducing deforestation (Watson, 2000). This has contributed to the commodification of C through various voluntary offset trading initiatives such as PES schemes (see section 2.6). There is growing interest in understanding the capacity of tropical forest systems such as the Miombo to sequester and store C under different land uses (see section 2.4). Despite the high levels of deforestation in Miombo woodland systems emanating from charcoal production and slash and burn agriculture, Miombo woodlands are able to recover once disturbances cease. Changes in C-stocks and biodiversity in the recovery trajectory is largely unknown (sections 2.4.1 & 2.4.2).

An integrated understanding of C storage, and the structural and floristic composition of trees in succession stages is important in understanding forest restoration processes and in designing forest management strategies in different forest disturbance regimes (Gutiérrez and Huth, 2012). Globally, there are increasing demands for land use changes aimed at restoring C and biodiversity in degraded forest ecosystems. According to Watson (2000), land use change activities have the potential to provide cost-effective ways of offsetting emissions either by increasing carbon storage or reducing deforestation.

This chapter provides empirical evidence of the impact of slash and burn agriculture and charcoal production on the Miombo woodlands. It provides an integrated understanding of floristic composition, species diversity and C storage in undisturbed woodlands and regrowth sites after slash and burn and charcoal abandonment at various successional stages. The chapter therefore provides empirical evidence of the potential of the Miombo for C-based PES to improve the woodlands' contribution to rural livelihoods. This chapter first outlines the details of the research design and methodology introduced earlier (section 3.6.2). Data collection and analysis techniques are outlined after which the results are presented and discussed.

5.2 Research design and methods

The study sites were selected using stratified purposive sampling (using the criteria discussed below) (Creswell, 1998). This method is appropriate in selecting a sample on the basis of the knowledge, its elements and the purpose of the study and facilitated comparisons between the stratified elements (Patterson and Coelho, 2009). Three different land use categories were identified for Miombo woodlands; (1) undisturbed Miombo, (2) Slash and burn fallows and (3) Charcoal fallows.

Undisturbed forest plots were used as reference points for assessing forest recovery. In recovering Miombo, analogous sites were used to provide insights on changes in floristic composition and carbon storage over time. Analogous sites were used in this research due to the unavailability of repeated tree inventories in recovering sites in the study area. The limitation in investigating succession using analogous sites (spatial) rather than temporal chronosequence lies in ensuring various stands of different ages along the identified chronosequence have similar soils, vegetation composition, climatic histories, and were previously subjected to similar disturbances (Schoonmaker and McKee, 1988). Inherent biophysical conditions, climate and species pool have the ability to affect forest composition and structure (Huston and Smith, 1987). This challenge was addressed by conducting the study in the same agro-ecological zone and creating a set of criteria for sample selection in the different land-use categories (Table 5.1).

Table 5.1- Descriptions of main characteristics of land use categories

Category	**Criteria for selection**
Undisturbed Miombo	• Not experienced any major human or natural disturbances. • No records of forest management treatments as supported by Forest Department records.
Slash and burn fallows	• Abandoned after slash and burn agriculture. • Knowledge of age of fallows. • Non-mechanised tillage. • Rain fed. • No evidence of post-abandonment removal of some trees (e.g. cutting of trees for poles) • Free of agrochemicals. • Not experienced any major human or natural disturbances.
Charcoal fallows	• Abandoned after cutting trees for charcoal production. • Knowledge of age of fallow • No evidence of use of fallows for agriculture purposes. • No evidence of post-abandonment removal of some trees (e.g. cutting of trees for poles) • Not experienced any major human or natural disturbances.

5.2.1 Sampling and plot establishment

5.2.1.1 Undisturbed Miombo

Ground inventories were completed in the identified land use categories. In undisturbed Miombo woodland, twenty-four 50 m x 50 m (0.25 ha) plots were established (i.e. 16 plots in Mwekera Forest Reserve and 8 in Katanino Forest Reserve). In Katanino, plots were established between Bwengo village and the Katanino Forest Reserve border along a transect line perpendicular to the Oposhi road junction. In Mwekera Forest Reserve, the plots were established along the Mwekera Forest reserve main road from the rail line near *Kamfisa* Prison through the Zambia Forest College to *Mabote* village. Plots were randomly established along the road at distances of at least 100 m between them to avoid overlapping. Trees at the centre and corners of the plots were then marked.

5.2.1.2 Recovering Miombo

The vegetation survey in recovering Miombo employed double stratified random sampling. The sites were first stratified according to pre-abandonment land use (i.e. slash and burn agriculture or charcoal, after the criteria summarised in Table 1), and then age of fallows, after which plots were established at random locations within the identified age categories. Land-use history and fallow age were obtained through informal interviews with local farmers, charcoal producers and traditional councillors (*Ba filolo*). 18 respondents were interviewed following a snowball sampling approach (Patton, 1990). This processes started by holding discussions with the traditional authorities, asking if they knew of any member of the community who had fallows. The leaders provided contact details of possible interviewees. This process was iterative, as participants provided details of other possible interviewees consistent with other studies in Miombo woodland systems (Mwampamba and Schwartz, 2011, Robertson, 1984, Syampungani, 2009, Walker and Desanker, 2004). Local people recalled the age of fallows using various events ranging from family experiences such as the birth, marriage or death of a family member or relative, to natural events. One man recalled that he cleared trees for charcoal on a day when it became dark in the afternoon during the total eclipse. Such events were confirmed with secondary literature. To probe fallow age, the researcher asked several questions to triangulate the ages given. The questions were broad and cut across several issues such as the political situation (e.g. the name of the Republican President), biographic data (e.g. age of the farmer/charcoal producer, records of births, marriages and deaths in respondents' families) and the national economic conditions at the time the land was left fallow.

Slash and burn recovering fallows ranged between 5 and 58 years. 24 plots were established with 4 plots in each identified age class. The ages of charcoal fallows ranged from 5 to 44 years, in a total of 34 plots. These age ranges represented the available fallow land in the study area which had undisturbed portions after abandonment. In these sites, 10 m x 20 m plots were established (Chidumayo, 1997, Munishi and Shear, 2004). The use of smaller plots in regrowth plots is due to the high tree density of these plots which makes the use of larger fixed plots time consuming (Syampungani et al., 2010b). Plot sizes were determined by a number of factors including study objectives, time and financial resources (Chidumayo, 1997). At least 4 plots were surveyed in recovering Miombo for each identified fallow age. These fall within the range of plot numbers used in similar studies (Syampungani, 2009, Williams et al., 2008).

5.2.2 Field measurements

In the established plots, the tree diameters were measured using a diameter tape at breast height (i.e. 1.3 m above ground) (Ditt et al., 2010, Lawton, 1978, Malimbwi et al., 1994) for all trees (trees defined as woody plants more than 2 m tall (Frost, 1996)). Trees forking below 1.3 m were measured and recorded separately, while those forking above 1.3 m were measured at breast height. Tree species were recorded for all trees within the plots using local names (with the help of traditional botanists), while a botanist from Mwekera Forestry College (engaged as a research assistant) and the researcher's botanical knowledge were also used in identifying tree species. For trees that were difficult to identify, voucher specimens were taken to the Kitwe Forest Research Herbarium for identification. A total of 8031 stems were recorded in the sampled plots.

5.3 Data analysis

5.3.1 Floristic indices and biodiversity

To describe the tree species composition and vegetation structure of the plots, this study used the Importance Values Index (IVI) (Curtis and McIntosh, 1951), which has been widely used to describe vegetation structure and species composition of forests (Ferreira and Prance, 1999, Johnson and Skousen, 1990, van Andel, 2001). IVI is a summation of the relative density, dominance and frequency of species, i.e. IVI = (Relative frequency + relative basal area + relative density)/3, where

$$\text{Relative frequency} = \frac{\text{Number of plots in which species is present x 100}}{\text{Total number of plots recorded}}$$

$$\text{Relative density} = \frac{\text{Number of stems recorded for the species x 100}}{\text{Number of stems recorded for all species}}$$

$$\text{Relative basal area} = \frac{\text{Basal area of a species in a plot x 100}}{\text{Total basal area for all species in the plot}}$$

The Jaccard similarity index (*J*) was used to estimate the species composition similarity between different age classes of the two management regimes, as it is useful in determining the extent of overlap of tree species between communities (Chidumayo, 1997). It measures similarity based on species composition and hence was used to compare changes in composition over time. This index was used to compare disturbed and undisturbed sites.

J was calculated using the formula:

$$J = \frac{A}{A + B + C}$$

where *A* = number of species found in both age classes, *B* = species in age class *A* and not in *B*, *C* = species in age class B but not in age class A (Chidumayo, 1997). The Jaccard index varies between 0 and 1. When all the species are similar between the compared groups, J is equal to 1 and 0 when there are no overlapping species.

To measure diversity, the Shannon index (*H′*) was calculated for the mature undisturbed forests and all the regrowth plots.

$$H' = \sum_{i=1}^{s} p_i \ln p_i$$

where $p_i = n_i / N$; n_i is the number of individual trees present for species *i*, *N* is the total number of individuals, and S is the total number of species (Chidumayo, 1997, Shannon, 1948). The Shannon index measures rarity and commonness of species within a sampled community. H'=0 when only one species is present in a population with no uncertainty about what species each individual can be in a population. H' usually ranges between 1.5 and 3.5 and often does not exceed 4 (Margalef, 1972). The Shannon index has been widely used in vegetation studies (Magurran, 2004, Munishi et al., 2008, Shirima et al., 2011, Syampungani, 2009), albeit its narrow range of values may affect interpretation of results (for a detailed critique see Magurran, 2004). Further, the Shannon index is sensitive to small sample sizes. The current study complemented the Shannon index with the Simpson index which is a useful index for relatively small samples (Magurran, 2004). The two indices were used together as evidence of the biological diversity of trees in the study sites.

5.3.2 Quantifying aboveground carbon storage

Allometric equations were used to estimate tree biomass (Table 5.2). These equations are applicable to the study area owing to the climatic, edaphic, geographic and taxonomic similarities between the study area and the locations in which the equations were developed. In their paper on errors of forest biomass estimates, Chave et al., (2004) suggest that errors arise from using equations beyond their range of applicability (such as those developed in different forest ecosystems). According to Brown et al. (1989) local equations are more suitable for accessing forest biomass. Here more than one equation was used so as to provide a better estimation of biomass. Research shows that species-specific allometric equations are not necessary to generate reliable estimates of carbon stocks in Miombo (Gibbs et al., 2007, Malimbwi et al., 1994). Generalized allometric equations for all species types in specific broad forest types and ecological zones are effective in determining the forest carbon stocks, as DBH alone explains more than 95% of the variations in aboveground forest carbon stocks (Brown, 2002, Gibbs et al., 2007). Studies conducted in the Miombo have shown a strong correlation between woody biomass and DBH (Chidumayo, 1991, Malimbwi et al., 1994). Biomass estimations were restricted to trees with DBH $\geq$ 5 cm owing to the DBH ranges in which the equations were developed. This was done to avoid errors in biomass estimates (see Chave et al., 2004). Carbon stocks in the plots were calculated by multiplying biomass by 0.5, owing to the fact that 50% of biomass is carbon (Brown and Lugo, 1982, Bryan et al., 2010, Williams et al., 2008).

Table 5.2- Biomass allometric equations

Reference	**Equation(s)**	**Source country**	**Notes**
Chidumayo (1997)	$B=3.01D-7.48$ $B=20.02D-203.37$	Zambia	for trees <0.1 m DBH for trees >0.1 m DBH
Malimbwi et al (1994)	$B= D^{2.516} / e^{2.462}$	Tanzania	Aboveground
Brown et al (1989)	$B=34.47-8.067D + 0.659D^2$	Dry tropics	

Where: B is biomass; D is diameter at breast height.

5.4 Results

5.4.1 Vegetation structure and floristic composition

5.4.1.1 Vegetation structure

In mature woodlands, a total of 2761 trees were measured over a total survey area of 6 ha. The mean stand density was 592 ± 28.01 stems ha^{-1}. Stems ranged from 308 to 736 stems ha^{-1}. The mean diameter was 16.57 ± 0.21 cm, with the majority of trees being found within the smaller diameter classes, with 88.2% of stems with diameter ≤30 cm, thus showing a reverse J–shaped size class (Figure 5.1). The mean basal area was estimated at 14.34 ± 0.52 m^2 ha^{-1}, and in the plots ranged from 10.48 to 18.8 m^2 ha^{-1}. The species density was 22 ± 1.2 species ha^{-1}, while species density ranged from 11 to 33 among the plots.

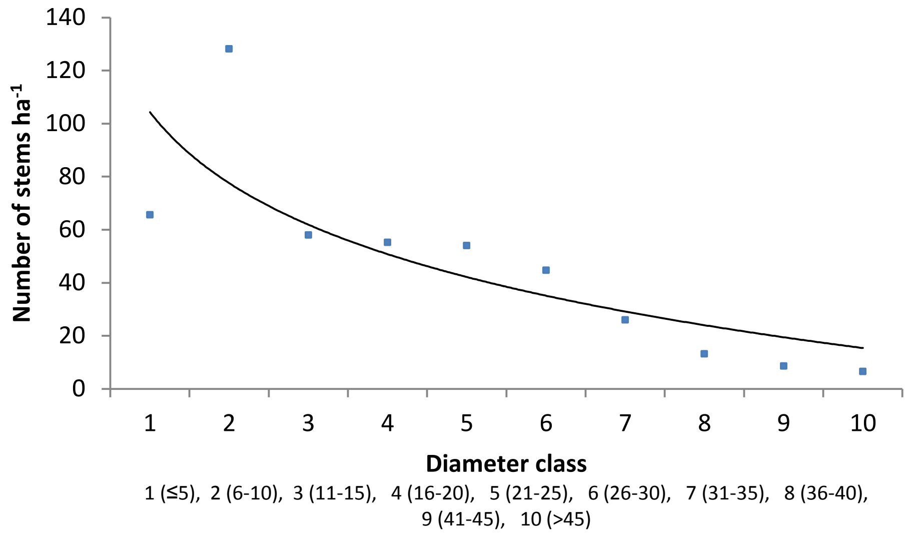

Figure 5.1- Diameter distribution showing reverse-J- shaped size classes

In slash and burn Fallows, the stem stocking density at 5 years was 1075 stems ha^{-1}. The stem density steadily increased, peaking at around 20 years, after which stocking density declined (Figure 5.2). A third-order polynomial fitted to the data explained 91% of the observed variability

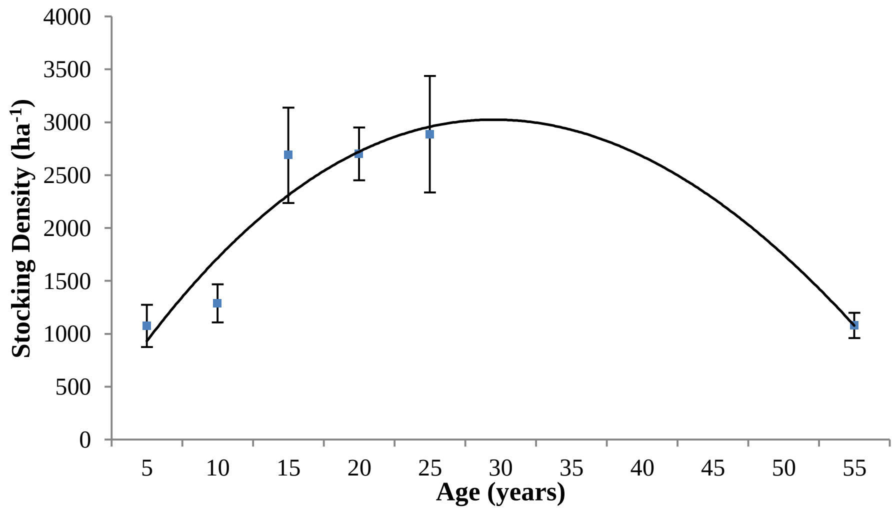

Figure 5.2- Stocking density (stems per ha) of slash and burn fallows plotted against age of plots. Stocking density=-50.2+1083.6t-102.4t^2-1.2t^3; t is the time in years.

In charcoal fallows, the stem density at 5-6 years was 1638 ha^{-1} and reached a peak at 12-18 years, then later steadily declined (Figure 5.3). A third-order polynomial fit to the data was able to explain 45% of the variability.

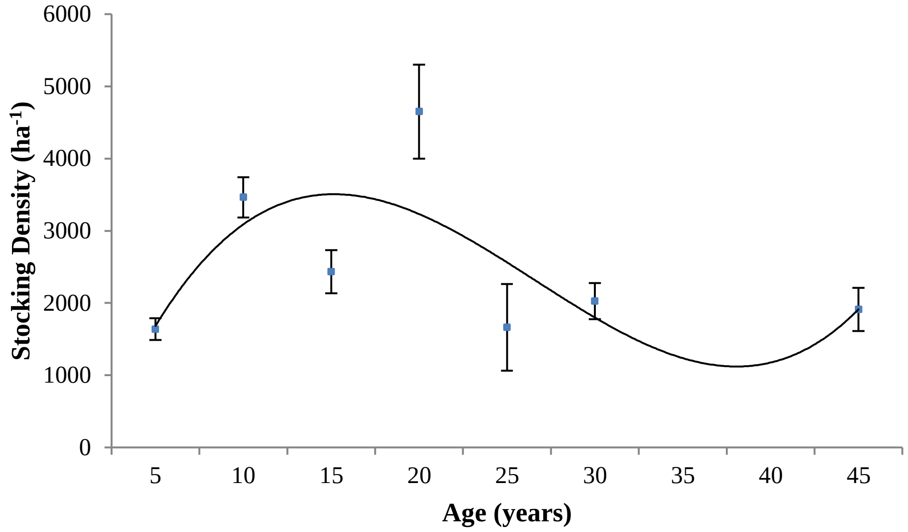

Figure 5.3- Stocking density of charcoal fallows plotted against age of plots. Stocking density $=-1013.1+3438t -792.9t^2 +49.8t^3$, where *t* is the age after abandonment.

The stocking density at 5 years after abandonment was not significantly different between slash and burn and charcoal fallows ($P > 0.05$), but later became significantly higher in charcoal fallows at 10 – 15 years. Tree density then later decreased with age for both regimes, with tree density differences narrowing as fallow age increased. The vegetation structure of fallows ≥20 years showed a diameter distribution with more trees in lower diameter classes, following a reverse-J shape as observed in mature woodlands.

Basal area for both slash and burn and charcoal regrowth sites were significantly positively correlated with time since abandonment (r^2 = 0.93, $P < 0.001$ and r^2 = 0.92, $P < 0.001$ respectively) as basal area increased with age of plots (Figure 5.4). In slash and burn sites, basal area per hectare along the surveyed chronosequence ranged 5.6 to 26.8 m^2ha^{-1}, and increased at an average of 0.58 m^2ha^{-1}. In charcoal regrowth sites, basal area was higher (ranging between 8.3 and 27.5 $m^2\ ha^{-1}$ along chronosequence of recovery), increasing at an average rate of 0.73 $m^2 ha^{-1}$

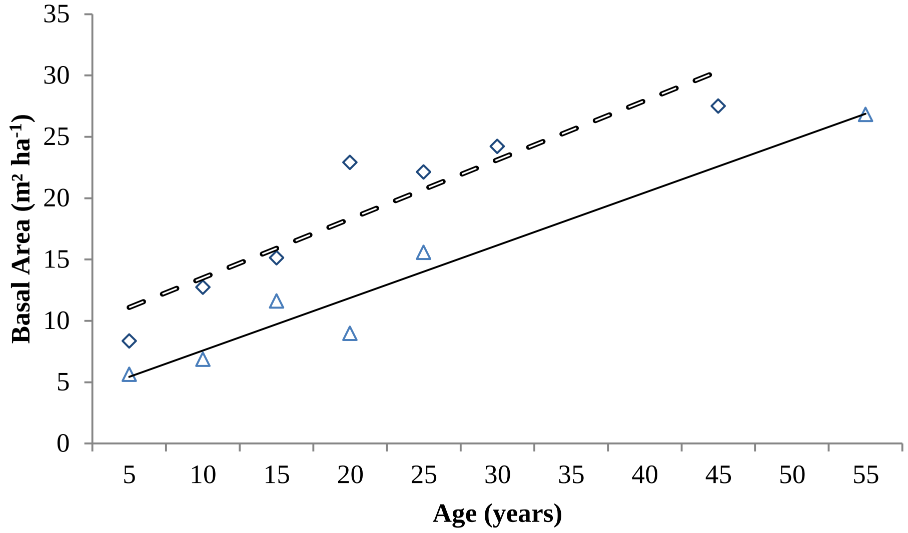

Figure 5.4- Basal area plotted against age of abandonment for Slash and burn (triangles, and solid line) and charcoal (diamonds, and dash line). Regression parameters for charcoal are y = 2.4t +8.7; r^2 = 86%, and slash and burn y = 2.1t + 3.3; r^2=95%, where *y* and *t* represent the basal area and time after abandonment respectively.

5.4.1.2 Floristic composition

The total number of species identified in the mature woodlands was 83 belonging to 53 families. The original mature Miombo consisted of little understory, with layers of litter on the forest floor. In terms of IVI, the most important species in mature woodland are *Julbernadia paniculata*, *Marquesia macroura*, and *Diplorhynchus condylocarpon*. The 20 most frequently occurring tree species in descending order are summarised in Table 5.3. These species are typical of the wet Miombo systems of this eco-region (Stromgaard, 1985, Vinya et al., 2012).

Table 5.3- Tree species composition of mature Miombo woodland ranking by IVIs

Rank	Tree species	Relative density (%)	Relative frequency %	Relative Basal area %	IVI %
1	*J. paniculata*	20	91.7	41.6	51.1
2	*M. macroura*	9.1	75	11.0	31.7
3	*D. condylocarpon*	5.3	87.5	1.0	31.3
4	*Parinari curatellifolia* Planch	2.4	83.3	3.0	29.5
5	*Pericopsis angolensis*	2.1	79.2	1.2	27.5
6	*Isoberlinia angolensis*	5.5	66.7	8.4	26.9
7	*Brachystegia speciformis*	3.5	70.8	6.2	26.8
8	*Pseudolachnostylis maprouneifolia*	2.8	75	1.0	26.3
9	*Monotes africanus*	2.5	66.7	1.1	23.4
10	*Brachystegia longifolia*	3.3	62.5	3.7	23.1
11	*Albizia antunesiana*	3	62.5	1.5	22.3
12	*Syzygium guineense*	1.7	62.5	0.3	21.5
13	*Ochna pulchra*	1.6	58.3	0.2	20.1
14	*Phyllocosmus lemaireanus*	4.3	54.2	0.6	19.7
15	*Brachystegia boehmii*	3	50	6.0	19.7
16	*Uapaca kirkiana*	2.4	54.2	1.0	19.2
17	*Anisophyllea boehmii*	2.9	54.2	0.6	19.2
18	*Pterocarpus angolensis*	1.0	54.2	0.3	18.5
19	*Baphia bequaertii*	1.9	50	0.5	17.5
20	*Brachystegia floribunda*	1.5	37.5	0.5	13.2

The floristic composition of regrowth plots differed according to the pre-disturbance land uses and the age of the fallows (Tables 5.4 and 5.5).

It was observed that in the early recovering plots (5-10 years), *D. condylocarpon* dominated slash and burn followed by *I. angolensis*, *Securidaca longepedunculata*, *Bridelia micrantha* and *B. bequaertii* (Table 5.4). Most of these species also dominated charcoal regrowth sites of the same age class (Table 5.5) except *U. kirkiana* fruit trees, which were restricted to charcoal regrowth plots.

Table 5.4- The ten most dominant species, ranked by IVI (in parenthesis) in each age class of abandoned slash and burn fallow, species richness, Jaccard similarity coefficient and diversity indices

Rank	5 year	10 years	15 years	20 years	25 years	58 years
1	*D. condylocarpon* (42.0)	*I. angolensis* (40.1)	*B. longifolia* (53.4)	*I. angolensis* (58.0)	*J. paniculata* (39.2)	*J. paniculata* (46.1)
2	*I. angolensis* (38.8)	*O. pulchra* (40.0)	*J. paniculata* (44.4)	*B. boehmii* (38.5)	*I. angolensis* (37.7)	*I. angolensis* (41.7)
3	*S. longepedunculata* (36.3)	*B. bequaertii* (39.2)	*B. speciformis* (38.4)	*O. pulchra* (38.2)	*Swartzia madagascariensis* (37.3)	*B. floribunda* (37.9)
4	*B. micrantha* (36.1)	*D. condylocarpon* (39.0)	*Uapaca nitida* (36.5)	*J. paniculata* (24.9)	*B. bequaertii* (37.1)	*P. lemaireanus* (37.7)
5	*B. bequaertii* (34.2)	*P. curatellifolia* (37.3)	*O. pulchra* (36.1)	*Strychnos spinosa .* (23.9)	*Dichrostachys cinerea.* (36.9)	*S. madagascariensis* (36.2)
6	*A. boehmii* (31.2)	*J. paniculata* (32.7)	*A. antunesiana* (35.8)	*S. cocculoides* (23.2)	*B. boehmii* (36.3)	*S. guineense* (35.3)
7	*A. antunesiana* (28.4)	*B. floribunda* (30.0)	*Strychnos cocculoides* (33.9)	*Vitex doniana* (12.6)	*B. floribunda* (30.3)	*Lannea discolour* (35.3)
8	*B. floribunda* (28.2)	*B. speciformis* (27.0)	*Strychnos pungens* (26.8)	*U. kirkiana* (12.6)	*P. maprouneifolia* (27.8)	*A. antunesiana* (28.4)
9	*P. lemaireanus* (28.2)	*A. antunesiana* (19.3)	*P. angolensis* (20.6)	*S. guineense* (12.6)	*Hymenocardia acida* (27.3)	*O. pulchra* (27.6)
10	*Ekebergia benguelensis*	*S. longepedunculata*	*M. africanus*	*D. condylocarpon*	*S. guineense* (27.6)	*B. boehmii* (27.0)

	(27.0)	(19.0)	(18.1)	(12.2)		
Species richness	19.5 ± 1.2	16.3 ± 1.9	14.8 ± 1.5	10.0 ± 3.7	19.5 ± 1.2	23.0 ± 0.41
J	0.35	0.36	0.26	0.19	0.32	0.37
H	2.1	2.4	2.5	2.1	2.6	2.8
D	0.80	0.87	0.89	0.83	0.90	0.92

Where; *J* = Jaccard similarity coefficient, *H* = Shannon index and *D* = Simpson diversity index.

At 15 years after slash and burn abandonment, the tree canopy was open and consisted of a high proportion of light demanding species (e.g. *Uapaca*, *Strychnos*, and *Albizia* spp). Some of the Miombo dominant trees species such as *J. paniculata* were present while others (such as *D. condylocarpon, P. curatellifolia*) had few individuals. After 20 years, the forest canopies closed up, with most species found in mature woodland becoming dominant.

In all charcoal fallows, this study observed high IVI for fire intolerant species such as *A. antunesiana* and *U. kirkiana,* while some Miombo defining species (e.g. *J. paniculata, I. angolensis, B. floribunda*) were observed in the first 5 years and throughout the chronosequence (Table 5.5).

Table 5.5- The ten most dominant species, ranked by IVI (in parenthesis) in each age class of abandoned charcoal fallow, species richness, Jaccard similarity coefficient and diversity indices

Rank	5 year	10 years	15 years	20 years	25 years	30 years	44 years
1	*B. floribunda* (42.5)	*D. condylocarpon* (55.0)	*B. boehmii* (50.6)	*U. kirkiana* (42.8)	*A. antunesiana* (48.2)	*M. macroura* (51.9)	*I. angolensis* (43.0)
2	*I. angolensis* (41.2)	*U. kirkiana* (48.6)	*O. pulchra* (41.0)	*J. paniculata* (42.6)	*B. boehmii* (41.3)	*U. kirkiana* (43.5)	*B. boehmii* (40.6)
3	*A. boehmii* (39.8)	*B. boehmii* (41.0)	*P. curatellifolia* (38.7)	*I. angolensis* (41.9)	*J. paniculata* (39.5)	*J. paniculata* (41.3)	*J. paniculata* (38.0)
4	*J. paniculata* (39.3)	*S. guineense* (39.6)	*J. paniculata* (38.4)	*O. pulchra* (37.7)	*B. floribunda* (37.1)	*I. angolensis* (38.7)	*P. angolensis* *(36.1)*
5	*A. antunesiana* (34.6)	*I. angolensis* (39.2)	*D. condylocarpon* (35.7)	*A. antunesiana* (36.8)	*P. lemaireanus* (34.5)	*B. boehmii* (29.4)	*B. floribunda* (36.0)
6	*P. lemaireanus* (36.5)	*B. bequaertii* (37.6)	*Diospyros batocana* (34.1)	*B. boehmii* (36.5)	*I. angolensis* (28.4)	*P. curatellifolia* (19.5)	*Uapaca benguelensis* (35.8)
7	*S. madagascariensis* (28.2)	*P. curatellifolia* (38.3)	*A. antunesiana* (25.4)	*A. boehmii* (36.3)	*D. condylocarpon* (27.9)	*A. antunesiana* (19.0)	*P. maprouneifolia* (34.2)
8	*S. guineense* (28.1)	*B. floribunda* (36.6)	*P. maprouneifolia*	*B. speciformis*	*D. cinerea* (26.7)	*P. angolensis* (19.0)	*Albizia antunesiana* (34.2)

			(25.2)	(35.9)			
9	*U. kirkiana* (26.8)	*P. lemaireanus* (36.2)	*M. africana* (25.0)	*M. africanus* (35.0)	*P. maprouneifolia* (26.4)	*O. pulchra* (18.7)	*P. lemaireanus* (28.8)
10	*B. speciformis* (26.7)	*M. africana* (35.5)	*Brachystegia manga* (24.3)	*P. lemaireanus* (34.9)	*A. boehmii* (26.1)	*Dalbergia nitudula* (18.4)	*U. kirkiana* (27.5)
Species richness	17.3 ± 2.1	23.3 ± 0.9	15.0 ± 1.2	27.0 ± 1.8	20.5 ± 1.2	18.8± 2.2	20.8± 0.9
J	0.33	0.45	0.26	0.44	0.39	0.26	0.33
H	2.0	2.4	2.3	2.5	2.6	2.6	2.7
D	0.78	0.88	0.87	0.89	0.90	0.89	0.91

Where; *J* = Jaccard similarity coefficient, *H* = Shannon index and *D* = Simpson diversity index.

The Jaccard similarity coefficient for comparing species composition between slash and burn regrowth sites and mature woodlands ranged from 0.19 to 0.37, and was highest in the oldest regrowth site (Table 5.4). In charcoal regrowth sites, the Jaccard coefficient ranged from a minimum of 0.26 to a maximum of 0.44 (Table 5.5). The study revealed that there was a relatively higher similarity with mature woodlands in charcoal (0.35 ± 0.03) than slash and burn regrowth sites (0.31 ± 0.03), though the difference was not statistically significant (t = 1.04, $P = 0.32$). A comparison of the dominant leguminous tree genera in mature woodlands and the oldest regrowth sites is summarised in Figure 5.5.

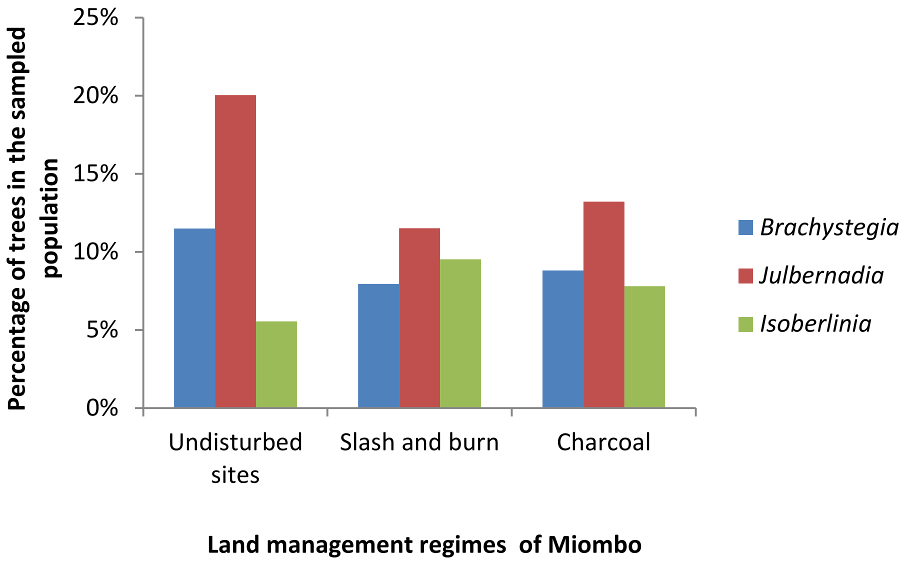

Figure 5.5- Distribution of dominant leguminous genera in undisturbed site and oldest regrowth sites

5.4.2 Diversity of tree species

The results of this study show that species richness in regrowth sites in the two management regimes was significantly different from mature woodlands ($F = 4.65$, $P < 0.05$), as undisturbed mature sites had higher species richness. There was however no significant differences between slash and burn and charcoal regrowth sites ($t = -0.18$, $P > 0.86$, equal variances assumed) though generally charcoal regrowth sites had more species (17.9 ± 6.5 and 17.6 ± 4.9 respectively). There was a significant positive correlation between species richness and age of abandonment in slash and burn regrowth ($P < 0.05$), and not in charcoal plots. There were no statistically significant differences in mean species richness between regrowth sites of slash and burn and charcoal of 20 years and above and mature woodlands ($F = 1.48$, $P > 0.05$).

Species diversity as measured by the Shannon index (*H'*) in slash and burn plots ranged from 2.1 to 2.8 as diversity increased along the chronosequence (Table 5.4). In charcoal regrowth plots, *H'* values ranged from 2 to 2.7 with diversity increasing with age (Table 5.5). In mature woodlands, the mean *H'* was 2.8 ± 0.1, while the Simpson index (*D*) was 0.92. Species diversity was not significantly different between mature woodlands and the sampled regrowth sites (*F*= 0.61, *P* > 0.05). The Simpson index of diversity further confirmed the diversity of regrowth with ranges of 0.8-0.92 and 0.78-0.91 in slash and burn and charcoal sites respectively.

5.4.3 Aboveground C storage

Using the mean of 3 allometric equations, in the mature woodlands, the estimated C was 39.6 ± 1.5 Mg C ha^{-1}, ranging from 28.7 to 52.8 Mg C ha^{-1}. Results from the slash and burn fallows showed that along the chronosequence of recovery, carbon storage ranged from 5.4 ± 1.1 Mg C ha^{-1} at between 5 and 6 years, to 61.7 ± 18.1 Mg C ha^{-1} in trees that were approximately 58 years old. Using a weighted mean of the three equations, carbon accumulation was estimated to be 0.98 Mg C ha^{-1} year^{-1}. The range was from 0.84 to 1.21 Mg C ha^{-1} year $^{-1}$. The recovery trajectory of charcoal fallows contained 10.5 ± 2. 7 Mg C ha^{-1} at the age of 5 years, and the storage was estimated at 64.3 ± 10.1 Mg C ha^{-1} in the oldest plots (44 year old plots). The average accumulation of C was estimated to be 1.42 Mg C ha^{-1} year^{-1}. The results show sequestration rates as highest in the initial regeneration phase (up to 2.1 Mg C ha^{-1} in the first 5 years), and lowest in the oldest plots i.e. over 25 years (0.89 Mg C ha^{-1} year^{-1}).

Comparing C storage in slash and burn and charcoal fallows, the results show that in the first 5 years, C storage was higher in charcoal than slash and burn plots, though not significantly different (*t* = -1.76, *P* > 0.05). The study found that at 10 years after abandonment, charcoal fallows had statistically significant higher C storage (19.2 ± 2.6 Mg C ha^{-1}) than slash and burn regrowth (9.6 ± 2.0 Mg C ha^{-1})(t = -3.23, P < 0.05). Statistically significant differences in carbon storage were also observed at 15-16 years, while there were no significant differences in C storage between the two management regimes after 20 years (Table 5.6).

A one-way ANOVA showed that there were no statistically significant differences (F = 2.22, P > 0.05) in C estimates between mature woodlands and regrowth stands ≥ 20 for both slash and burn and charcoal fallows. Carbon estimates in regrowth stands were positively and significantly correlated with the age of fallow (*P* < 0.001).

Table 5.6- Comparisons of carbon stocks between slash & burn and charcoal regrowth at different age classes of abandoned fallows

Age of Plot	Mean C stocks		t-value	P Value
	Slash and burn	Charcoal		
5 years	5.4 ± 1.1	10.5 ± 2.7	-1.76	0.16
10 years	9.6 ± 2.0	19.2 ± 2.6	-3.23	0.018*
15 years	15.7 ± 2.4	24.1 ± 1.7	-2.63	0.046*
20 years	22.0 ± 7.6	32.9 ± 3.7	-1.30	0.24
25 years	26.5 ± 3.9	44.9 ± 17.6	-1.019	0.35
30 years	X	51.9 ± 11.8	X	X
44 years	X	64.3 ± 10.1	X	X
˜58 years	61.7 ± 1 8.1	X	X	X

*Significant at 0.05

X: t was not computed as at least one of the management regimes did not have plots corresponding with the age.

5.5 Discussion

5.5.1 Vegetation structure and floristic composition

5.5.1.1 Vegetation structure

In mature woodlands, the inverse J-shaped size classes showing more trees in the smaller size classes is an indicator of a steady and expanding population, which according to Peters (1994) is a self-maintaining population, in which young trees will eventually replace the older trees. Other studies within the Miombo have reported a similar size class distribution (Chidumayo, 1997, Munishi et al., 2008, Shirima et al., 2011). In this size class profile, young trees continue to regenerate under the canopies of more mature trees indicating that they are shade tolerant, as well as resistant to fire (Peters, 1994). When the forest canopy closes, some seedlings are stunted as some Miombo species require high light intensities for growth

(Chidumayo and Frost, 1996). The diameter distribution obtained at 25 years old regrowth and older suggests that the Miombo has the capacity to achieve its mature vegetation structure after 25 years of abandonment. These findings add to previous Miombo ecological assessments by demonstrating that Miombo systems return to primary forest characteristics within 2-3 decades of fallow after being degraded through either charcoal and agriculture production. This finding is similar to observations by Chazdon (2003) in slash and burn regrowth sites of secondary forests in tropical rainforests.

The basal area obtained in charcoal fallows was higher than the slash and burn fallows. This can be attributed to the fact that after charcoal production, most Miombo trees grow from coppices, and thus grow faster than on slash and burn sites where trees are sometimes uprooted in land preparation, reducing future sources of propagules. Furthermore, the fire in slash and burn agriculture has the potential to kill the roots and substantially reduce the seed bank, thereby slowing plant succession after abandonment (Ferreira and Prance, 1999). The stem density per hectare declines with age of regrowth due to inter-shoot competition (Chidumayo, 1988a, Chidumayo, 1988b).

5.5.1.2 Floristic composition

The Miombo floristic structure changed at various stages in the chronosequence. The vegetation composition of regrowth sites suggests that pre-disturbance land use affects the vegetation composition in recovery. After disturbances, increases in sunlight reaching the forest floor due to removal of canopies during tree cutting provides favourable germinating conditions and thus triggering regeneration of light demanding species (Peters, 1994). The tree species that grow earlier are those whose seeds are available in the soil before disturbance or the sprouting of the cut adults (Connell and Slatyer, 1977).

This study shows that in early regrowth, after slash and burn, fire tolerant species e.g. *D. condylocarpon*, *B. bequaertii*, *I. angolensis*, *J. paniculata*, *B. boehmii* and *B. floribunda* were dominant (see Lawton, 1978, Strang, 1974). These findings are consistent with the findings of Peters (1994) and Stromgaard (1984) who reported dominance of fire and drought tolerant species in the early stages of recovery after slash and burn agriculture. This study shows a high concentration of less fire-resistant species (such as *B. speciformis, S. guineense, and U. kirkiana*) in early charcoal regrowth sites. These species' successful establishment in early stages under slash and burn regrowth sites is hampered by fire (Orwa et al., 2009), though fire can be later used for management after establishment. High-intensity fires and subsequent high soil temperatures during slash and burn causes mortality of plant propagules of fire susceptible tree species (Beadle, 1940) which affects the rate of post-fire recolonisation. At about 15 years regrowth, sites were still associated with light demanding pioneer species growing in open canopies (such as *U. kirkiana*, *O. pulchra, and A. antunesiana*) which is the case until the canopy begins to close after 25 years. These trees are eventually replaced by species which are also dominant in mature woodlands (e.g. *I. angolensis*, *J. paniculata* and *Brachystegia* spp).

Results of this study shows varying diameters of key Miombo species in regrowth sites of different ages with higher proportions observed in charcoal sites. These findings contradict the findings of Williams et al. (2008) in Mozambique who did not find any Miombo defining species in regrowth from slash and burn among the top five dominant species in all the re-growing plots sampled. The difference may be partly attributed to responses of Miombo species being different between wet and drier regions, or the differences in proximity of regrowth sites to mature Miombo woodland which was further from the plots measured in their Mozambique study.

The changes in species dominance along the chronosequence may be explained by the fact that tree species such as *D. condylocarpon, B. Bequaertii* dominate in initial Miombo recovery after slash and burn due to their rapid dispersal ability and fire tolerance, and occupy the 'empty area' (Lawton, 1978, Strang, 1974). In the middle stages of recovery, reduction in incidences of fire enhances growth conditions for less-fire resistant and light demanding species such as *Uapaca spp* and *Albizia spp.* These species are shade intolerant and cannot continue to grow under their own shade (Stromgaard, 1987). They start reducing with the age of the forest stand (Connell and Slatyer, 1977, Saldarriaga et al., 1988) as dominant Miombo species increase thus explaining the changes in species dominance. Initial stages of charcoal regrowth sites are dominated by a mixture of fire–tolerant and less tolerable species, while the presence of key Miombo woodland species in early recovery stages can be attributed to regeneration from stumps shoots and root suckers (Chidumayo, 1997, Stromgaard, 1985).

5.5.2 Diversity, species composition and ecosystem functioning

Both the Simpson diversity index and the Shannon index show that the Miombo woodlands have high biodiversity. Shannon index results (2.8) show a high diversity as Shannon index values greater than 2 are indicative of medium to high diversity (Barbour et al., 1987). This study further shows a higher diversity than other studies in the Miombo region such as in Tanzania where Shannon indices of 1.05 and 1.25 were obtained (Shirima et al., 2011), and from Mozambique's Miombo (Williams *et al.*, 2008), but similar to diversity (2.7) in the landscapes of the west Usarambara (Munishi et al., 2008) probably due to the comparable rainfall gradients. These results corroborate that within the Miombo region, our study region is biologically diverse at tree species level and could be important for various biogeochemical cycles since diversity often is indicative of better ecosystem functioning/productivity (Barbour et al., 1987).

Once land is abandoned after slash and burn and charcoal production, tree species diversity remains high in Miombo once the woodland is left to recover without subjecting it to further disturbances. Slash and burn agriculture has been linked to extensive losses of biodiversity (Chidumayo, 1987a, Kotto-Same et al., 1997). Findings of this study show that in recovery, biodiversity is comparable with mature woodlands. This study has however shown a low similarity in floristic composition of oldest (both charcoal and slash and burn plots, though slightly higher in charcoal fallows) and mature woodlands. This therefore suggests that 58 and 44 years after abandonment for slash and burn and charcoal respectively, the floristic composition is still different from mature woodlands. In their study on species composition after slash and burn agriculture in the Amazon, Ferreira and Prance (1999) suggested that 40 years of re-growth was not sufficient for the species composition of re-growth sites to equal that of primary forests, while in Indonesia, low species similarities were observed between primary forests and 55 year-old secondary forest (Brearley et al., 2004). According to Jacobs et al. (1988), the return to primary forest species composition takes centuries and they warned that as the fallow age increases, regrowth sites closely resemble primary forests to the extent that only a detailed examination of species composition can reveal the dissimilarities.

Miombo dominant species have tree-specific fungi symbiotic relationships (mycorrhizal associations) and termite symbiotic associations important for ecosystem functioning and producing non-wood forest products such as indigenous mushrooms that cannot be domesticated (Hogberg, 1982, Munyanziza, 1996), which are important for livelihoods. Further, since Miombo soils are nutrient poor (Trapnell et al., 1976) mycorrhizal associations are needed for effective nutrient uptake and retention, which are important for growth (Hogberg, 1982), and ultimately enhancing productivity of the ecosystem, and other complex relationships among organisms within the Miombo. Changes in tree species composition have the potential to affect the ecological functioning of ecosystems altering nutrient recycling and an array of ensuing ecosystem benefits (Chapin et al., 2000). These changes though often gradual, may eventually cause irreversible large species shifts (see Figueiredo and Pereira, 2011) and affect the resilience and resistance of ecosystems to environmental change (Chapin et al., 2000).

5.5.3 C–stocks and changes in the recovery trajectory

Carbon storage in mature Miombo woodland estimated in this study (39.6 ± 1.5 Mg C ha^{-1}) is higher than that reported in Tanzania's Miombo by Shirima et al., (2011), and Munishi et al., (2010), i.e. 23.3 Mg C ha^{-1} and 19.1 Mg C ha^{-1} respectively. The differences observed with studies in Tanzania may be attributed to human disturbances. Although their studies were conducted in the forest reserve, they neither targeted undisturbed or intact plots. Further, the studies measured diameters ≥ 10 (Shirima et al., 2011) and ≥ 6 cm (Munishi et al., 2010) which may have an impact on the measured C storage as some trees are excluded from the measurement. The results from this study are higher than estimates for Mozambique i.e. 19.0 ± 8.0 Mg C ha^{-1} (Williams et al., 2008) which has drier Miombo than Copperbelt Zambia.

The estimated C storage in this study is lower than estimates from tropical rainforests of Africa i.e. 202 Mg C ha^{-1} and over 350 Mg C ha^{-1} (Lewis et al., 2009, Munishi and Shear, 2004). The C storage in the Miombo is likely to be higher than estimated as the allometric equations developed for the Miombo use a diameter minimum of 5 cm, and relatively more trees are found with DBH >5 cm.

In regrowth sites, charcoal abandoned sites had higher C storage than slash and burn agriculture sites. This may be attributed to higher regeneration rates on charcoal sites as trees grow from coppices which are new shoots emerging from stumps of cut trees. The ability of the Miombo species to regenerate from coppices has been reported (Boaler and Sciwale, 1966, Chisha-Kasumu et al., 2007, Guy, 1981). Miombo species' main regeneration is through coppice regrowth and root suckers as opposed to seeds (Strang, 1974, Trapnell, 1959).

Regeneration after slash and burn agriculture from coppices may be reduced as some plants may be uprooted or die due to injuries sustained during cultivation (Strang, 1974, Syampungani, 2009). The high regeneration in charcoal regrowth increases C storage rapidly after abandonment, until after 20 years when C storage differences between the two management regimes decrease with increasing fallow period and is not significantly different. In a study in northern Zambia on fresh biomass of 16 year-old regrowth, Stromgaard (1985) found biomass in regrowth vegetation cleared, burned and cultivated was less than half when compared to trees that were cut without land being cultivated (i.e. 15. 8 and 48.3 t ha^{-1}respectively). Recovery of forests is slow after disturbances that affect soil and aboveground vegetation (Chazdon, 2003). Cultivation using hand hoes has the potential to disturb the soil structure. This may partially explain why carbon accumulation was higher in charcoal regrowth plots than slash and burn agriculture. Furthermore, seedlings may have been left during charcoal production, therefore increasing C storage rapidly.

The changes in C storage observed in the recovery trajectory of both management regimes in this study provide empirical evidence of the importance of the Miombo in carbon sequestration. The sequestration rates obtained in this study in slash and burn regrowth sites are comparable with those obtained by other studies (Kotto-Same et al., 1997, Stromgaard, 1985, Williams et al., 2008) i.e. 0.7, 0.98 and 0.98 Mg ha^{-1} $year^{-1}$ respectively. This accumulative evidence, as demonstrated by this study, suggests that tropical woodlands sequester vast amounts of carbon in their various eco-regions spreading across different countries, even with different topographic and edaphic characteristics.

This study has shown a higher C storage in the oldest recovery sites (both slash and burn and charcoal) than mature woodlands, though differences were not significant. These results correspond with those from an earlier study on forest chronosequence in Panama which found biomass to reach its peak after 70 years of disturbance, and declining after 100 years to reach the old-growth value (Denslow and Guzman, 2000). I suggest this trend to be applicable to Miombo as demonstrated by my findings. The lack of significant differences in C storage between older regrowth (≥20 year-old) and undisturbed mature woodlands, shows empirical evidence that after abandonment (whether after slash and burn or charcoal production), 20 years is sufficient for C storage to attain that of undisturbed woodland. It should be noted that the extent of disturbances may affect recovery, and therefore results from the study must be understood within the context of small-scale farmers, who do not use highly mechanised equipment which has the potential to heavily impact on soil structure (Chazdon, 2003), therefore extending the recovery period.

5.6 Conclusion

The Miombo is an important C store and has great potential to provide financial resources through C-based PES to local people. This chapter has shown that when left undisturbed, fallows sufficiently recover C stocks after 20 years of abandonment. Changes in species composition, forest structure and C storage change in the recovery trajectory have been detailed, thereby improving understanding of restoring degraded woodlands. In view of the use of forests in livelihoods (chapter 4) and the changes in the ecology after forest uses demonstrated in this chapter, the next chapter investigates how deforestation and forest degradation are discussed in policy documents and examines policy measures to reduce forest losses.

Chapter 6 Policy coherence, interaction and implementation: implications for Zambia's Miombo woodlands[11]

Abstract

This chapter analyses policy interaction and implementation and the consequent implications for Miombo woodlands in Zambia. It explores the ways in which deforestation is discussed in national forestry, agricultural and energy policy documents, and national statements to Rio Conventions to understand policy coherence and interaction, and examines policy implementation. Policy documents were analysed using content analysis while policy actors across governance levels (i.e. local, district and national) were interviewed to assess policy implementation. Results show that at the national level, positive horizontal interplays exist between energy and forestry policies though on-the-ground implementation is lacking at the District and local level. Agricultural policy shows conflicts with the forest policy despite the potential of conservation farming to provide a mutually supportive link. The results have further shown policy inconsistencies between national sectoral policies and national statements to the Rio Conventions. Additionally, although national statements to Rio Conventions share common ground on measures to address deforestation, they are poorly mainstreamed into national policies and broader development policies at national level. This suggests that although developing countries, such as Zambia, are ratifying international environmental conventions, measures are often not drafted into national policies and linkages remain largely superficial. To reduce conflicts among sectoral policies, there is need to mainstream national statement to Rio Conventions into national sectoral policies and development policies. Policy implementation could potentially be improved through improved cross-sectoral coordination and cooperation, with well-defined roles and responsibilities.

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[11] This chapter is developed from the following journal article: Kalaba, F.K., Quinn, C.H., Dougill, A.J. (2014) Policy coherence and interplay between Zambia's forest, agricultural, energy and climate change policies and multilateral environmental agreements. *International Environmental Agreements: Politics, Law and Economics*. doi: 10.1007/s10784-013-9236-z

6.1 Introduction

Deforestation and forest degradation contributes 17 per cent to global C emissions, and are the main source of C emissions in tropical countries (IPCC, 2007). In tropical and subtropical countries, deforestation is mainly driven by the agriculture and energy sectors (Graham, 2011). The high rates of deforestation and forest degradation in Zambia (i.e. 250, 000 – 300,000 ha annually) has raised concerns about the effectiveness of policies and strategies that intersect in the forest sector, questioning both their consistency in addressing deforestation, and interactions between various policy objectives (Chundama, 2009, Mwape and Gumbo, 2010). This is because as policies interact, they may affect each others' effectiveness. Interaction between policies can result in positive, negative or neutral interplay, while two policies may be involved in several cases of interactions. Policy interaction can occur at the same level of governance (horizontal interaction) or different spatial scale of governance (vertical interaction) (see section 2.5.1 for more detailed discussion of policy interplay). Although the agricultural and energy sectors have been identified as direct drivers of deforestation in Zambia (Bond et al., 2010, Vinya et al., 2011), little is known on how national agricultural and energy policies interact with the forest policy (Chundama, 2009).

Globally, it has become increasingly apparent that policies influence human-environmental interactions and trigger land use changes (see section 2.5), although little is known about policy interaction and implementation at national levels as most studies on policy interactions have focused on interactions between international policies (Rosendal, 2001, Stokke, 2009, Young, 2002). Additionally, although Zambia has made national statements to multilateral environmental agreements that include aspects of forest management (see section 6.1.1); the coherence between national level policies and international agreements is understudied. Improving conservation efforts requires a better understanding of how policies influence forest resource management, hence a need for better analysis of policy interplay and implementation. The next section provides the context for Zambia in international environmental agreements under Rio Conventions.

6.1.1 Zambia in the international policy context of Rio Conventions

In the past two decades, global environmental policy discussions have increasingly encouraged the sustainable management of forests to enhance carbon sequestration, conserve biodiversity and increase local people's use of forests for continued livelihood benefits (Chhatre and Agrawal, 2009). At the international level, forests are increasingly dominating global policy debates; with the 1992 Rio de Janeiro's United Nations Conference on Environment and Development (UNCED) leading to the formulation of the United Nations Framework Convention on Climate Change (UNFCCC), United Nations Convention to Combat Desertification (UNCCD) and United Nations Convention on Biodiversity (CBD), all of which intersect in the forest sector.

The UNFCCC is the principal international tool for addressing climate change, focusing on two approaches i.e. mitigation and adaptation (Stringer et al., 2010). Since 2001, the UNFCCC has institutionalised climate adaptation at the international level through National Adaptation Programmes of Action (NAPAs), which mandates each of the 49 Least Developed Countries (LDCs) to identify priority activities that respond to their urgent and immediate needs to adapt to climate change, whose delay would increase vulnerability and/ or costs at a later stage. Involvement of local stakeholders in developing NAPAs is vital to incorporate existing coping strategies at the local level so that proposed priority activities are built on existing coping strategies (Stringer et al., 2009).

The UNCCD is the primary international institution for addressing desertification. Similar to UNFCCC's NAPAs, parties to the UNCCD that declare themselves affected by desertification are required to develop National Action Programmes (NAPs). NAPs underscore the main challenges that each affected country faces and provide strategies to address the identified challenges (Stringer et al., 2009). The primary international institution for conservation of biological diversity is the CBD. All parties to the CBD are required to develop National Biodiversity Strategy and Action Plans (NBSAPs). NBSAPs should highlight national strategies for the conservation and sustainable use of national biodiversity. Like NAPAs and NAPs, involvement of all stakeholders in developing NBSAPs is considered vital.

Zambia has ratified all 3 Rio Conventions and developed national statements/programmes for specific conventions. These are; CBD's NBSAP which has identified threats to biodiversity and planned measures to address them (GRZ, 1999); UNCCD's NAP which has identified the main national challenges contributing to desertification and proposed strategies to combat desertification and mitigate the negative effects of drought (GRZ, 2002); and UNFCCC's NAPA, which has identified priority national activities needed to adapt to climate change (GRZ, 2007a). Although these strategies target different environmental challenges, they all promote sustainable forest management.

This chapter aims to examine how drivers of deforestation are discussed in policy documents and policy interactions across forestry, agricultural and energy sectors. It examines the consistency between national sectoral policies and national programmes under Rio Conventions in addressing deforestation. It then examines on-the-ground implementation of proposed policy measures. The following section provides details of the research design and methods used, after which results are presented and discussed.

6.2 Research design and methodology

6.2.1 Policy analysis

Policy analyses were conducted to examine awareness of deforestation issues and how they are handled in policy documents. This research analysed national policies and strategies summarised in Table 6.1. The researcher further consulted national economic development plans i.e. Vision 2030 and the sixth national development plan (SNDP) in order to understand the national economic development pathways and how they potentially affect the policies that impact on the forest resource base.

Table 6.1-Policy documentation

Document	Description of document	Year produced	Government ministry/department
National Agriculture policy	National Agriculture Policy, Government Republic of Zambia	2004	Ministry of Agriculture and co-operatives
National Energy Policy	National Energy Policy, Government Republic of Zambia	2007	Ministry of Energy and Water Development
National Forestry Policy	National Forestry Policy , Government Republic of Zambia	1998	Ministry of Tourism, Environment and Natural Resources (Forestry Department)
Forest Law	Government Republic of Zambia	1973	Ministry of Justice
National Biodiversity Strategy Action Plan	National strategic plan to the United Nations Convention on Biodiversity (UNCBD)	1999	Ministry of Tourism, Environment and Natural Resources (Department of Environment)
National Action Programme	Strategy to reduce desertification submitted to United Nations Convention to Combat Desertification (UNCCD)	2002	Ministry of Tourism, Environment and Natural Resources (Department of Environment)
National Adaptation Programme of Action	National strategy to adapt to climate change submitted to United Nations Framework Convention on Climate Change (UNFCCC)	2007	Ministry of Tourism, Environment and Natural Resources (Department of Environment)

Policy documents were analysed using iterative content analysis (Forbes, 2000), which is a widely used method for analysing textual data (Benner, 1985, Creswell, 1998, Taylor and Bogdan, 1984). This involved examining dominant narratives within each document, analysing awareness of drivers of deforestation in policy documents and identifying policy measures that have the potential to either drive or reduce deforestation. Key categories were then developed in which to place policy decisions from the selected policy documents, broadly based on the inductive grounded theory approach (Strauss and Corbin, 1990) in which themes emerged from the analysis. Next, the researcher examined overlaps and differences in the identified categories, addressing similarities and differences between the analysed policy documents. Matrices were then developed to assess the results.

Policy interactions were determined by examining how policy goals in one policy affect the effectiveness of achieving policy goals of another policy to understand policy interaction and implications for forests (for details on policy interaction see section 2.5.1). Categories of policy interaction typologies were determined as suggested by Oberthür and Gehring (2006a). Policy interplay can be identified as negative (i.e. a policy goal in one policy undermines effectiveness of measures of another policy to achieve its goals), positive (i.e. policy goals of one policy are supported by policy measures originating from another policy), and neutral (i.e. a policy goal in one policy does not affect policy goals of another policy).

6.2.2 Expert interviews

Expert interviews were conducted with policy actors at various levels of governance (national, district, village) to provide policy implementation lessons across different sectors and governance levels. In selecting participants, interviewees were chosen by first establishing stakeholders through the process of stakeholder analysis (Patton, 1990), based on a wider analysis of policies, government ministries, traditional authority, NGOs and academics based on internet searches and prior knowledge and experience of the researcher. The study then used purposive sampling for initial interviews, which was combined with snowball sampling where participants provided contact details of possible further interviewees. Snowball sampling was used as it “identifies cases of interest from people who know people who know people who know what cases are information-rich” (Patton, 1990:175). The profile of policy actors ranged from local users to those involved in planning, financing and executing programmes aimed at reducing deforestation and forest degradation. The researcher used a topic guide, however, interviews were flexible and pursued the issues that were raised by respondents. According to Babbie and Mouton (2001), these interviews are fundamentally a discussion in which the interviewer establishes a broad direction for the conversation and pursues specific topics raised by the respondents. A total of 55 interviews were conducted, distributed as summarized below in Table 6.2.

Table 6.2- Summary of expert interview participants

Category	Description of participants	Number of respondents
Local residents in villages	Traditional leaders, and different forest users (e.g. farmers, charcoal burners, etc)	15
Government Departments	Ministry of Agriculture, Department of Energy, Department of Forestry, Ministry of Lands and Natural Resources.	22
Non-governmental organisations (NGOs) and International agencies.	Local and international NGOs (which were broad ranging covering environment and development)	10
Academics and consultants in environmental management	Researchers from local universities and national research institutes in disciplines of forestry, agriculture and energy.	8

National level interviews with respondents discussed policy goals in their respective sectors and policy implementation strategies. Interviewing government officers at various governance levels provided insight into policy implementation at various levels and the horizontal relationships in policy implementation. Interviews with local and international NGOs provided insight on policy implementation at local scales, and local peoples' concerns. Village level interviews with residents provided an opportunity to explore policy implementation at local level and underlying drivers of deforestation and forest degradation as viewed by local people. Local residents included traditional leaders and other elderly males and females who were knowledgeable on forest management issues (see section 4.2.4).

Interviews were carried out in English for all stakeholders except for local key informants who were interviewed using local languages (i.e. *Bemba* and *Lamba*).

Interviews were digitally recorded and later transcribed. Notes were also taken throughout interviews to avoid loss of information in cases of technological failures. Categories were then developed around themes that arose repeatedly from the interviews (Stringer et al., 2012b).

In this research, content analysis of policy documents provided a top-down perspective while the expert interview data provided insights from the bottom-up. A combination of these two approaches has been recommended for understanding public policies (Urwin and Jordan, 2008) and their implementation (Fraser et al., 2006), since the success of policy documents must be judged by examining their impact at a local level (Jordan, 1999).

6.3 Results

6.3.1 Policy consistency in identifying drivers of deforestation and forest degradation

Conversion of forest area to agricultural land is widely recognised as a driver of deforestation and forest degradation in policy documents (Table 6.3). National statements to Rio Conventions also explicitly identify agriculture as the main driver of forest loss, which according to UNCBD's NBSAP is threatening 316 endemic species of flora and fauna, 31 of which are endangered (GRZ, 1999). UNCCD's NAP has further associated agriculture with land degradation and loss of environmental benefits (GRZ, 2002).

Nationally, agriculture is the main source of livelihood for about 60% of the Zambian population, while in rural areas over 90% of households engage in agricultural production activities (Central Statistics Office, 2005) predominantly using slash and burn (*Chitemene*) agriculture. The vision of the Zambia national agriculture policy is to increase production and productivity of the agricultural sector thereby increasing food security and incomes and reducing poverty. ZAP has ambitious plans to attain food security for 90% of households by 2015 (GRZ, 2004) and to increase agricultural exports. The policy seeks to ensure that land under crop production is expanded. The national agricultural policy's priority is to;

"ensure that the existing agricultural resource base is maintained and improved upon" (Zambia Agricultural Policy (GRZ, 2004:6)).

Land devoted to annual agricultural crop production is planned to increase to 900,000 hectares (over three times the current area) by 2030 (GRZ, 2006), with livestock doubled to six million. The agricultural policy also promotes increased access to credit and extension services for small scale farmers in order to increase productivity.

The Zambian government has embarked on a targeted agricultural input programme (fertilizer support programme) providing fertilizer and maize seeds to smallholder farmers at subsidized prices, while commercial farmers receive investment incentives (e.g. tax incentives on imported agricultural equipment), to increase food production in line with national economic development plans (GRZ, 2006, SNDP, 2011). Despite the agricultural sector being a driver of deforestation and forest degradation, the national agriculture policy is silent on the sector's contribution to forest loss, and only refers to deforestation in the policy discourse as a challenge to the agricultural sector. The policy states that:

"current environmental problems of major concern to the agricultural sector include rapid deforestation, loss of agrobiodiversity, land degradation and over-fishing"(Zambia Agricultural Policy (GRZ, 2004:7)).

The forestry policy has highlighted that;

"forest destruction is leading to soil erosion, dwindling water and agricultural productivity" (National Forestry Policy (GRZ, 1998a:19)).

Inadequate extension services and technical support on sustainable use and management of forest resources is identified as driving deforestation and forest degradation in the national energy and forestry policies, and all national statements to Rio Conventions with the exception of NBSAP (Table 6.3).

Woodfuel is identified as a dominant recurrent driver of forest loss in policy discourses. In both the inward looking sectoral policies (with the exception of the agriculture policy) and the national statements to Rio Conventions, cutting of trees for woodfuel has been identified as a key driver of forest cover loss (Table 6.3). Woodfuel is the major source of energy in Zambia contributing to over 70% of the total national energy budget (GRZ, 2007b). At a household level, woodfuel is used for cooking and heating by 85% and 97% of urban and rural households respectively (Central Statistics Office, 2005). The National Energy Policy attributes the high dependency on woodfuel to;

"low income levels of energy consumers and abundance of wood resources"
((National Energy Policy (GRZ, 2007b:2)).

Woodfuel is further used commercially in the mining industry in copper smelting processes, and in tobacco curing (GRZ, 2007b).

Uncontrolled bush fires and overgrazing by livestock have been identified by national statements to Rio Conventions as driving deforestation and forest degradation but they are absent from sectoral policies. For example, the UNCCD's NAP has highlighted increasing population of animals as exerting high browsing pressure on vegetation (GRZ, 2002), while the CBD's NBSAP has highlighted livestock grazing as causing forest degradation and threatening biodiversity in forest ecosystems.

Forest loss through poor land management practices in farming systems is explicitly emphasised in the policy discourse among national statements. Overexploitation of non-timber forest products (NTFPs) for both domestic and commercial uses is identified as causing forest degradation by CBD's NBSAP and UNFCCC's NAPA (Table 6.3) while the forestry policy is less emphatic, mentioning overharvesting of NTFPs as likely to cause forest degradation. Human encroachment into Forest Reserves and commercial developments such as mining are the other drivers of deforestation overlapping among the forestry sectoral policy, CBD's NBSAP and the UNCCD's NAP (Table 6.3).

Table 6.3- Drivers of deforestation and forest degradation as identified in policy documents

Drivers	NEP	NFP	ZAP	NBSAP (CBD)	NAP (UNCCD)	NAPA (UNFCCC)
Conversion of forest area to agricultural land		Y	Z	Y	Y	Y
High reliance on woodfuel (charcoal and firewood)	Y	Y		Y	Y	Y
Poor land management practices				Y	Y	Y
Human encroachment of Forest Reserves		Y		Y	Y	
Uncontrolled bush fires				Y	Y	Y
Mining concessions and other commercial developments		Y		Y		
Livestock overgrazing		Z		Y	Y	Y
Inadequate extension and technical support	Y	Y			Y	Y
Excessive use of NTFPs for domestic and commercial uses		Z		Y		Y

Y = significantly mentioned, Z=mentioned in passing but no significant attention given

NEP (National Energy Policy), NFP (National Forestry Policy), ZAP (Zambia Agricultural Policy), NBSAP (National Biodiversity Strategy and Action Plan), NAP (National Action Programme), NAPA (National Adaptation Programme of Action).

National statements to Rio Conventions are more explicit in identifying the drivers of deforestation and forest degradation, and identify more drivers than national sectoral policies (Table 6.3). These externally facing statements also provide details of the consequences of deforestation, which are not considered in national sectoral policies.

6.3.2 Key policy measures to address deforestation and forest degradation

To address deforestation and forest degradation, several measures have been outlined in both national sectoral policies and national statements to Rio Conventions (Table 6.4). Measures recurring in policy discourses include; promotion of conservation farming practices, more efficient production and utilisation of woodfuel, promoting alternative energy sources, improving extension services, policy and legal reforms and integrated planning among various sectors. Each of these is outlined below to demonstrate how policy documents seek to reduce deforestation.

6.3.2.1 Conservation farming practices

Conservation farming is widely recognised in the UNCCD-NAP, UNCBD-NBSAP and UNFCCC-NAPA policy discourses as having potential to reduce agriculture induced deforestation and enhance soil fertility (Table 6.4). Whilst conservation agriculture is perceived as having potential to reduce forest cover loss in the national statements to Rio Conventions, the national forest policy contains no reference to conservation farming opportunities. The agricultural policy has highlighted conservation farming as a land management method for enhancing soil nutrients and increasing agricultural productivity, but does not mention associated benefits of reducing deforestation and forest degradation. The agriculture policy promotes intensification primarily to increase production per unit area, increase agricultural exports and improve foreign exchange earnings from 3-5% in 2004, to 10-20% by 2015 (GRZ, 2004) increasing the sector's contribution to Gross Domestic Product (GDP). The agriculture policy is silent on reducing conversion of forest land into agricultural land (extensification).

6.3.2.2 Efficient production and utilization of woodfuel and alternative energy sources

All national statements to Rio Conventions, and national energy and forest policies, seek to promote use of energy efficient charcoal stoves and improve the efficiency of traditional charcoal production technology, whilst establishing woodlots as sources of woodfuel to reduce pressure on natural woodlands as sources of woodfuel (Table 6.4). These policies highlight the need to promote alternative sources of energy, with an emphasis on biofuels by the national energy policy. Biofuels are viewed as an effective way of enhancing national energy security through using locally available feedstock and reducing the cost of importing petroleum. According to the Sixth National Development Plan (SNDP), between 2011-2015, the target for biofuel blending in the national fuel mix is 5% in diesel, and 10% in petrol (SNDP, 2011). The national development plan aims to reduce national woodfuel use to 40% by 2030 (GRZ, 2006). Further electrification of rural areas is promoted by the national energy policy to reduce woodfuel dependency in rural areas.

6.3.2.3 Increasing forest cover

Increasing forest cover through reforestation and afforestation are promoted by national forest and energy policies, and UNCCD NAP and UNFCCC NAPA. The NAP aims to;

"promote and support a programme of afforestation, community plantations and agroforestry" (National Action Programme (GRZ, 2002:47)).

It further highlights a need to plant indigenous drought tolerant species. UNFCCC's NAPA has similarly underscored the importance of promoting of indigenous tree species in adapting to climate change.

The NAPA has set to;

"Promote natural regeneration of indigenous forests"(National Adaptation Programme of Action (GRZ, 2007a:34)).

In contrast to the NAP and NAPA, the national forestry policy focuses on growing of exotic tree species. The national forestry policy seeks to promote investment in plantation forestry by;

"establishing an investment framework for investors in forest plantation including land availability and security of tenure"(National Forestry Policy (GRZ, 1998a:21))

To increase forest cover, the national forestry, energy policies, and national statements to Rio Conventions have underscored the need to engage local communities in forest management and ensure that mechanisms are established to ensure equitable sharing of costs and benefits from forests amongst all stakeholders.

6.3.2.4 Integrated planning among sectors

Acknowledging the cross-sectoral nature of drivers of deforestation and forest degradation, national statements to Rio Conventions propose integrated cross sectoral planning in environmental management, but this is not addressed by national sectoral policies. Although the forestry policy has acknowledged that agriculture and energy sectors exert on pressure on forests, and therefore stated the need to;

> *"facilitate sufficient and sustainable allocation of land between major competing land uses and sectors such as agriculture and energy"(National Forestry Policy (GRZ, 1998a:22));*

it has not provided for integrated planning and coordination with these institutions. National statements take a more cross sectoral approach in addressing drivers of forest loss, combining poverty reduction and environmental management, while sectoral policies do not. The energy policy has attempted to link energy to poverty but the linkage in the current policy discourse is superficial as it only refers to access to energy as having capacity to reduce poverty, while the forestry policy has not explicitly discussed its contribution to food security.

6.3.2.5 Policy and legal reforms

Weak institutions and legislation are identified as providing incentives for deforestation and forest degradation, and therefore amendments to the Forest Law have been proposed by the Forestry policy and national statements to Rio Conventions (Table 6.4). For example, currently the Forest Law does not provide for stakeholder involvement in forestry management and no benefit sharing mechanisms exist to ensure equitable distribution of benefits among stakeholders, even though these are explicit in the national forestry policy and statements to Rio Conventions.

Table 6.4- Policy coherence of measures to address deforestation and forest degradation

Focus	**Overall aim**	**Specific measures**	**NEP**	**NFP**	**ZAP**	**NBSAP (CBD)**	**NAP (UNCCD)**	**NAPA (UNFCCC)**
Energy sector	Reduce woodfuel use	Improve efficiency and technology of charcoal production and use	Y	Y		Y	Y	Y
		Promote use of alternative sources of energy	Y	Y		Y	Y	Y
	Reduce pressure on natural woodlands as sources of woodfuel	Establish community woodlots for woodfuel	Y	Y			Y	Y
Agriculture sector	Increase agricultural intensification	Conservation farming systems			Z	Y	Y	Y
		Increase agricultural productivity per hectare			Z	Y	Y	Y
	Ensure sustainable land use	Improve extension services		Y	Y		Y	Y
Forest sector	Increase forest cover	Afforestation and reforestation		Y			Y	Y
		Engage local communities in forest management	Y	Y		Y	Y	Y
	Benefit sharing mechanisms	Equitable sharing of benefits from forests with stakeholders.	Y	Y		Y	Y	Y
	Legal and institutional framework	Strengthen legal and institutional frameworks		Y		Y		Y
	Extension services	Improve forest extension services	Y	Y		Y	Y	
All sectors	Integrated planning and communication					Y	Y	Y

Y = Strategy proposed, Z Strategy proposed with no emphasis on reducing forest loss.

Overall, national statements to Rio Conventions are more explicit on measures to reduce deforestation and forest degradation compared to national sectoral policies.

6.3.3 Policy interactions

Policy interaction is a casual relationship between two policies, occurring at the same level of governance (horizontal) or different levels of governance (vertical), resulting in positive, negative or neutral interactions (see section 2.5.1). Policy goals among international facing UNCCD's NAP and UNFCCC's NAP are mutually reinforcing in measures to reduce deforestation and forest degradation. The implementations of policy goals addressing desertification will invariably support adaptation efforts pursued by the NAPA, thus showing positive horizontal interaction (i.e. policy goals of one policy is supported by measures originating from another policy). The proposed strategies to reduce forest loss in national programmes/statements to Rio Conventions often overlap and are mutually reinforcing (Table 6.4).

In national sectoral policy documents, a positive horizontal interaction exists between the energy and forestry sectors policy goals to promote renewable energy sources to reduce dependence on woodfuel. This creates a positive vertical interaction with national statements under UNFCCC, CBD and UNCCD. It is worth noting that growing of biofuel crops such as *Jatropha* as promoted by the national energy policy may have a negative interaction with the forest policy as natural trees are cleared in preference for biofuel monocrops. The energy policy may further have negative interaction with the agriculture policy's aim for food security when agricultural land is set aside for growing biofuel crops. A negative horizontal interplay also exists between agriculture and forest policies. The agriculture policy discourse emphasises increasing food production by expanding agricultural land in forest frontiers. This creates negative vertical relationships with national statements to Rio Conventions which all seek to reduce deforestation.

6.3.4 Policy implementation

Interview data revealed disparities between what is contained in the policies and implementation, resulting in implementation deficits. For example, despite the overwhelming emphasis by policies on reducing woodfuel use through promotion of efficient production and use of charcoal and adoption of other renewable energy sources, evidence on the ground revealed a lack of implementation. Interviews with district level government officials and local NGOs revealed lack of awareness of alternative energy sources at district and village levels.

"In this district, I am not aware of any training offered to local people on improved charcoal production methods or promotion of efficient charcoal stoves" (NGO representative, Kitwe)

Further, conservation farming is currently not practised under government programmes and is restricted to areas under carbon related projects.

In terms of intersectoral coordination and multi-stakeholder participation, interviewees at national level reported cooperation among various stakeholders. This has been enhanced through establishment of the Environment and Natural Resources Management and Mainstreaming Program (ENRMMP) which aims to improve coordination of environmental and natural resources projects. The ENRMMP steering committee consists of government officials and international cooperating partners i.e. United Nations Development Programme (UNDP), United Nations Environmental Programme (UNEP) and FAO, who represent cooperating partners working in the environmental sector.

The ENRMMP has a multisectoral technical committee consisting of members from agricultural, forestry, energy and other environmental sectors. Interview data at national level further revealed that Zambia's designation as a UN-REDD pilot country has now provided opportunities for national level policy actors to regularly meet to develop the national UN-REDD preparedness strategy, therefore improving the connections between institutions. National policy actors explained that joint meetings enable knowledge sharing between different government ministries. Although there seems to be improved cooperation and input from across ministries due to ENRMMP and UN-REDD, government ministries are still autonomous in their operation and there remains a lack of harmonisation in decision-making. Multisectoral approaches have not been mainstreamed into sectoral policies.

Interview data with policy actors at district level shows that despite increasing attention on coordination and cooperation between government ministries and other stakeholders, cross sectoral policy level meetings have not filtered down from national to sub-national and district levels. A district government official highlighted that there is currently no consistent coordination among various environmental related sectors at district and village levels.

"Coordination among sectors is driven by projects, and lasts as long as the project" (Government forest officer)

6.3.5 Policy actors' perceptions of barriers to policy implementation

Interview data with various policy actors revealed that implementation of policies aimed at reducing deforestation is hampered primarily by the five factors outlined below.

6.3.5.1 Population increase and markets

Interviews with key informants revealed demographic pressure on forest resources as an underlying driver of deforestation and forest degradation. Population increase in rural villages is increasing pressure on forests for agricultural land, energy and non-timber forest products, as more people compete for declining resources. Population increase in rural villages is partly attributed to high urban-rural migration driven by low employment opportunities in urban areas.

"We used to migrate to urban areas to work in the mines but now people living in towns do not have jobs and have to come back home because life is expensive in urban areas" (key informant, Katanino site)

Further, interviews with key informants in both study sites overwhelmingly indicated that low income levels coupled with limited off-farm employment opportunities in rural areas compel local people to clear forests for charcoal production, which is a more lucrative forest use in the short-term. Revenue from charcoal sales is important for meeting various household needs including buying agricultural inputs such as fertilizers.

"Charcoal has a ready market. Money realised from charcoal sales helps us meet household financial needs such as paying school fees and buying fertilizer" (key informant, Mwekera site)

6.3.5.2 Inadequate legal framework

Interviews with government agencies, academics and NGOs revealed policy implementation is constrained by a non-supportive legal framework. For example, although engagement of local communities in forest management for various uses is prominent in national statements to Rio Conventions, the Forest Law lacks legal foundations for stakeholder participation in forest management. Despite adopting the Forest Policy of 1998 which encourages community involvement in forest management decision-making, the legal framework has not been enacted. The Forest Act of 1999 exists to provide a legal framework for implementing the forest policy of 1998 and to repeal the old Forest Act of 1973, however the government has (as yet) failed to establish a Forest Commission (an autonomous institution to manage forests) and to repeal the old Forest Act. As a result the Forest Act of 1973 which embodies centralized forestry management and excludes stakeholder participation is still in force.

6.3.5.3 Intersectoral coordination

Interview data with District government officials revealed a lack of integrated planning and a lack of communication among sectors despite national statements to Rio Conventions emphasising integrated planning. An officer from the Ministry of Agriculture at District level highlighted a lack of intersectoral coordination with forestry and energy sectors;

"We do not have joint meetings with the stakeholders from forestry and energy sectors" (Government agricultural officer)

Although policy documents show overlaps in activities targeted at reducing deforestation and forest degradation, there is no sharing of information, joint meetings, or joint activities among the various actors mandated to implement policies even though the activities proposed are similar. For example, despite the energy policy stipulating reforestation and afforestation activities, which are essentially a mandate of the forest department, there are no formal guidelines for intersectoral coordination, and government ministries in these sectors do not have structures to promote talking to each other. Similarly, no coordination exists between the agriculture and forest sectors in providing extension services to communities or for advising on tree growing under conservation farming systems.

Poor communication between autonomous sectors has led to conflicting extension services, especially between agriculture and forestry extension staff. For example, agricultural extension workers have provided agricultural subsidies (seeds and fertilizer) and extension services to farmers cultivating in a designated forest reserve because of their lack of knowledge about the forest reserve boundaries.

"Our primary goal is to increase food production; our measure of performance for a farming season is the quantity of crops produced, we are not very interested in how or where it is produced" (Government agricultural officer)

6.3.5.4 Insecure land tenure and political influences

At village level, interviewees disclosed that uncertainties in land tenure contribute to agriculture induced deforestation. The current trend by central government to degazette Forest Reserves that are severely degraded provides incentives for forest clearance. Squatters encroach on the forest with a view to obtaining formal title once human population increases and the Forest Reserve is degazetted. Encroachment is sometimes due to political influences as politicians illegally allocate land to people, especially in the run-up to elections.

Furthermore, retention of customary land is by evidence of use and therefore trees are cut to retain land under customary tenure and reduce the risk of expropriation. Forested areas are often viewed as unproductive, so clearing of trees for agricultural production is encouraged. Interviews with government forest officers revealed that at national level, forest land is degazetted and land converted to other land uses either for economic benefits such as mining exploration, building of housing units or establishment of recreation facilities. For example, the Botanical Forest Reserve in Ndola was degazetted in 2007 and a football stadium constructed on the land. An interview with a government forest officer highlighted a lack of political will to conserve forests. It was highlighted that;

"Forests are looked upon as bush earmarked for future development" (Government forest officer)

6.3.5.5 Poor funding and inadequate institutional capacity

Insufficient funding undermines the implementation of proposed activities to reduce deforestation. Expert interviews with government district forest officers revealed insufficient funding for activities and inadequate institutions for governance as challenges to forest management. Implementation of conservation farming technologies and efficient energy production requires sufficient technical, scientific and human resources (Chandra and Idrisova, 2011). Interviews with local key informants revealed little awareness of conservation farming technologies and efficient technologies for woodfuel production and use.

In terms of formal institutional structures, the Forest Department has management structures executing management responsibilities from national to district level, while the Ministry of Agriculture has management structures from national to village level. Loss of forest has been partly attributed to the inadequate institutional structures of the Forest Department, which do not exist at village level. This is coupled with low staffing levels in the Forest Department at all levels (i.e. district, provincial and national). Vinya et al. (2011) has highlighted that out of the 544 technical and professional positions available in the Zambia's Forest Department, 390 have not been filled due to inadequate funding from central government. An interview with a national forest officer highlighted that;

"The quantity of human resource is insufficient when compared to tasks required to implement activities for sustainable forest management" (Government forest officer)

Apart from insufficient staffing levels, forest officers at the district level highlighted that they lack appropriate technology and equipment to conduct forest patrols in the extensive Forest Reserves.

Implementation of activities proposed in statements to Rio Conventions is hindered by lack of access to funds to implement proposed activities. A national forest expert revealed that;

"Development of international facing national programmes such as under Rio Conventions is motivated by prospects of external donors to fund proposed activities" (Government Forest officer)

6.4 Discussion

6.4.1 Consistency of policies in addressing deforestation

This study has observed that national statements to Rio Conventions are more explicit in addressing drivers of deforestation and forest degradation than national sectoral policies, which ignore some drivers. The empirical evidence (see section 6.3.1) suggests that although forest clearance is high, the drivers of deforestation are known and documented in various national policy documents. This study has observed inconsistencies in addressing deforestation between national policies and national statements to Rio Conventions.

Measures to reduce forest cover loss in statements to Rio Conventions address various sectors, mainly due to environmental policy integration (EPI) being more pronounced in regional or international policies (Ledoux et al., 2000) while national sectoral policy development remains narrowly focused on specific sectoral policy goals. The differences between national sectoral policies and Rio Conventions seems to suggest that externally driven policies are often ratified, and subsequent national statements or programmes developed, without national governments changing national sectoral policies. These findings corroborate a study in Burkina Faso which found gaps between NAPA and sectoral policies (Kalame et al., 2011). Similarly, Chandra and Idrisova (2011) in their global review of national challenges for implementation of the CBD's NBSAPs have highlighted that implementation efforts are hindered by the sectoral focus of national policies. In Malawi, Stringer et al. (2010), have reported differences between national policy efforts to address climate change and desertification They further revealed that despite the emphasis on agriculture and food security in Malawi's NAP and NAPA, a lack of cooperation and coordination exists between the government ministries responsible for agriculture and environment. Stringer et al. (2009) in their study of southern Africa have highlighted that countries often develop national programmes due to their international commitment rather than a willingness to change at the national strategic level.

This study has observed inconsistencies between policies and the national legal framework. Inadequate legal frameworks and policy mismatches are a hindrance to policy implementation (Colchester et al., 2006). Although statements to Rio Conventions and forest policy have stressed the need for stakeholder involvement in forest resource management, these measures are not supported by the Forest Law. Disenabling of the legal framework impedes policy implementation. These findings are consistent with earlier studies which report forest laws as restrictive to local people (Ghimire and Pimbert, 1997, Syampungani et al., 2009) and unrecognising of the role of traditional leadership and local people in natural resources management (Virtanen, 2002). It is therefore clear from these findings that Rio Conventions have not been adequately domesticated into sectoral policies and the national legal framework. According to Phiri (2009), legal frameworks lag behind forest policies due to political reasons, such as the unwillingness of central governments to share incomes obtained from timber licencing and other benefits with other stakeholders

6.4.2 Intersectoral coordination and cooperation

This study has shown a lack of intersectoral coordination among agriculture, energy and forest sectors, as each sector is independent in decision making within its policy domain. This impedes active participation and collaboration between policy actors contributing to deforestation and forest degradation. Intersectoral coordination is important in reducing conflicts among sectors and in further aggregating competences and resources needed to address deforestation and forest degradation (De Bruijn and ten Heuvelhof, 2000, Rogers and Whetten, 1982). Although national statements to Rio Conventions have stressed the importance of intersectoral coordination and integrated planning among sectors, the statements are ambiguous in how that might be achieved and as yet no cross-cutting institutional structure have been formally established to facilitate such linkages. This study further observed that despite the forest policy recognising coordination among stakeholders through strengthened institutional collaborative arrangements as key to developing holistic strategies for sustainable forest management it is silent on what the role is of the other sectors is in practice.

It is clear from the findings that despite increasing national-level efforts toward intersectoral coordination under the UN-REDD programme and ENRMMP (section 6.3.4), intersectoral coordination has not been mainstreamed into planning processes across sectors probably due to lack of political will, lack of capacity and poor funding. Ministries remain autonomous in their operation and decision making. This has been exemplified by failure by the Energy Department to engage the Forest Department in establishing woodfuel plantations, while similarly, failure of the Forest Department to acknowledge the importance of agricultural issues in the National Programme for reforestation.

Lack of coordination across government ministries despite the existence of governance structures for multisectoral coordination at national-level is not unique to Zambia. Similar observations have been made in Mozambique and Zimbabwe where despite establishment of national-level governance structures to coordinate multisectoral activities in Climate Compatible Development projects (CCD), there remains tensions and challenges in sharing costs and benefits and assigning responsibilities across different government ministries (see Stringer et al., 2013).

Addressing existing institutional coordination deficits relies substantially on political will (Stringer et al., 2013). To ensure intersectoral coordination, decision makers in sectors must review the basis on which other sectors make decisions and understand the consequences of those decisions in their areas of responsibility (Willows and Connell, 2003). Intersectoral coordination across government ministries at all governance levels (i.e. local, district, national and international) has been identified as one of the key areas that requires good example of good practices (Reed et al., 2011, Stringer et al., 2013). Central to intersectoral coordination success is deliberate formal planning which is a precursor to improved coordination (Bryson et al., 2006). This requires carefully articulating the objectives of different sectors, roles and responsibilities. Once coordination among the forest, energy and agriculture sectors is well developed at the local level, it is likely to help coordinate extension services which could reduce the conflicting information passed by government agencies to rural communities.

6.4.3 Policy interaction and implications for forests

The findings of this research (section 6.3.3) have shown that Zambia's national forestry and agricultural policies are in conflict. Conflicts between forestry and agricultural policies have also been reported in Latin America as being amongst the main factors driving agricultural induced deforestation (Graham and Vignola, 2011). In contrast, the energy and forestry policies have shown positive interaction, a result which differs with earlier studies (Graham, 2011, Vinya et al., 2011). National statements to Rio Conventions are mutually supportive across the different conventions, while the forestry and energy policies show positive interactions with Rio Conventions. It is worth noting that due to the autonomous nature of government ministries in decision making, the extent to which multilateral environmental agreements are mainstreamed is different across ministries.

In terms of policy interaction, a key argument emerging from this analysis is that while environmental related policies may have positive interactions in policy documents they tend to lack implementation. Although policy discourses in the energy and forestry sectors show positive horizontal interaction and positive vertical interaction with national statements to Rio Conventions as regards to reducing woodfuel use, local level evidence reveals a lack of implementation of policy measures. It is therefore clear that positive and reinforcing policy measures to reduce deforestation on their own are not enough. Findings of this research on policy actor's perceptions of barriers to policy implementations (section 6.3.5) corroborates earlier studies which highlight policy implementation as being hindered by a number of factors among them; insufficient institutional capacity and lack of cooperation among different sectors or recognition of stakeholders (Chandra and Idrisova, 2011), lack of sufficient funding to implement activities, lack of human resources, and the financial incentives that unsustainable forest uses provide to local people who have limited revenue streams (Bond et al., 2010). Findings in this study have highlighted the importance of charcoal as a source of income in rural households' thereby increasing pressure on forests (section 4.4.4).

The agriculture policy shows negative interaction with the forest policy, which affects the effectiveness of the forest policy. In Zambia, increasing agricultural productivity is synonymous with agricultural extensification. Despite national statements to Rio Conventions being explicit on more sustainable agricultural farming practices and agricultural intensification as opposed to extensification, little emphasis is observed in the agricultural policy. The agricultural policy, focuses on increasing agricultural productivity in line with the national development plan (i.e. Vision 2030), and is thus a direct threat to forests. Although all national statements to the three Rio Conventions view agricultural intensification as having the potential to reduce deforestation, a study has shown that increases in agriculture yields stimulates more agricultural production and therefore makes forest conversion more attractive (Angelsen, 2010). This therefore requires deliberate measures to regulate expansion of land under crop production.

To strengthen synergies between forestry and agriculture policies, there is need for explicit recognition of mutually supportive links between sectoral policies as regards to food security and agroforestry. Food security is prioritised in national development plans, hence the emphasis on increasing food production in the agriculture policy, which is seen as solely contributing to food security. The forest policy and national statements are not explicit on the role of forests in contributing to food security despite the importance of forest products in the diets of local people as observed in this research (section 4.4.2) and elsewhere (e.g. Akinnifesi et al., 2008b, Campbell et al., 1997). Once the importance of forests for food is acknowledged in policies, forests may be considered side-by-side with agriculture in national strategies for food security, enhancing synergy and coherence between the two policy instruments.

Since rural areas still face problems of food insecurity, the challenge remains to increase food production by intensifying agricultural crop production systems using cheaper technology affordable to rural households (Angelsen, 2010). Agriculture and forest sector synergy could be strengthened through promoting agroforestry, which is the management of trees in agricultural landscapes using technologies such as improved fallow, rotational woodlots and intercropping to increase soil fertility

(Quinion et al., 2010). Trees in agroforestry systems are important in intensifying farming systems, promote integrated land use management and provide opportunities for livelihood diversification. Promoting agroforestry has the potential to improve coordination between sectors and would help integrate extension services which is currently lacking

6.4.4 Institutional capacity and land tenure

Local level evidence in this study suggests that institutional structures for competing land uses have implications for policy implementation. This can be attributed to the fact that when formal structures exist at village level, the cost of executing policy activities and monitoring is less when compared to structures that exist only at national or district levels. Levels of institutional structures affect policy effectiveness due to their inherent ability to either support or undermine policy implementation (Dougill et al., 2012). Related studies have shown that establishing formal institutions to implement policies at village level increases the efficiency of institutions to understand the local context and their geo-political scenarios (Gregersen et al., 2005).

This research provides additional evidence to earlier studies that highlight how insecure land tenure promotes deforestation and forest degradation (Anderson and Hill, 1990, Mendelsohn, 1994). Further, where there is competition or conflicts over land ownership between government agencies and local communities, forest clearing is done by local communities to secure ownership (Angelsen and Kaimowitz, 1999). Although studies have shown that tenure security improves forest management, it is worth noting that once legal property rights are obtained, land is often sold while encroachment of protected areas continues. This cycle has been described as a “race to the frontiers” (Angelsen, 2010:19641).

6.5 Conclusion

The ultimate forest management challenge for countries in tropical and subtropical regions remains halting deforestation and forest degradation. This chapter has examined policy coherence and interplay amongst the energy, agricultural and forestry sectors and the subsequent impacts on forest resource management. It has shown that while the drivers of deforestation and forest degradation have been identified in the policy discourse, outward looking national statements to Rio Conventions are more explicit in identifying drivers than national sectoral policies. It is clear from the evidence in this chapter that international environmental policies under the Rio Conventions have not been sufficiently mainstreamed in national sectoral policies and as a result there are conflicts among sectoral policies, and a lack of integrated cross-sectoral cooperation and coordination among agriculture, forestry and energy sectors.

In terms of policy interactions, the chapter has shown negative horizontal interaction between the agricultural and forest policies, while the mutually supportive link through conservation farming is poorly developed. This chapter has further shown that energy and forestry policies show positive horizontal interplay, however, policies lack on-the-ground implementation. The key challenges to implementation of measures to address deforestation include economic, legal, political, and institutional factors. Forests are managed using a centralised system through the Forest Department which has limited capacity in terms of both financial and human resources to ensure forest management.

This chapter has highlighted a lack of intersectoral cooperation and coordination between the agriculture, energy and forestry sectors, indicating a need for a more holistic landscape management approach to bridge sectoral divides. National statements to Rio Conventions have mutually reinforcing strategies with the national forest policy, but lack appropriate legislation for implementation. To address forest cover losses, a myriad of activities are needed, starting with integrated planning at national level, harmonization of national policies and national statements made in relation to international environmental conventions, appropriate legislation for policy implementation and strengthened regulatory mechanisms.

Chapter 7 Opportunities and challenges for C-based PES schemes generally and REDD+ in particular in Zambian Miombo woodlands

7.1 Introduction

The magnitude of observed and anticipated future consequences of climate change on the environment and livelihoods is increasingly informing the development of international climate change policy initiatives, formalised through UNFCCC and their CoP meetings, which aim to integrate climate change and sustainable development efforts (Bizikova et al., 2007, Lesnikowski et al., 2011). Initiatives such as United Nations Reduction of Emission from Deforestation and forest Degradation (REDD+) seek to deliver direct livelihood benefits to the rural poor through improved land management and provide payments for specific ecosystem services such as C-sequestration, thereby providing multiple benefits for climate mitigation and poverty alleviation (Munang et al., 2013). This chapter brings together the findings from the results chapters (chapters 4-6), to examine the opportunities and challenges for C-based PES in Zambia and provide insight for REDD+ policy development at a national level (objective 4).

This chapter will demonstrate that developing forest-based national climate mitigation policies in Miombo woodlands requires an understanding of these forest systems as socio-ecological systems, exploring how social and ecological components interact and the implications for C storage, to inform more holistic management strategies. The chapter examines how use of FPES in local livelihoods, as shown in chapter 4, impacts on woodland C-storage and the consequences for C-based PES schemes. Further, estimates of C-storage (chapter 5) and evaluation of policy frameworks (chapter 6) are discussed in light of what these findings mean for REDD+ initiatives. The chapter begins by first revisiting and synthesising research objectives 1-3 after which the opportunities and challenges for REDD+ facing initiatives in Zambia's Miombo woodland systems are presented and discussed in light of the research findings. The chapter then outlines the main policy implications of the research.

7.2 Revisiting the research objectives

This thesis has addressed four inter-related research objectives which are summarised here to review the main research findings and provide insight on the opportunities and challenges for developing and implementing REDD+ schemes in Miombo woodland systems and more broadly in relation to other global woodland systems.

7.2.1 Objective 1: To identify the key FPES obtained in the Copperbelt Miombo and to assess their relative contribution to local livelihoods

Miombo woodlands provide various FPES to rural livelihoods. The key categories of provisioning services are food, medicine, construction materials and fodder (section 4.4.2). Rural livelihoods in Copperbelt Miombo systems have limited sources of income and sale of FPES is an important source of income, making the highest total contribution to total household incomes. The findings of this study (section 4.4.4) show that charcoal constitutes the largest proportion of forest income. Wealthy households derive the highest mean incomes from the sale of FPES but exhibit the lowest relative contribution of FPES to total household income. The results further indicate that incomes from FPES make the greatest proportional contribution to the income portfolios of poor households with limited income streams. Chapter 4 has indicated that gender of household head is not a significant determinant of a household's engagement in the sale of FPES disagreeing with earlier studies (e.g. Yemiru et al., 2010), rather the sale of FPES is influenced by wealth status of households and contextual factors such as proximity to markets. A significantly higher proportion of households in Mwekera sold FPES with a short shelf-life, probably due to proximity to markets.

Findings of this research (section 4.4.6) have further shown that rural households in the study area face multiple shocks which negatively impact on livelihood assets and options. To cope households use various strategies, with FPES being the most widely used coping strategy for both idiosyncratic shocks and seasonal food stresses. It is clear from the findings (section 4.4.7) that FPES make an important contribution to livelihoods as a natural insurance against stresses and shocks.

Evidence from section 4.4.9 suggests that high dependence on Miombo woodland by local people to meet various livelihood needs is increasing pressure on woodland systems, resulting in decreasing forest cover which has led to reduction in availability of mushrooms, wild fruits, and some medicinal trees species. Residents therefore walk long distances to harvest some products such as wild mushrooms (e.g. *T. titanicus*), while others use less preferred tree species, as reported by other studies (e.g. Bandyopadhyay et al., 2011, Shanley and Luz, 2003). Households have reported loss of forest revenue as a consequence of reduction in forest cover and subsequent reduction of quantities of FPES sold (section 4.4.10).

The magnitude of local people's reliance on FPES for woodfuel as a source of income observed in this study suggests that development of national REDD+ policy is likely going to reduce income streams for local people and that payments are unlikely to fully compensate income losses. The use of forests as insurance means that national REDD+ initiatives, which are likely to limit access to and use of forest resources, should provide alternative safety nets to help households cope with stresses and shocks. Currently, REDD+ debates do not address household uses of forests to cope with stresses and shocks. If this important use is neglected in national REDD+ policy development, it will have negative impacts on poor households who seldom have access to other coping mechanisms and have limited income streams.

7.2.2 Objective 2: To understand floristic composition, forest diversity and quantify AG C stores in Copperbelt Miombo under different land management regimes

Forest ecosystems are known to be significant terrestrial biomes contributing to C sequestration and storage (Gibbs et al., 2007). Findings from this research (section 5.4.3) show that Miombo is a substantial AG C store and thus crucial for national climate change mitigation policies. Once mature Miombo woodland systems are cleared, AG C stocks are reduced by 39.6 Mg C ha^{-1}, and after abandonment and subsequent recovery through natural succession, AG C accumulates at rates of 0.98 and 1.42 Mg C ha^{-1} for agricultural and charcoal land uses respectively, with accumulation increasing rapidly in the first 15 post-abandonment years. After 20 years, the C storage in regrowth sites shows no significant difference compared with mature woodlands. Miombo woodlands are able to achieve mature vegetation structure (DBH, basal area) after 20 years of abandonment.

This research also shows that floristic composition in regrowth plots is affected by the pre-disturbance land uses and age of fallows. Although 20 years is sufficient for the forest structure of re-growing Miombo to resemble mature woodlands, this time is not sufficient for the floristic composition to recover. The research has shown low species similarities between mature undisturbed Miombo and the oldest regrowth sites of both charcoal and slash and burn agriculture, while diversity indices remain high throughout the recovery trajectory. Caution therefore must be taken in the interpretation of diversity indices in developing management strategies. Attention must be paid to actual species composition and the presence of Miombo dominant species. In view of the unclear time required for the floristic composition of regrowth to recover to mature woodland there is a need to conserve existing mature Miombo for various ecological and socio-economic benefits.

In view of current global attention on land use changes aimed at restoring C and biodiversity in degraded forest ecosystems, the accumulation of C in the recovery trajectory after disturbances, as indicated by this research, shows that charcoal production and slash and burn agriculture have the potential to be considered in emerging C markets, where incentives are given to local people to manage fallows to increase carbon storage and restore other ecosystem services. These land uses hold an enormous management potential which remains neglected in current national forest management strategies (see detailed discussion in section 7.3.5). The implications of forest recovery, as shown in this study, provide an opportunity for inclusion of fallow management in national REDD+ policy development. The challenge still remains for monitoring, reporting and verification of C sequestration in recovering fallows and the avoidance of leakages (i.e. managing fallows, while deforestation or forest degradation is moved to another area of forest).

7.2.3 Objective 3: To examine policy interactions across forest, agriculture and energy sectors, and their consistency with national programmes under Rio conventions

Various national sectoral policies and strategies for international environmental conventions interact across the forest sector. These policies have identified Zambia's main drivers of deforestation as charcoal production, and slash and burn agriculture (section 6.3.1). To reduce deforestation and forest degradation, various policy measures have been identified in national statements to Rio Conventions, as well as forestry and energy sectoral policies (see section 6.3.2). In terms of policy interactions, the energy and forest policy goals show positive horizontal interplay, though measures are seldom implemented on-the-ground due to socio-economic factors and the cost of alternative renewable energy sources. Conflicts continue to arise between national policies in agriculture and forestry. The agriculture policy's focus on expanding agricultural land shows negative horizontal interaction with the forest policy, while the mutually supportive link through conservation farming is poorly developed. This has been exacerbated by the lack of intersectoral cooperation and coordination between the agriculture, energy and forestry sectors, indicating a need for a more holistic landscape management approach to bridge sectoral divides. National statements to Rio Conventions have highlighted the need for greater collaboration between forestry, agriculture and energy sectors. However, efforts to implement this collaboration are generally lacking. One of the main barriers to intersectoral collaboration emerges from personnel and resource constraints within government ministries and field extension services. National statements to Rio Conventions have mutually reinforcing strategies with the national forest policy, but lack appropriate legislation for implementation. Section 6.3.5 has shown that implementation of policy measures to reduce forest loss is hampered by various factors, among them socio-economic factors, inadequate institutional structures, insecure land tenure, political interference and inadequate legislation.

The establishment of the UN-REDD secretariat and ENRMMP provide an opportunity for improved coordination and implementation capacity in the environment and natural resources sectors. It is however clear from chapter 6 that national REDD+ policy development in Zambia will require changes to national sectoral policies to build synergies between forestry, agricultural and energy sectors and address implementation deficits. Further, implementation of REDD+ initiatives demands changes in institutional ethos of government ministries which are sectoral in focus and lack multisectoral coordination and cooperation, especially at district and local levels where project implementation is focused.

7.3 Opportunities and challenges for REDD+ facing initiatives

International initiatives that embrace the integration of climate change and poverty alleviation efforts require national policies and actions that are informed by an integrated understanding of C-sequestration, livelihoods and ecosystem provision (Asare et al., 2013, Stringer et al., 2012a). This chapter conducts an analysis of the results of this study and discusses the implications on C-based PES in Miombo woodlands of Zambia and provides insight to guide government and other stakeholders in REDD+ project development.

7.3.1 Miombo use in rural livelihoods and implications on woodland C-storage

Forest provisioning ecosystem services from Miombo woodlands are widely used in rural households for household consumption, as a source of income, and as a coping strategy for households facing various shocks and seasonal food shortages, as presented in chapter 4. The various land and FPES uses have implications for woodland C stores and trade-offs will have to be made between various forest uses and pursuing income streams through C-based PES, as land use changes and management impacts on provisioning ecosystem services (Bryan, 2013). Four categories of interactions between uses emerge based on how uses affect each other when implemented in combination in the same landscape. These are compatible uses, incompatible uses and mutually reinforcing uses (either positively or negatively) (Chundama, 2009, Mwape and Gumbo, 2010).

FPES uses of thatching grass, wild vegetables, mushrooms and fodder are compatible, as these can be harvested collectively without negatively affecting the availability of each other or other forest products as their harvesting does not involve removal of trees (Table 7.1). Although collection of honey, fruits and medicine are compatible with C-storage (Table 7.1), sustainable harvesting practices should be observed as these uses have the potential to cause negative impacts on C-storage due to damaging of trees. In an earlier study on indigenous fruit trees of Miombo woodland systems, Kalaba et al. (2009a) reported unsustainable harvesting by cutting of fruit trees, and throwing of objects to dislodge fruits and so injuring trees, making them susceptible to fungi and insect attacks. Further, honey harvesting practices using traditional bark-hives of specific tree species such as *J. paniculata* (Malambo and Syampungani, 2008), and unsustainable harvesting of barks for traditional medicines causes severe injuries on trees making them prone to fungal infections and insect infestations leading to wood deterioration and so contributing to forest degradation (Chungu et al., 2007). Extraction of these FPES requires developing sustainable harvesting practices with local communities and appropriate monitoring measures. Detailed forest management plans at a village level are therefore needed to guide forest use and management and ensure community level monitoring.

Charcoal production and slash and burn agriculture drastically reduce forest cover, thus impairing the ability of woodland to provide other FPES (Table 7.1). To ensure supply of ecosystem services, these land uses require good integrated management practices such as integrating charcoal production into a mosaic of land uses across the landscape at a village scale. Some commentators assert that integrating charcoal production with swidden-fallow agroforestry systems reduces forest destruction and improves land management at local level (Coomes and Burt, 2001). Charcoal production land use is negatively mutually reinforcing with forest uses that require cutting down of trees (slash and burn, firewood, timber and wood carvings) and adversely reduces C-stores.

Table 7.1- Compatibility of forest uses in the Miombo woodlands (style adapted from Chundama (2009)

	Charcoal	Thatching grass	Honey	Medicines	Fodder	Timber	Firewood	Mushrooms	Fruits	Wild vegetables	Slash & burn	Woodcarving	Cultural	C-storage
Charcoal	0	+	-	-	+	-/-	-/-	-	-	-	-/-	-/-	-	-
Thatching grass		0	+	+	+	+	+	+	+	+	+	+	+	+
Honey			0	+	+	-	-	+	+	+	-	-	+	+
Medicines				0	+	-	-	-	+	+	-	-	+	+
Fodder					0	+	+	+	+	+	-	+	+	+
Timber						0	-/-	-	-	-	-/-	-/-	-	-
Firewood							0	-	-	-	-/-	-/-	-	-
Mushrooms								0	+	+	-	-	+	+
Fruits									0	+	-	-	-	+
Wild vegetables										0	-	-	+	+
Slash & burn											0	-/-	+	-
Woodcarving												0	-	-
Cultural													0	+/+
C-storage														0

+	Compatible uses	-/-	Mutually reinforcing (negatively)
-	Incompatible uses	+/+	Mutually reinforcing (positively)

It is worth noting that although firewood has often been reported as collected from deadwood or by-products from slash and burn agriculture (Chundama, 2009), evidence from this research showed significant use of firewood for commercial purposes which requires cutting of trees, thus increasing pressure on forests close to urban centres (see section 4.4.9).

Woodland management strategies under REDD+ programmes that provide incentives and support for forest protection could help prevent the loss of forest cover and increase the availability of Miombo forest products for local people. This would provide direct livelihood benefits to local people even before any C payments are delivered (Garrity et al., 2010, Stringer et al., 2012b). This means that REDD+ initiatives could provide co-benefits while at the same time providing payments for C-storage to compensate for the loss of FPES uses which are incompatible. Increasing efficiency of woodfuel production and use, and promotion of sustainable land use in national REDD+ policy has the potential to significantly reduce pressure on forests.

7.3.2 Rural household incomes and implications for REDD+ facing initiatives

Studies have shown that for PES schemes to impact positively on livelihood strategies, it is imperative that they provide economic incentives that are higher than competing land-uses (see section 2.6). Evidence from this research shows that the main competing land uses for C storage, i.e. charcoal and agriculture, are currently the main sources of rural household income in rural Zambia. The high relative contribution of charcoal to rural incomes suggests that direct income from C trading is unlikely to exceed financial returns from competing land-uses. It is therefore important that income benefits from C-based PES are viewed in light of other income and non-income co-benefits that could potentially arise from Miombo management. Other studies by Dougill et al. (2012) and Stringer et al. (2012b), report that benefits of C-PES schemes lie in incorporating payments for C with other livelihood benefits such as increasing agricultural yields associated with increased soil nutrients from agroforestry technologies and soil conservation, sale of tree crop produce, and income generated from sale of FPES. These co-benefits can help rural households build their resilience to climate change through providing ecosystem based adaptation benefits and increasing opportunities for livelihood diversification.

In terms of wealth of household and income from sale of FPES, this research has shown that poorer households obtain a higher proportion of their income from sale of

FPES, engaging significantly in the sale of products such as mushrooms and wild fruits (see section 4.4.4.2). These uses are compatible with C-storage and so should be allowed in REDD+ facing initiatives. If this approach is taken, then REDD+ schemes could have positive impacts on the poor.

This research has shown that prices for charcoal and other FPES are affected by contextual factors such as distance from the market (see section 4.4.4.1). This means that the opportunity cost for avoiding deforestation is different between communities even within the same forest type due to distance to markets and subsequent demand for products. Although debates continue on the need to understand local contexts in forest management (Blom et al., 2010, Bond et al., 2010), little evidence is presented in the literature to advocate for forest carbon prices to be reflective of opportunity costs of competing land uses in different project areas. The differences in sale of FPES observed in the two study areas provides evidence of the need to analyse local socio-ecological systems so that C-based PES projects are better informed by local contexts. The opportunity costs for different land uses vary and are therefore crucial to successful project development at local scales. It is important to note that fluctuations in carbon prices on global markets may affect local people's conservation of forests (Karky and Skutsch, 2010). This evidence suggests that C-offset prices need to be stable and relevant to retain a competitive advantage over other land uses in specific localities.

7.3.3 FPES use as a coping strategy and implications for REDD+ facing initiatives

This research has shown that rural livelihoods face various stresses and shocks and many rely on FPES as a coping strategy. The role of forest use as a coping strategy among rural households is, however, overlooked in the national climate change adaption programme of action (GRZ, 2007a) and national economic development programmes (GRZ, 2006). Studies from other parts of southern Africa (Jumbe et al., 2009, Paumgarten and Shackleton, 2011) and elsewhere (Wunder, 2001) have similarly reported a lack of recognition by national governments of the role forests play in poverty reduction strategies.

This research underscores the need for both national poverty reduction strategies and climate change national adaptation plans to recognise the value of forests as a key element of adaptation in rural livelihoods especially among the poor. It is worth noting that charcoal production is the most widely used strategy for coping with food stresses (section 4.5.3) and household income shocks. This means projects developed under REDD+ initiatives should provide resources to help households cope with stresses and shocks in rural areas where social support services seldom exist and people rely heavily on forests for survival.

7.3.4 Gender and wealth differentiation and implications for REDD+ facing initiatives

To improve Miombo woodland management, it is important that management strategies under REDD+ depart from past forest management strategies that considered communities as homogenous, without considering socio-economic factors in developing management plans. This research has shown that when use of FPES is analysed at household level, there is no difference in use between male and female headed households but that there are gender specific roles in regards to specific uses. It is important that conservation strategies enhance women's representation and participation in forest management as women have greater responsibility for collection of forest foods and medicine (see section 4.4.4.3). This is particularly important as women often do not actively participate in forest governance decision-making in Zambia (GRZ, 1998a). Lack of participation by women in decision making in natural resources management results from disparities in the freedom that men and women enjoy in different societies (Sen, 1992). These gender norms often constrain women's participation in decision making and therefore REDD+ projects require analysis of gender norms in project areas to provide women with equal opportunities in decision making and participation in various project activities. A review of women's participation in community forestry projects in Africa and Latin America found that women's participation in forest management groups reduces unsustainable harvesting of forest products and improves conflict resolution capacity of forest management groups (Sun et al., 2011). Similarly, studies in India and Nepal have also reported a significant improvement in forest conditions in forest management groups dominated by women (Agarwal, 2009, Rodgers, 2012). In REDD+ projects, women, men and young people should therefore be able to participate in various activities such as woodland management, biomass monitoring and development of land-use plans. It is further worth noting that matrilineal land ownership among the *Lamba* people in Katanino study sites empowers women to make land decisions, as men's right to land is tied to marriage (Mitchell and Barnes, 1950). The differences in land ownership among different tribes reemphasises the importance of engaging both women and men in forest management in a culturally diverse country such as Zambia.

This research has shown that wealth status of households correlates with average incomes derived from forest products, with the proportional contribution of FPES to total household income being highest among poor households (section 4.4.4.2). In planning and implementation of REDD+ projects, it is important that consideration is also given to the wealth categories of local people and that the poor who heavily depend on FPES are included in forest management to ensure their representation in decision making. This is particularly important as commentators have observed that wealthy elite households dominate decision making in natural resources management and often neglect the interests of poor households in making forest management decisions (McKean, 1992). There is also a need for equitable cost and benefit sharing in forest conservation and management among households with different wealth status and gender of household head. This research reiterates the assertion of earlier studies that developing initiatives aimed at forest conservation and economic development demands careful consideration of underlying conditions that give rise to differential forest reliance (Coomes and Burt, 2001, Paumgarten and Shackleton, 2011, Shackleton and Shackleton, 2006). It is worth noting that how wealth of household affects use of FPES and existing gender differentiated uses as demonstrated in this study are indicative of how different socio-economic factors may affect use of Miombo woodlands in rural livelihoods. As such, there is a clear need for more sub-national case studies in different forest socio-ecological contexts to provide guidance in national REDD+ policy development.

7.3.5 Carbon storage and implications of Miombo recovery for REDD+

This research has shown that Miombo woodland is an important C store (section 5.4.3). Its vast extent means that it contributes immensely to controlling the global C cycle. The findings suggest that Miombo offers potential for C-based PES to provide incentives for forest conservation. The recovery of Miombo C stocks after disturbances, as shown in this research, provides evidence that fallows of slash and burn agriculture and charcoal production have the potential to be managed sustainably under REDD+ to ensure degraded forests recover their lost carbon stocks, retain local tree diversity and restore the flow of various ecosystem services such as FPES, soil erosion prevention and climate regulation. This has the potential to generate income for local communities through the sale of carbon credits, diversifying their livelihood strategies beyond their use of traditional non-timber forest products and incentivising them to leave fallows out of production. The recovery of fallow land requires a long-term commitment, and resource investment across different levels to ensure monitoring, reporting and verification (MRV) to estimate emission reductions as accurately as possible. This is important in ensuring longevity of forest management impacts at local scale and for sustainable national development programmes.

In establishing MRV under REDD+, Merger et al. (2011) has recommended a less complex MRV process to reduce bureaucracy such as observed in CDM projects, drawing lessons from Voluntary Carbon Markets (VCM) standards being implemented around the world at different project scales (e.g. Plan Vivo Standard, Voluntary Carbon Standards, CarbonFix Standard, and Global Conservation Standard).

Herold and Skutsch (2011) have suggested that forest management interventions under REDD+ should target areas where interventions are easiest so as to have an immediate positive impact on carbon stocks. These areas, which could include fallows, should therefore be subjected to systematic data measurements based on stakeholder self-monitoring and independent verification.

In the past, little attention has been paid to reversing forest degradation through restoration of degraded forests (Sasaki et al., 2011). The Kyoto Protocol’s narrow focus on afforestation and reforestation excluded natural restoration mechanisms such as seen in Miombo woodlands after cutting for charcoal production or clearance for agriculture. Post-Kyoto negotiations of the Copenhagen Accord of 2009 adopted at the 15th Conference of the Parties (CoP 15) and subsequent meetings (Cancun, Durban, Doha and Warsaw; CoP 16 and 17, 18 and 19 respectively) have opened a window of opportunity for forest restoration under improved forest management to enhance carbon sinks, conserve biodiversity and improve livelihoods[12]. Forest restoration has a significant role to play in both global climate change mitigation and supporting livelihoods (Sasaki et al., 2011). Regrowth vegetation is important in offsetting GHG emissions from agriculture and other industries, and conserving biodiversity of native flora (Dwyer et al., 2009).

In the management of Miombo under the REDD+ initiative, it is important that rather than only focusing on avoided deforestation, forest restoration management be considered. This will require the creation of local monitoring methods to assess C storage and harness the potential livelihood benefits that it could deliver. In Miombo woodlands, promotion of mosaic restoration, which is landscape scale restoration that accommodates a variety of objectives, is ideal for small-scale farmers and charcoal producers where patches of forests are subjected to different uses. Mosaic restoration is suitable for areas with considerable differences in land use (such as agriculture, charcoal production, human settlements, grazing) (IUCN, 2011), and populations that are between 10-100 persons/Km^2 (WRI, 2011), which are common in rural areas within Zambia's Miombo woodland systems. Evidence at project level, e.g. Trees for Global Benefits project in Uganda, shows that households can incorporate trees into their agricultural landscape without negatively affecting their food production (Finighan, 2011). These simultaneous tree-crop systems have been reported to increase maize yields and are therefore important in achieving sustainable food production (Akinnifesi et al., 2008a), and conserving agrobiodiversity (Chirwa

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[12] There has been an increase in international climate finance commitment for REDD+ facing initiatives by developed countries. At the Warsaw CoP 19 meeting, the UK, USA and Norway have pledged $280 million to protect forests through a new initiative called 'BioCarbon Fund Initiative for Sustainable Forest Landscapes' (http://www.worldbank.org/en/news/feature/2013/11/20/biocarbon-fund-initiative-promote-sustainable-forest-landscapes).

et al., 2008a). Implementing such systems requires integrated land management and narrowing the sectoral divides between government ministries responsible for agriculture and forestry.

Miombo forest restoration will require involvement of various stakeholders to collectively decide on the forest areas to be restored. This will help degraded forests to recover their lost carbon stocks, provide other ecosystem services such as nutrient cycling and climate regulation, and provide an array of benefits to people (Sasaki et al., 2011). Despite the observed uncertainties in the time required for Miombo biodiversity to recuperate after disturbances (section 5.4.2), regrowth under natural regeneration supports species that are adapted to local conditions and provides suitable habitat for local fauna (Bowen et al., 2007). Further, local people are realising the use of species in naturally regenerating forests. As a result they are capable of providing more benefits to local people than forest plantations, given that Miombo woodland products already underpin many rural livelihood strategies (section 4.4.2).

Management of fallows should be complemented by efforts to reduce pressure on forests from agriculture and charcoal production, without which it will be difficult to get local buy-in for long term fallow management. To meet the growing demand for agricultural products while avoiding transferring forest clearance to other areas (i.e. leakage), agriculture could be made more permanent through the use of agroforestry tree species or other conservation farming techniques, as asserted by some commentators (Sileshi et al., 2007, Syampungani et al., 2010a). Establishment of woodlots is also likely to reduce pressure on woodlands at village level, and further promotion of alternative clean energy sources e.g. solar power, would also help to reduce local demand for charcoal.

Promoting Miombo recovery requires local communities' participation, long-term political commitment and provision of long-term financial incentives for fallow management under any Post-Kyoto agreement. Lack of investment funds hampers restoration efforts (IUCN, 2011). To support forest restoration, appropriate national policies, institutional arrangements and local participation are needed (Sasaki et al., 2011) together with legal instruments to ensure effective REDD+ implementation

(FAO, 2013, Williams, 2013). Once adopted under REDD+, management of fallows could be cost effective when compared to conventional planting, but it comes with the challenge of long-term monitoring.

7.3.6 Implications of policies on REDD+

REDD+ implementation in Zambia is faced with barriers from the existing policy context, mostly from the poor legal framework for forest management, and the single sector focus of forest governance, which prevents management of forests in light of the wider livelihood activities of local people. Agriculture and energy are the main drivers of deforestation and forest degradation in Zambia, but at the same time they are important sectors for economic development. Evidence from this integrated research indicates conflicts between forestry and agricultural sectoral policies which negatively impacts on Miombo woodlands, a trend which has also been observed in Asia and Latin America (Graham, 2011). The findings of this research underscore the need to enhance synergies between the forest and agricultural sectors. Harmonizing forestry and agriculture priorities under REDD+ will require limiting agricultural expansion and encouraging more permanent agricultural practices. This will require promotion of agroforestry technologies and the provision of incentives for agriculture intensification on existing agricultural land to increase yields.

This research has observed implementation gaps between policy documents and on-the-ground actions. This suggests that emerging REDD+ initiatives should consider addressing implementation deficits, and strengthening cross-sectoral collaboration and integrated planning between agriculture and forestry sectors, as well as harmonization of the agricultural and forestry policies and legal frameworks. This study has shown weak forest governance at district and local level due to limited funding and limited capacity. Reducing ecosystem degradation requires effective governance systems to reverse current trends and improve synergies in land use management (Vignola et al., 2013). Local capacity can be strengthened through instituting local-level interaction forums so that local people can discuss land management and economic incentives within their broader social goals (Hodge, 2007). The Rio +20 UN Conference on Sustainable Development in the document *The Future We Want* highlighted the fact that sustainable development in developing countries is rooted in ecosystem maintenance which requires strengthening of ecosystem and biodiversity governance and institutions at local and national levels (UN, 2012). This is important for ecosystems to provide opportunities for economic prosperity (Munang et al., 2013). It is clear from the findings of this research that due to the multiple uses of Miombo woodland systems, improving governance under REDD+ initiatives entails a shift from current sectoral focus to a more holistic landscape management approach that bridges sectoral divides. Currently, Zambia's Integrated Land Use Assessment (ILUA) II project which is a REDD readiness activity support by FAO us seeking to support REDD implementation through improving monitoring systems that capture livelihood needs and improved multi-sectoral dialogue[13].

This research has shown positive interaction between energy and forestry policies (section 6.3.2.2) but a lack of implementation, which is attributable to several factors, among them policy inconsistencies, inadequate legal frameworks, institutional capacity and resource constraints (section 6.3.5). Other studies have highlighted lack of intersectoral linkages and communication among various actors, and the lack of public involvement as contributing to the gap between environmental policy statements and their implementation (Blahna and Yonts-Shepard, 1989, Jordan, 1999). Leventon and Antypas (2012) have highlighted a lack of policy implementation as a key problem in environmental governance. To understand the disparities between policy and implementation in forest management, this study suggests that in national REDD+ policy development, it is vitally important that further case study research is conducted to elucidate the factors that affect the implementation of policy goals at various governance levels to improve implementation of policy goals.

This research has observed mismatches between national statements to international environmental conventions and national sectoral policies. It is imperative that sectoral policies are reviewed in order to draw on existing capacity to match national

[13] http://www.fao.org/forestry/17847/en/zmb/

statements made in relation to the Rio conventions. Sectoral policy development will therefore require a multi-stakeholder approach to enhance coordination among forestry, energy and agricultural sectors, and improved stakeholder communication at all levels. This is important as information sharing among various institutions is influenced by existing formal and institutional structures and governance arrangements, which influences how institutions respond to ecosystem degradation (Ostrom, 2007). Although this study has shown improved communication through Zambia's REDD+ secretariat and the ENRMMP, which draws membership from different government ministries, evidence at district and local scales has shown a lack of communication between stakeholders. Engaging stakeholders at district and local levels promotes common perceptions and understanding of environmental problems (Vignola et al., 2013). Stakeholder participation could be encouraged at district level through promoting joint meetings in initiatives such as those currently at national level (i.e. REDD+ and ENRMMP).

Comparing national statements to the Rio Conventions, it is worth noting that external facing plans or national strategies are often developed in response to global debates without significant reforms to change existing national laws, like observed in this study. This is probably due to international facing plans being driven by funding opportunities which are often available for proposed activities. Translation of international facing policies into national policies may be hindered by differences in national policy objectives or perceived loses of revenue to government by implementation of policies such as engaging local communities in forest management and sharing costs and benefits.

In line with previous studies (e.g Colchester et al., 2006, Ghimire and Pimbert, 1997), this research has shown that the absence of legal frameworks to support community benefit sharing mechanisms in forest management is a major setback that discourages local people from actively engaging in forest management

7.4 Identifying policy implications

This research has highlighted the use of Miombo woodlands in rural households and the potential for C based PES in Copperbelt Province, Zambia. The findings of this thesis (chapters 4-6) have identified various measures that could be implemented by policy development or actions to reduce forest loss and improve the contribution of Miombo to livelihoods. The following are key policy implications as informed by this research:

- Forest management strategies in Miombo woodland systems require an understanding of the woodlands as a socio-ecological system, developing management plans which pay attention to both the ecological and social components and their interactions. This demands a shift from past forest management strategies which have been dominated by an ecological focus while neglecting use of woodlands in rural livelihoods.
- FPES are highly relied upon by rural households for consumption, as source of income and for coping with household stresses and shocks. National poverty reduction strategies and economic development plan must recognise the contribution of FPES to rural livelihoods. Additionally, use of FPES in rural livelihoods as shown in this study, must be considered in developing forest management plans and PES projects.
- Integrated land use planning in land management is required, thereby integrating various land uses for agriculture, forest and energy needs across landscapes, and strengthening institutional structures for these sectors at district and local level to ensure effective enforcement. This is likely to strengthen cross-sectoral collaboration and communication among various government departments at all levels.
- Extension services by agriculture, energy and forestry government workers need to be co-ordinated to reduce conflicts between sectors and enhance synergies. This coordination would enable the promotion of sustainable practices and livelihood diversification, and the implementation of monitoring measures for FPES. Furthermore, there is need for coordination and integration of activities among national statements to Rio Conventions with national sectoral policies in order to reduce duplication of activities and improve forest management.
- Forest law requires amendment to allow participation of local communities in making decisions over forest management, as well as their involvement in

activities such as woodland management, biomass monitoring and development of land-use plans. The law should further provide provisions for benefit sharing mechanisms to encourage participation of local people.

- To reduce deforestation and forest degradation, promotion of agroforestry technologies is needed, alongside incentives for agriculture intensification to increase yields, while regulating agricultural expansion. Further, provision of incentives to farmers engaging in conservation farming would encourage conservation farming practices.
- Production and consumption of woodfuel needs to be optimised. Additionally, there is need to improve awareness of alternative fuels both in rural and urban areas, and making them affordable to provide incentives for people to adopt these energy sources and reduce fuelwood use.

7.5 Reflections

This thesis has used mixed-method approaches which have provided an understanding of the different dimensions of Miombo socio-ecological systems. Use of different methods (i.e. household survey, focus group meetings and key informant interviews) was also important in validating the results through triangulation. Allowing input from local people using participatory approaches was important in understanding use of FPES in rural livelihoods. Policymakers and development agencies are increasingly recognising the importance of local knowledge in natural resources management as an important source of information for understanding natural resources based livelihood strategies, for sustainable management of natural resources and for developing climate mitigation and adaptation plans. Therefore findings from this thesis provide local knowledge on the current status of forest use and management in Miombo woodland systems which are important in developing forest management strategies and developing climate change mitigation and adaptation plan.

The conceptual framework developed and applied in this research is useful in providing insight on human-environmental interactions within a spatially explicit socio-ecological system. The framework should be applied to other areas within the

Miombo woodlands and other forest systems under different socio-political conditions to understand its applicability and to provide insight for improved management. This is important as socio-ecological systems are characterised by spatial and temporal changes which create challenges in understanding these systems in different geographical regions (Turner et al., 2003) and this study is the first to attempt to incorporate spatial and temporal change in an integrated framework for understanding Miombo socio-ecological systems.

This thesis has estimated C storage using allometric equations. The diameter ranges for available equations range from 5 cm and above, and therefore equations for trees below 5 cm are lacking. Although previous studies (e.g. Brown et al., 1989, Chidumayo, 1997, Grundy, 1995, Malimbwi et al., 1994) have reported C storage in these small trees as being negligible, the high number of trees found under this diameter class observed in this thesis (see figure 5.1) and by other studies (Peters, 1994, Syampungani, 2009) suggests that C storage may be under reported. Despite C storage of individual trees being low, in trees of small diameter class (i.e. <5 cm), the cumulative value of C storage may be high and therefore developing allometric equations for these trees will greatly improve C estimation. Additionally, this thesis has not estimated soil C storage and so underestimates the total C storage in Miombo woodlands. Previous studies in drylands (e.g. Johnson et al., 2002, Williams et al., 2008) have shown that C storage in soil is higher than in aboveground vegetation. This means that C storage in both soil and aboveground biomass need to be estimated to give a better estimation of C storage. In designing C-based PES projects, C estimation should be linked to institutional and livelihood analysis as provided in this thesis to inform future REDD+ activities.

Chapter 8 Conclusions and priorities for future research

This chapter presents the overall conclusions of this research and summarises future research priorities.

8.1 General conclusions

This research set out to understand the socio-ecological linkages between rural people and the Miombo woodlands in the Copperbelt region, Zambia in order to establish the potential for community-based PES schemes. The integration of livelihood analysis, ecological analysis and policy evaluation within an extended framework for ecosystem services assessment allowed an exploration of the relative importance of FPES in rural livelihoods, the C storage potential of Miombo and policy interaction across the forestry, energy and agriculture sectors. The framework has highlighted dynamic interactions between Miombo ecosystems and rural people as a socio-ecological system and provided potential intervention points for improved forest ecosystem management. This framework forms the context into which new interdisciplinary research can be placed.

In this thesis, a contribution to the evidence and knowledge base for forests and rural livelihoods has been made by providing empirical evidence on the effects of socio-economic factors on the use and sale of forest products from Miombo woodlands. The research has also provided detailed understanding on use of FPES in coping with household stresses and shocks in rural livelihoods. To reconcile forest conservation and livelihood improvement under emerging global initiatives such REDD+, it is necessary to understand the contribution of FPES to livelihoods and acknowledge the various factors that influence forest resource use to inform the development of locally appropriate management practices.

Forest use by rural people impacts on Miombo woodlands, leading to deforestation and forest degradation. This research has shown that the Miombo woodlands are an important C pool and an estimation of C storage has been made under different land management practices related to fallow period and regrowth. This research has shown that once Miombo are cleared, the woodlands are able to re-grow once disturbances cease. Changes in floristic composition and C storage in the recovery trajectory have been presented, providing empirical evidence that C storage recovers after two decades while biodiversity takes a lot longer to recover in the restoration processes of degraded Miombo. An improved understanding of forest restoration processes as presented in this research has given insight into how degraded forests can be managed in order to recover, as well as the need to manage and protect mature Miombo woodlands to protect tree biodiversity. The evidence presented in this research is important in guiding policy makers in developing forest management strategies and policy interventions to increase C storage on which many emerging initiatives in forest based PES are based. Charcoal production and slash and burn agriculture fallows could be managed by local people for C sequestration and provisioning of other ecosystem services. This would however require incentives for local people to allow fallows to recover. This research has therefore provided timely evidence to guide REDD+ initiatives in Zambia and more broadly in global drylands.

The research has also shown a lack of harmonisation between policies and legislation that affects management of forests. Further, forest management is affected by resource constraints which weaken the governance systems at district and village levels. A comparison between national sectoral policies and national statements to Rio conventions has revealed some policy conflicts, while the legal framework does not have provisions for implementation measures aimed at benefit sharing. Policy and legislation changes are required in order to amend sectoral policies to match national statements to Rio conventions, and coordinate land management at landscape scale.

Miombo woodlands have tremendous potential to contribute to rural development. Apart from the direct uses shown in this research, the woodlands are able to provide additional benefits from C trading once projects are established and monitoring schemes implemented. In order for these benefits to be realised, there is need for amendments to the Forest Law to allow community participation in forest management and benefit sharing mechanisms. This would enable positive livelihood and environmental outcomes.

8.2 Priorities for future research

In spite of the valuable insights on Miombo forest socio-ecological systems provided in this thesis, there remain questions that need further investigation. The specific results of this thesis cannot be generalised to other socio-ecological systems in Zambia, but they can provide useful insight to guide development of forest management strategies both in Zambia and more widely in woodland systems in developing countries. In attempting to undertake this interdisciplinary research that covers social, ecological and policy analysis in a single study, the approach taken has been largely exploratory. This results in the inherent tensions of doing research in socio-ecological systems in which the researcher grapples with either broad and shallow or deep and narrow research (Luks and Siebenhüner, 2007). It would be useful to increase the depth of understanding by conducting more detailed examination of individual components, such as the transforming structures that link social and ecological components of these systems.

Firstly, in terms of Miombo use in rural livelihoods, although this study has investigated the use of FPES in rural livelihoods, it would be useful to conduct a more detailed socio-economic analysis on the influence of ethnicity on forest use in Zambia, a country which is ethnically diverse (73 tribes). This is particularly important in regards to gender as ethnic groups often have cultural practices that may hinder or encourage different gender use of forests. Investigating the influence of ethnicity on forest use will provide insight in developing locally appropriate management measures in different regions of the country and guide in future national policy development. This will be crucial to inform social safeguards under REDD+ by adding an ethnic dimension that is absent in this research. Secondly, the research has identified land tenure as driving forest use. Further research would be useful to enhance understanding of how land tenure affects forest use and management. Thirdly, the findings of this research have shown that FPES are used in rural households regardless of wealth status. Further research would be necessary to measure the quantities of the different uses to help map and differentiate forest dependency according to poverty levels and other socio-economic factors. Finally, this study has analysed the interaction between policies. There is a need to examine information flow within organisations and investigate how this affects policy implementation. A more detailed examination of barriers to policy implementation would contribute to improved forest management by addressing factors that hinder policy implementation. This is particularly important as most measures to address deforestation identified in policies (section 6.3.2) are not implemented. If these barriers are not thoroughly examined, new policy measures are likely to fail. This therefore calls for a detailed study building on the evidence from this study. It is recommended that future work is set within a socio-ecological approach to provide further integrated analysis that seeks to understand forest use and management at local scale, which should feed into sub-national and national level project development.

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Appendices

Appendix 1 Vegetation plot proforma

Date: *Site:* *Plot number:* *location:*

Age of the forest: *Land management:* *Recorder:*

#	**Name of tree species**	**DBH (cm)**	**Height (m)**		**#**	**Name of tree species**	**DBH (cm)**	**Height(m)**

Comments:

Appendix 2 Focus group meetings topic guide

1. What are the main livelihood activities in the village, and how has this changed over the past 30 years?
2. What are the current key livelihood activities and their impacts on forest resources?
3. How does the forest contribute to local livelihoods in the village
4. What are the most important forest products for the livelihoods of the people in the village?
5. What is the nature of access rights that people have forest resources; can you defend the forest against use by outsiders?
6. What are the local institutions and structures that shape use of forests and forest management in your village?
7. Does the village practice any form of active and deliberate forest management?
8. What are the drivers of forest cover changes in your village?
9. How has the availability of forest products changed over 30 years and how has it impacted on livelihood options?
10. What forest uses are complementary (do not reduce the availability of the other products)?

Appendix 3 Household questionnaire

A. IDENTIFICATION

1. Household name and code	*(name)*	(HID)
2. Village name and code	*(name)*	*(VID)*
3. Name of respondent		

B. DEMOGRAPHIC INFORMATION

4. Gender of household head M F

5. No. of people in the household

6. What is the marital status of household head?

7. What is the ethnic group of the household head?

8. Was the household head born in this village? Yes No
If ‘no’, go to section C

9. Where did the household head come from?

10. Why did the household head migrate to this village?

C. LIVELIHOOD PORTFOLIO

11. What are the household livelihood activities? (Tick against the appropriate activities)

	Livelihood activity	
1.	Crop farming	
2.	Charcoal production	
3.	Beekeeping	
4.	Collecting forest products	
5.	Livestock	
6.	Handicraft production	
7.	Full-time employment	
8.	Piecework	
10.	Other (Specify	
11.		

12. Have your livelihood activities changed over the past 10 years? Yes No

13. If yes, briefly explain how and why your livelihood activities have changed.

14. Does your household have adequate food supply for the whole year? Yes No

15. If no, what months during the year (12 months) does the household experience problems of satisfying the food needs?

16. What do you do to meet the food deficits in the months mentioned above?

D. FOREST PROVISIONING ECOSYSTEM SERVICES

17. Do you obtain any foods from the forest? Yes No

18. Provide details of the foods obtained from the forests

19.

Product	**Collected by code**	**Household consumption 1=Yes 0=No**	**Sale 1=Yes 0=No**	**Nature of access rights to the forest**	**Distance from homestead to the forest where products are collected**		**Change in availability over 10 years 1=decreased 2=Increased 3=Same**
					Km	Time	
Fruits							
Honey							
Mushrooms							
Wild vegetables							

Codes: 1=only/mainly by wife and adult female household members; 2=both adult males and adult females participate about equally; 3=only/mainly by the husband and adult male household members; 4=only/mainly by girls (<15 years);5=only/mainly by boys (<15 years); 6=only/mainly by children (<15 years), and boys and girls participate about equally;7=all members of household participate equally; 8=none of the above alternatives; 9=person employed by and living with the household

20. Does your household use forest trees for medicinal purposes Yes No

21. Provide details of the medicinal trees used in your household

Tree species	Parts	Ailment treated

22. What sources of energy does your household use for the following?

Purpose	Energy source(s)
Cooking	
Heating	
Lighting	

23. If you use charcoal, do you produce it? Yes No

24. Do you use the forest as a source of forage or grazing livestock? Yes No

25. Does your household use forests as a source of construction material? Yes No

26. Which forest products (and tree species) does your household use for building purposes

27. Are the preferred tree species for construction available? Yes No

28. What are the tree species that have become rare?

29. What are the most important forest products to your household?

30. Do you observe any cultural rules when harvesting forest products? Yes No

    If yes, Name the product and the associated rules

31. Apart from harvesting forest products, do you use the forests for any other purposes? If so explain

E. Household source of income

33. What are the different household source (s) of income

34. What is the approximate income that your household obtained from selling of forest products in the last 12 months?

Forest product	Quantity sold	Unit price	Type of market	Total income
1. Timber				
2. Charcoal				
3. Fruits				
5. Poles				
6. Firewood				
7. Mushrooms				
8. Thatching grass				

35. What are the quantities and values of crops that household has harvested during **the past 12months**?

Crops	Area of production	Unit(for production)	Own use (incl. gifts)	Sold (incl.	Price per unit	Total income
Maize						
Beans						
Groundnuts						

36. Please list any other income that the household has received during the past **12months.**

Type of income	Total amount received past 12months
1. Remittances	
2. Support from government, NGO,	
3. Gifts/support from friends and relatives	
4. Pension	
6. Payment for renting out land (if in kind, state the equivalent in cash)	
7. Sale of livestock	
8. Other, specify:	

F. Crisis and unexpected expenditures

39. Has the household faced any major income shortfalls or unexpectedly large expenditures during the past 2 years? Yes No

Event	How did you cope?
1. Serious crop failure	
2. Serious illness	
3. Death of productive age-group adult	
4. Land loss (expropriation, etc.)	
5. Major livestock loss (theft, drought, etc.)	
6. Other major asset loss (fire, theft, flood, etc.)	
7. Lost wage employment	
8. Wedding or other costly social events	
9. Other, specify:	