Food and Agriculture Organization of the United Nations

SUSTAINABLE MANAGEMENT OF MIOMBO WOODLANDS

FOOD SECURITY, NUTRITION AND WOOD ENERGY

Sustainable management of Miombo woodlands

Food security, nutrition and wood energy

This paper was prepared by Davison J. Gumbo from CIFOR Zambia and
Marc Dumas-Johansen, Giulia Muir, Fritjof Boerstler and Zuzhang Xia from FAO.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2018

Recommended citation:
Gumbo, D.J., Dumas-Johansen, M., Muir, G., Boerstler, F., Xia, Z. 2018. Sustainable management of Miombo woodlands – Food security, nutrition and wood energy. Rome, Food and Agriculture Organization of the United Nations.

ISBN 978-92-5-130423-5

CONTENTS

ACKNOWLEDGEMENTS

FAO and the authors are grateful to workshop participants from Angola, Malawi, Mozambique, the United Republic of Tanzania, Zambia and Zimbabwe, facilitator Yemi Katerere, who provided valuable input into the workshop and into this document, and the NGO BIOHUB for workshop preparations and management.

The following FAO colleagues provided valuable support and feedback to the authors in the development of the paper: Anna Tjarvar, Daowei Zhang, Mats Nordberg, Nora Berrahmouni and Patricia Tendi.

Mitzi Du Plessis and Elke Momberg of Malachite Marketing and Media edited and managed the design and layout of this paper. Maria Guardia for the cover design.

ACRONYMS

CBD	Convention on Biodiversity
CBFM	Community-based forest management
CFS	Committee on World Food Security
CIFOR	Center for International Forestry Research
CO_2	Carbon dioxide
CSA	Climate Smart Agriculture
DRC	Democratic Republic of the Congo
ES	Ecosystem services
FAO	Food and Agriculture Organization of the United Nations
GACC	Global Alliance for Clean Cookstoves
GEA	Global Energy Assessment
GHG	Greenhouse gas
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
JFM	Joint forest management
NAPA	National Adaption Programmes of Action
NBSAPs	National Biodiversity Strategy and Action Plans
NDCs	Nationally Determined Contributions
NTFPs	Non-timber forest products
NWFPs	Non-wood forest products
SDG	Sustainable development goal
SFM	Sustainable forest management
SLF	Sustainable Livelihood Framework
SSA	Sub-Saharan Africa
UNCCD	United Nations Convention to Combat Desertification
UN DESA	United Nations Department of Economic and Social Affairs
UNDP	United Nations Development Programme
UNEP/WCMC	United Nations Environment Programme – World Conservation Monitoring Centre
UNFCC	United Nations Framework Convention on Climate Change
UNFI	United Nations Forest Instrument

©FAO/R. Faidutti

©FAO/S. Maina

EXECUTIVE SUMMARY

The Miombo woodland is a vast African dryland forest ecosystem covering close to 2.7 million km^2 across southern Africa (Angola, Democratic Republic of the Congo, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe). The woodlands are characterized by the dominance of *Brachystegia* species, either alone or in association with *Julbernardia* and *Isoberlinia* species. It is estimated that the woodlands – through their numerous goods and services which include various non-wood forest products (NWFPs) (e.g. insects, mushrooms, fruits, tubers, medicine, fodder, honey, seeds) and woodfuels, which, for simplicity, will be referred to as non-timber forest products, or NTFPs, throughout the publication – sustain the livelihoods of more than 100 million rural poor and 50 million urban people. The charcoal sector alone employs vast numbers of rural people and offers additional income to many poor rural families.

Communities moreover rely directly on the woodlands for food and nutrition. NWFPs add vital micro- and macronutrients to local diets and contribute to diversified food systems, while woodfuel is essential for cooking and sterilizing, thus ensuring proper nutrient absorption and providing clean water for drinking. Forests and trees, if managed sustainably, are an important source of resilience for rural people in the Miombo woodlands, supporting households to absorb and recover from climatic or economic calamities and contributing to resolving the underlying causes of food insecurity, undernutrition and poverty by providing nutritious edible products and woodfuel for cooking in addition to conserving biodiversity and water resources, buffering extreme weather conditions and preventing land degradation and desertification. Generally speaking, it is now accepted that forests managed for both timber and NTFPs retain more biodiversity and resilience than forests managed solely for one aspect, e.g. timber and exotic timber plantations.

However, a growing population in high need of agricultural land and unsustainable use and overharvesting of natural resources in parts of the Miombo woodlands, combined with climate change impacts (e.g. drought, fires), leave insufficient time for many trees and associated species to regenerate naturally, posing a serious threat to the products and services of the woodlands, and to the livelihoods depending on them. Compounding the problem and hindering development of the Miombo ecosystem, are: i) lack of an enabling policy environment; ii) unsustainable management; iii) limited willingness and ability to pay for and access to energy-efficiency technologies; iv) inadequate awareness and information, including technical capacity; v) high poverty levels; and vi) limited access to microcredit facilities.

With the Committee on World Food Security's endorsement of the recommendations presented in the *High Level Panel of Experts Report on Sustainable Forestry for Food Security and Nutrition* in late 2017 – which include promoting multifunctional landscapes, integrated food-forestry systems, and research on associated linkages, among other things – forests and trees are expected to play a greater role in future land-use decisions and related policies. This paper provides an overview of these linkages in the context of the Miombo woodlands, in the hope that future land use, policy decisions and financial investments are shaped to support the contributions of forests and trees to the health and livelihoods of communities in the ecoregion.

The following key messages were formulated:

- Forests and trees, if managed sustainably, are an important source of resilience for rural people in the Miombo woodlands, supporting households to absorb and recover from climatic or economic calamities and contributing to resolving the underlying causes of food insecurity, undernutrition and poverty by providing nutritious edible products and woodfuel for cooking in addition to conserving biodiversity and water resources, buffering extreme weather conditions and preventing land degradation and desertification.
- Current data bases referring to the value of the Miombo must be analysed and used as evidence to improve policy-making.
- Miombo woodlands may be dominant (spatially), but they have not been addressed as a single unit but as part of the region's forests. They form part of the overall forestry strategies and no specific mention in the conventions does not suggest that their importance is underplayed.
- The management of Miombo will require some changes in management structures, especially in providing benefits emerging from trade in forest products to local managers.
- Local forest managers should play a greater role in allocating resources for feedstock for charcoal production.

©FAO/S. Terrill

1 INTRODUCTION

©FAO

Since time immemorial, humans have been modifying forests (Bhaskar *et al*., 2015), the Miombo woodlands included, through activities such as agricultural expansion, slash and burn, livestock rearing, settlements, gathering of wild foods, and harvesting forests for timber and fuel. These activities can have deleterious impacts on the associated ecosystems unless undertaken in a responsible and sustainable manner.

As with almost all forests today, the Miombo woodlands are showing signs of past anthropogenic interventions (Lambin and Meyfroidt, 2011), which have resulted in biological diversity losses (FAO, 2014). Central to these changes is the desire to meet livelihood demands, especially for food and energy, which together with water and forests, are inextricably linked. In sub-Saharan Africa, an estimated 80 percent of rural people still rely on "non-timber" forest products and services like wild foods and fuelwood for food and nutrition, energy, medicine and livelihoods (Dewees *et al*., 2010; Chidumayo and Gumbo, 2010; Syampungani *et al*., 2009; Mistry, 2000). Over 100 million rural and 50 million urban people are thought to depend directly or indirectly on the Miombo woodlands for their lives and livelihoods (Ryan *et al*., 2016; Syampungani *et al*., 2009). Wood remains the main source of energy for cooking, which ensures proper nutrient absorption, and for boiling water. Wild forest foods such as edible nuts, mushrooms, fruits, aromatic plants, game and insects (Agustino *et al*., 2011; FAO, 2001b; Chidumayo, 1997; Peckam, 1993; Campbell, 1987) – and other products such as fodder and medicinal plants – also make a significant contribution to food and nutrition security, helping ward off debilitating micronutrient deficiencies, diversifying diets and livelihoods (Vincenti *et al.*, 2013) and acting as safety nets in times of stress (Paumgarten and Shackleton, 2011; Jumbe *et al*., 2008).

Forests and trees, if managed sustainably, are therefore an important source of resilience for rural people in the Miombo woodlands, helping households absorb and recover from climatic or economic calamities, for instance, as well as resolving the underlying causes of food insecurity, undernutrition and poverty by providing nutritious edible products, woodfuel for cooking in addition to conserving water resources and biodiversity and buffering extreme weather conditions. The ability of the Miombo woodlands to continue to provide these goods and services is premised on the need for responsible forest management and restoration, which underpins the concept of sustainable forest management (SFM). The adoption of SFM in the Miombo woodlands should address the relationships between food and energy that are inextricably linked.

A workshop was conducted with key stakeholders from Miombo countries from 30 to 31 August 2017, to identify and learn from ongoing work on the sustainable management of the woodlands. The workshop concluded that there was a strong need to boost regional collaboration among Miombo countries and called for:

1) increasing recognition of the importance of the Miombo woodlands for food and nutrition security and poverty alleviation;
2) greater knowledge sharing and cooperation between the Miombo countries on sustainable forest management (SFM) and restoration;
3) the establishment of a framework/process for harmonizing policies and guidelines on the sustainable use of forests;
4) enabling transboundary sustainable management and restoration of the Miombo woodlands, including systematic monitoring of resources; and
5) identifying and providing training for alternative livelihood opportunities.

The paper served as background paper for the workshop.

This paper begins with an analysis of the linkages between food security, nutrition and wood energy in the Miombo woodlands (*Chapter 2*). The impacts of climate change and variability are subsequently reviewed, illustrating the role of the Miombo woodlands in acting as safety nets (*Chapter 3*). The paper provides a brief overview of ongoing activities of relevance to the Miombo woodlands and highlights priority areas for urgent action and investment (*Chapter 4*) and continues with existing barriers and gaps (*Chapter 5*) and finally with key messages and ways forward (*Conclusion*).

©D. Gumbo

2 BACKGROUND

©FAO/S. Maina

This chapter provides a general introduction to Miombo woodlands and an overview of the Miombo food system.

Box 1. What are Miombo woodlands?
Miombo is the Swahili word for *Brachystegia*, one of many species found across this transboundary ecosystem. The ecosystem describes the vastest dry forest biome in southern Africa, stretching over seven countries (Angola, DRC, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe), covering more than 2.7 million km^2.

2.1 General introduction to the Miombo ecoregion

Miombo woodlands cover two-thirds of the Sudan-Zambezian phytoregion (circa. 2.7 million km^2) (Figure 1), representing an important source of energy in the form of firewood and charcoal in parts of Angola, the Democratic Republic of the Congo, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe (Ribeiro *et al*., 2016). In addition, the biome is a crucial source of essential subsistence goods such as poles and construction products, timber, materials for tool handles and household utensils, foods, medicines, leaf litter, grazing and browse (Dewees *et al*., 2010; Campbell *et al*., 1996; Clarke *et al*., 1996). Furthermore, the woodlands harbour biodiversity, maintain carbon stocks (thereby regulating climate), control soil erosion, provide shade, modify hydrological cycles and maintain soil fertility, all of which are essential ecosystem services (Jew *et al*., 2016). Lately, it has become apparent that the Miombo woodlands are threatened by settlements, land clearance and agricultural expansion, logging, wood energy collection through rural-based enterprises, tobacco curing, and unsustainable charcoal production that are accelerating the processes of deforestation and degradation. These drivers are likely to intensify under climate change (IPCC, 2007).

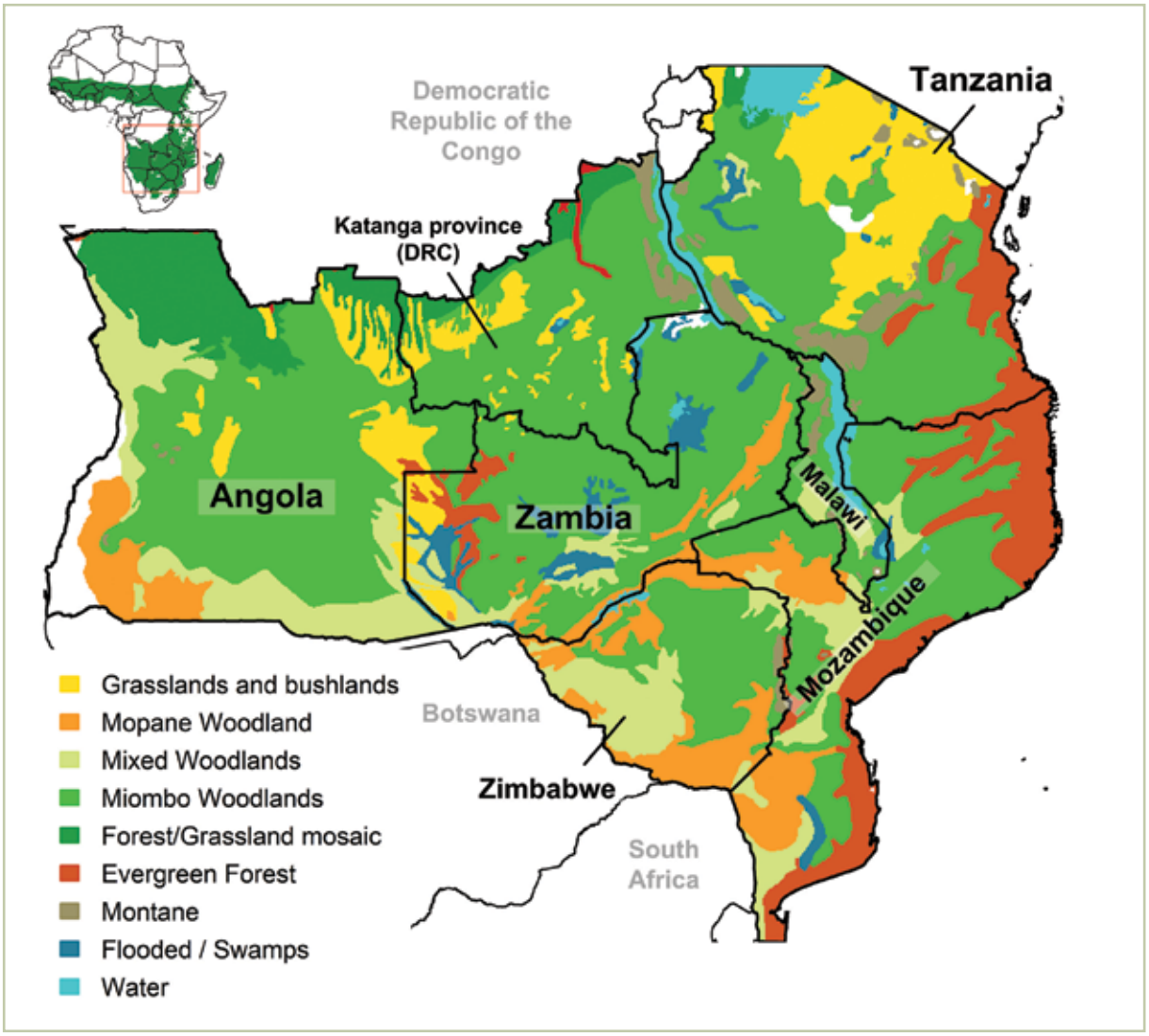


Figure 1. Main land cover types in the Miombo ecoregion. Ryan *et al*., 2016.

Miombo vegetation is characterized by the dominance of *Brachystegia* species, either alone or in association with *Julbernardia* and *Isoberlinia* species. The Miombo is found in the broader tropical dry forests of southern Africa. While two distinct Miombo vegetation groups can be found – dry and wet – separated by the 1 000 mm isohyet covering southern Malawi, Mozambique and Zimbabwe and northern Zambia, Eastern Angola, southwest Tanzania and northern Malawi respectively (Frost, 1996), the Miombo is often enriched in those places where it interfaces with Mopane or coastal woodlands. These largely undifferentiated woodlands need to be separated from the "True Miombo" defined above.

Table 1. Overview of type and quantity of non-timber forest products

A wide range of terms and definitions are currently in use to define "NTFPs". FAO defines *non-wood* forest products as goods of biological origin other than wood, derived from forests, other wooded land and trees outside forests. This definition excludes timber, chips, charcoal and fuelwood, as well as small woods such as tools, household equipment and carvings (Belcher, 2003). As the focus of this publication is also wood energy, the term '*non-timber forest product*' (NTFP), which encompasses all biological materials (including fuelwood) other than timber which are extracted from forests for human use (de beer and Mcdermott, 1989), will be used.

Category		Number of species	Notes on species and use
	**Fuelwood, poles, tools, handcrafts**	34 different species (Mgumia *et al.*, 2017).	
	**Fruits**	83 known indigenous fruit species (Kadzere *et al.*, 1998).	*Sclerocarya birrea, Adansonia digitata, Uapaca kirkiana, Parinari curatellifolia, Strychnos cocculoides, Anisophyllea boehmii, Azanza garckeana, Flacourtia indica*, among others.
	**Medicine**	At least 32 different species are used in health care (Mgumia *et al.*, 2017).	Roots, leaves, bark, seeds of different species.
	**Fodder**	9 species (Mgumia *et al.*, 2017). 15 species (CIFOR, 1996).	
	**Mushrooms**	34 edible species have been identified in Tanzania; 60 in Malawi (FAO, 2000); 25 species in Zambia (Pegler and Pearce, 1980).	
	**Wild meat (including insects)**	At least 20 species of rodents eaten (Malaisse, 1982). 31 species of edible caterpillars found in Zambia alone (De Foliart, 1999).	The most popular are caterpillars (mostly silk moth family *Saturniidae*); the most well-known species in the southern African region is *Gonimbrasia belina*, locally known as mopane worm (World Bank, 2008).

Source: Mgumia *et al.*, 2017; Chirwa *et al.*, 2008; Kalaba *et al.*, 2008.

The table showcases a non-exhaustive list of existing species documented in literature.

The Miombo woodlands are under three types of ownership: state owned, local government owned and community managed (Counsell, 2009).

Under *state owned*, some woodlands are gazetted by central government and managed by the same or under some joint forest management (JFM)/sustainable forest management (SFM) regimes. In this regime, communities/villages partner with the central government to manage forests.

Under the *local government ownership* regime, forests are owned and managed by local government authorities (Districts) under JFM/SFM, or District Councils with the participation of communities. JFM has been widely promoted in all catchment forests in Tanzania, particularly those considered to be important biodiversity areas with high conservation value. In many places, the protection status of the most critically endangered forests is now being upgraded to nature reserves, which provides them with additional protection (Blomley and Iddi, 2009).

Under the *community ownership* regime, forests are owned and managed by communities/villages, with technical assistance from public forestry institutions. Each village in such areas has a village environmental/natural resources committee, which has the overall management responsibilities of community/village forests. These committees also assist in the management of central government and local government forests by carrying out patrols in these forests. The management approach of community-based forest management (CBFM) emphasizes full delegation of management rights, responsibilities and returns to village-level institutions and below. Although the institutions and policies are in place, they often do not have the desired effect owing to the capacity of local-level institutions (Kokwe, 2012; Kowero *et al.*, 2003).

©FAO/S. Maina

©FAO/S. Maina

2.2 Importance of Miombo woodlands to rural communities

Miombo woodlands provide resources that are vital to the livelihoods of millions of rural and urban people living in and around these woodlands in central, eastern and southern Africa. In fact, people obtain a multitude of products from these woodlands including food, energy, shelter, medicines, and invaluable environmental and spiritual services (Chirwa *et al.*, 2009; Campbell *et al.*, 2007; Campbell *et al.*, 1996). Many indigenous fruit trees such as *Sclerocarya birrea, Azanza garckeana, Parinari curatellifolia* and *Uapaca kirkiana* also play an important – yet underutilized – role in food and nutrition security as well as poverty alleviation, as do nectar-producing genera such as *Brachystegia, Julbernardia, Syzygium* and *Combretum*, which sustain beekeeping activities (FAO, 2009; Michels-Kokwe, 2006; CIFOR, 1996; Clauss, 1992). Establishment of woodlots or plantations to cater for multiple purposes has the potential to create benefits throughout the entire food system, provided that proper forest planning takes place (FAO, 2003; ICRAF, 2004). Numerous surveys have been conducted to understand the importance local communities attach to different species (also highlighting the differences among men and women, including diversified knowledge on uses) and resource availability of the most "useful" plants (Kadzere, 1998 in Akkinifesi, 2008; FAO, 2003). Local perceptions should be accounted for in monitoring activities and when establishing plantations or tree-domestication programmes. These activities should also consider the different species considered useful by men, women and children, who often have distinct experiences with different trees.

Environmental resources from the Miombo woodlands make particularly significant contributions to household economies in rural sub-Saharan Africa (Shackleton and Shackleton, 2004; Paumgarten and Shackleton, 2011) and to food and nutrition security. In addition, forest products in these woodlands are important for rural livelihoods (Arnold, 2008; Arnold and Perez, 1998). Lately, the commercialization of some forest products has bolstered the importance and contribution of these products (Sunderland *et al.*, 2004). Some of the products increasingly contribute to both nutrition (NFNC, 2014) and incomes, e.g. edible caterpillars (Ghaly, 2009; Chidumayo and Mbata, 2002; Holden, 1991), indigenous fruits and by-products (Mofya-Mukuka and Simoloka, 2016; Akinnifesi *et al.*, 2006).

Woodlands provide 76 percent of total energy used in the Miombo ecoregion. Between 1.4 and 2.5 million people are employed in the traded woodfuels sector, with a traded value of $780 million per year. According to Bailis *et al.* (2015) and FAO (2001), the majority of the Miombo ecoregion countries are among the countries

with the highest per capita woodfuel energy consumption (i.e. Angola, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe), with biomass accounting for between 60 and 90 percent of total energy consumption in these countries. Most woodfuel used in rural areas is in the form of firewood and is collected locally, often harvested as dead material, although this can change in situations of scarcity (Brouwer *et al.*, 1997). By contrast, urban people consume traded woodfuels, primarily charcoal. These traded woodfuels are used by 70 to 90 percent of the 50 million urban population in the region (CAMCO, 2014; Falcao, 2008; Kambewa *et al*., 2007) and support a significant flow of money from urban to rural areas (the higher values of woodland income in the supplementary material are typically in areas producing charcoal). The main beneficiaries are urban consumers who benefit from reliable, consistently priced energy (Maes and Verbist, 2012), accessible and usable without substantial capital investment, and available in small quantities; rural producers who sell charcoal for 12 to 53 percent of the final price (van der Plas *et al.*, 2012; Kambewa *et al.*, 2007; Zulu, 2010; World Bank, 2009); governments and their officials who tax woodfuel transport, most often privately (i.e. bribes) (Zulu and Richardson, 2013; Minten *et al.*, 2013); and wholesalers and retailers – for instance, charcoal retailing provides employment for poor urban women (Puna, 2008).

This array of products acts as an important safety net against economic or natural shocks such as droughts, floods and fire damage, and helps build resilient communities that can better withstand and absorb shocks. Fires, for instance, are a serious issue, often damaging the regenerative capacity of the Miombo woodlands (Chidumayo *et al.*, 1996). Solid fire management is a strong tool in the woodlands and is normally conducted for timber production management or grazing (Chidumayo *et al.*, 1996). A fire late in the dry season favours grasses, while an early fire favours the trees in general. It is recommended that for proper management fires should be site specific, identifying the age of the species present and desired, their phenology, land use and overall management objectives of the area (Chidumayo *et al.*, 1996). Areas with young regrowth should be protected from late fires by conducting early fires to minimize their damage.

This highlights the need for incorporating the Miombo woodlands into poverty reduction strategies in most of the countries of eastern and southern Africa where the woodlands occur. Linkages between income levels and Miombo resource use are complex. Poorer households tend to use Miombo resources for subsistence, while richer households use them for cash income (overexploitation). Microlevel analyses can help provide more tailored policy interventions for sustainable use of the Miombo woodlands. It is, therefore, imperative to quantify woodland contributions to individual and household welfare and raise the profile of these woodlands in policy debates, developing policies that achieve the twin objectives of woodland conservation and local livelihood improvement. Such policy interventions will be important as currently many researchers have assumed that forest products serve as "gap fillers" or "famine foods" in the case of edible NWFPs (i.e. income supplements or safety nets during income shortfalls) rather than engines of development (Godoy *et al.*, 2000). Improving data on the consumption and production of this vast array of forest products, and the degree to which households depend on them relative to other foods or sources of income, is vital to improve policies and guidelines for the ecoregion.

Livelihoods in the Miombo woodlands are strongly based on available biological resources. It has been observed over time that the biological resources are being overused, leading to substantial stress on ecosystems and loss of biodiversity (Ryan *et al.*, 2016). The critical question that re-emerges relates to the extent to which the use of biological resources can contribute to poverty reduction while safeguarding the resource base. From the harvesting of fruits, edible caterpillars and other insects, other NWFPs, woodfuel, etc. the resources of the Miombo offer a broad array of potential strategies that can be used to address livelihood issues, especially through income generation (Abbot and Homewood, 1999). Whatever approach is adopted, that tactic must not only enhance the ways in which households cope with and withstand economic shocks with the available capabilities, assets (including both material and social resources) and activities, i.e. on the household livelihood strategy (Paumgarten and Shackleton, 2011; Ellis, 1998; Dercon and Krishnan, 1996), but must also contribute to building the resilience of households so that they are better equipped (nutritionally and in terms of income) to absorb future shocks. The diversity of aspirations must be recognized, as well as the importance of assets and communities, and the constraints and opportunities provided by institutional structures and processes

considered (Ashley and Carney, 1999). These aspirations provide a way to order information and understand not only the nature of poverty, but also the links between different aspects of people's livelihoods. In addition, this will help broaden the policy dialogue and assist in identifying the relevance of programmes as well as where the key constraints and opportunities lie with respect to adopting SFM (Clark and Carney, 2008).

There is evidence that rural households in Africa use environmental resources more extensively (Sale, 1981; Campbell, 1996; Campbell and Luckert, 2002; Kaimowitz, 2002). As mentioned before, quantitative analysis of household use of Miombo resources is limited, and detailed accounts of a full range of environmental resources are scant. Given that an ecosystem represents a basket of highly differentiated goods and services, more empirical evidence examining household dependence on these resources in a robust analytical framework is necessary (Cavendish, 2000).

The beneficiaries of provisioning services vary widely, depending on the degree of commercialization (Ruiz-Pe´rez *et al.*, 2004). Women are disproportionately involved in the harvesting, processing and sometimes consumption of many of these goods, although this changes in favour of men for labour-intensive commercial products such as charcoal, honey and timber (Fisher *et al.*, 2010; Kalaba *et al.*, 2013). Marginalized groups unable to compete in local labour markets depend heavily on these goods, and wild food nutrition is important for children. Only a few products have international commodity chains (e.g. honey, marula and baobab fruit pulp and seed oil), despite their considerable potential have not been utilized to this effect. Many case studies in the study region attest to the importance of these food sources during droughts or other household income shocks (Kalaba *et al.*, 2013; Paumgarten and Shackleton, 2011; Fisher *et al.*, 2010; Shackleton and Gumbo, 2010; Eriksen *et al.*, 2008; Eriksen *et al.*, 2005). For instance, during a year characterized by poor harvests, wild foods can account for 30 percent of calorie intake (Woittiez *et al.*, 2013). However, a recent global analysis has questioned the prevalence of this coping strategy, indicating that households prioritize reducing consumption and selling assets in times of crisis and that wildland products play a minor complementary role in the coping strategy portfolio (Wunder *et al.*, 2014). It is important to note the value of these products beyond just lifelines (Shanley *et al.*, 2016) – particularly their nutritional and socio-cultural values, for example – that may not be accounted for in this type of study, particularly with regards to how these resources may contribute to building resilience.

©FAO/A. Conti

©FAO/A. Conti

©FAO/P.N. Chitembwe

2.3 Sustainable forest management and Miombo woodlands

Sustainable forest management (SFM) is defined by the UN General Assembly as "a dynamic and evolving concept, (which) aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations" (UN, 2008). The United Nations Forest Instrument (UNFI) depicts SFM as consisting of seven pillars (FAO, 2013):

1) Extent of forest resources
2) Forest biological diversity
3) Forest health and vitality
4) Productive functions of forests
5) Protective functions of forests
6) Socio-economic functions of forests
7) Legal, policy and institutional framework

The concept of SFM is well-embedded in the various statutes governing the forest sector across the Miombo ecoregion. It is perhaps best observed at the community level, where numerous approaches and studies have documented the success of integrating communities into the improved management of natural resources such as the Campfire movement in Zimbabwe (Communal Areas Management Programme for Indigenous Resources) (e.g. Balint and Mashinya, 2009) and community-based natural resource management (CBNRM)[1]. The extent to which these have been used exclusively for forests is unclear, however.

[1] Pailler, S., Naidoo, R., Burgess, N. D., Freeman, O. E., Fisher, B. 2015. Impacts of Community-Based Natural Resource Management on Wealth, Food Security and Child Health in Tanzania. *PLoS ONE* 10(7): e0133252. https://doi.org/10.1371/journal.pone.0133252

Miombo woodlands have many different uses. Each of these has varying impacts on the woodlands and influences the forest management schemes applied (e.g. charcoal, timber, fruits, medicines and mushrooms) (Malambo and Syampungani, 2008). One of the key questions is: What is the best approach within SFM to properly manage the woodlands and simultaneously ensure that the various uses do not have a negative impact on the preservation and regeneration of the Miombo?

A key pillar of SFM is natural regeneration. One of the many important traits found in Miombo woodlands is their regenerative capacity, despite the general perception that charcoal production and slash-and-burn agriculture lead to their loss (Syampungani *et al.*, 2016). The regeneration is fast (Dewees *et al.*, 2011) provided that the area is left relatively undisturbed for a number of years. If properly managed following SFM principles, Miombo woodlands are able restore themselves at very low costs over a limited period. These woodlands can show an almost full (100 percent) recovery after having been cleared for agriculture or charcoal production (Vinya *et al.*, 2011). According to Kalaba *et al.* (2013), woodlands harvested for charcoal production can regain their full capacity after 20 years.

Chirwa *et al.* (2009) summarize three main silvicultural practices in the harvesting of Miombo products: coppice-with-standards systems (leaving a few valuable tree species behind on a cleared area); selection system (cutting of selected species according to set criteria such as minimum size) and clear felling. Missanjo *et al.* (2014) found from regeneration studies of Miombo in Malawi, that coppice-with-standards systems (removal of 70 to 80 percent of the basal area or canopy) was the most effective silvicultural practice for natural regeneration of Miombo after a timeframe of 20 years. Syampungani *et al.* (2017) found that proper coppice management in Zambia contributes to livelihood strategies through its contribution to charcoal production and simultaneously facilitates natural recovery of the Miombo woodlands.

Despite numerous well-documented examples of SFM in Miombo woodlands, many unanswered questions remain. Chirwa *et al.* (2009) refer to the lack of research into the identification of proper harvest rates and sustainable harvesting rates for NTFPs as an impediment to the adoption of SFM in the Miombo countries.

A study on SFM and Nationally Determined Contributions (NDCs) conducted for this publication, revealed that only Malawi and Zambia highlight SFM in their NDCs, referring to more investments in SFM and a standalone programme under the mitigation component respectively.

Key challenges to implementation summarized by Campbell *et al.* (2007) comprise the following:

- Low inherent productivity
- Elite and external role-players capture values
- Restrictive regulations reduce access and increase transaction costs of producers and traders
- Limited support for local forest enterprise development
- The lack of strong local organization
- A legacy of armed conflict
- Low resource rents – high management transaction costs
- Weak local institutions
- "Forestry" is marginalized
- Domestication of high-value species reduces importance of natural forests
- Cash constraints

©FAO

©FAO/L. Makombe

2.4 Farming systems in Miombo woodlands

The main farming systems found across the Miombo ecoregion are mixed maize and agropastoral. The main components in the mixed maize system are maize, tobacco, cotton, legumes, cassava and livestock. For the agropastoral farming system, the main components are sorghum, maize, millet and livestock (Garrity *et al.*, 2012).

The mixed maize farming system is the most widespread in the Miombo ecoregion, with approximately 91 million hectares under cultivation (Garrity *et al.*, 2012) and accounting for the most important food production in southern Africa (FAO, 2001). The Miombo region is mainly characterized by smallholders with high population rates and increasing land change pressures (Mayes *et al.*, 2015). Not surprisingly, agricultural expansion is one of the main drivers of deforestation (Campbell *et al.*, 2007). Practiced on inherently infertile soils, productivity is generally low, which in some cases has been responsible for the widespread opening-up of forests for agriculture akin to slash-and-burn practices as farmers seek more virgin land. Low productivity, coupled with poor crop yields often linked to mid-season and at times outright droughts, have left households with no food. In situations like these the forests often become an important source of food.

The current business-as-usual scenario cannot continue indefinitely without leading to further degradation and, ultimately, the disappearance of the Miombo ecosystem. Alternative land-use approaches are required to maintain agricultural production and conserve the woodlands at the same time (Sileshi *et al.*, 2007). Experiences from FAO's Save and Grow, for example, underline how an ecosystem approach must underpin agricultural production (FAO, 2011).

There are numerous strong linkages between the Miombo woodlands and the farming communities surrounding them. Lowore (2006) highlights four main dimensions for these linkages from a case study conducted in Malawi: 1) domestic material goods and energy; 2) food, nutrition and health; 3) trade and economic activity (selling of products); and 4) environmental services. Lowore further points to the fact that while the use of the Miombo woodlands has not changed over time, the size of the woodlands has diminished, thereby complicating the normally strong and healthy relationship between the communities and the woodlands.

2.5 Forest and tree-based food systems

Forest and tree-based food systems have attracted increasing attention in recent years due to the growing number of studies that show a positive correlation between nutritious diets and tree cover, and biodiversity in general (Ickowitz *et al*., 2016; Ickowitz *et al*., 2014; Powell, 2015; Rowland *et al*., 2016 and Termote *et al.,* 2014). Likewise, there has been a growing recognition of the role of diversified diets based on local biodiversity and traditional food such as NWFPs in ensuring food and nutritional security and in health – including the importance of capitalizing on traditional culture and food sources.[2,3] A number of studies provide evidence that large numbers of different species are important food sources. These include plants, animals, insects and fungi (Golden, 2009; Gavin, 2009; Gebauer *et al.*, 2007; Nasi *et al.*, 2011; and Nkem *et al.*, 2013).

The role played by forests and trees is well documented in the Committee on Food Security's High Level Panel of Experts Report on Sustainable Forestry for Food and Nutrition, which presents irrefutable evidence of this important link, highlighting the need to acknowledge how different sectors are involved in the food system and, more broadly, in landscapes.

As the term implies, forest foods are sourced from forests and trees. They are also often referred to as NWFPs or NTFPs (although these latter terms include non-edible products as well). Forests foods complement staple foods throughout the year. It is *well-established* that forest foods like fruits, insects, wild vegetables, honey, roots and tubers can become critical for household coping strategies during times of stress, but can also be important sources of subsistence and cash income. Several studies have recorded nearly 150 food plants in the Miombo woodlands – from wild fruits to medicinal plants to vegetables – bearing testimony to the woodlands' immense value in terms of food and nutrition. There are over 80 known species of edible indigenous fruits in Miombo woodlands (Chirwa *et al.*, 2008; Kadzere *et al.*, 1998), contributing not only important vitamins and minerals but also being sold for cash, or consumed at home during periods of stress (Akinnifesi *et al.*, 2004; Akinnifesi *et al.*, 2006). Fruits and products derived from forests and trees moreover constitute an affordable and abundant source of food, particularly for women and children in the Miombo woodlands area.

©FAO/S. Maina

[2] FAO. Biodiversity and nutrition: A common path

[3] FAO (2013). Indigenous peoples' food systems & well-being – Interventions & policies for healthy communities

Where the main livelihood is agriculture, forest food products may provide income, food and nutrients, especially during lean months of the year (Misra and Dash, 2000; Nguyen, 1994), or for coping with drought and other calamities (Gebauer *et al.*, 2007). In an FAO study in Mtara district, Tanzania, one particular forest species (*ming'oko* – a forest vine) was noted as playing a crucial role in food security in lean months (Nguyen, 1994). Forest foods often complement staple foods by adding vitamins and minerals to diets that are important for nutrition (McGregor, 1995), particularly in impoverished communities and households.

Packham (1993) underlines the fact that wild fruits generally contribute to diet quality rather than quantity, noting many cases of wild fruits that contain higher concentrations of vitamin C than exotic fruits, for instance. Vitamin C levels in *Adansonia digitata* fruits, for example, are much higher than in fresh oranges (179 mg/100g versus 50-70 mg) (Saka *et al.*, 2008). The seed kernel of *Adansonia digitata* is particularly rich in protein (28.7%) and fat (29.5%), values similar to leguminous seeds. The same is true for *Sclerocarya birrea* (28% protein and 57% oil) (Saka *et al.*, 2008). Various seed kernels and nuts (e.g. *Telfaria pedata, Terminalia catappa, Trculia africana, Larkia filicoidea* and *Parinari curatellifolia*) are important sources of vegetable oil and are rich in protein. *Ricinodendron rautanenii* contains 60% protein compared with 48-56% for groundnut (Zabregas, 1957). The nutritional values of a range of products are well documented in Saka & Msonthi (1994).

Edible insects are another major source of protein and micronutrients (e.g. *Gynanisa maya* and *Gonimbrasia zambesina*). Over 20 Miombo tree species have been found to host these two species (Chidumayo and Mbata, 2002; Holden, 1991). In Malawi, fourteen species of edible caterpillars were recorded in one district alone (CIFOR, 1996). In some rural communities, other types of "wild meat", also called bushmeat, have been found to provide as much as 80 percent of protein intake for some households. Another component of the local food system is forage, an often forgotten "NWFP", which is indispensable for *feed* security. At least 15 tree species have been identified as important sources of fodder in Miombo woodlands (CIFOR, 1996). The sustainable management of (host) tree species is thus vital to maintain these important sources of macro- and micronutrients.

©FAO/G. Napolitano

©FAO/S. Maina

Wild foods gathered from the Miombo woodlands are an important supplementary source of income as well, which is vital for the diversification of people's livelihoods, helping to reduce risk and food insecurity (Ibnouf, 2009). Results of a study in Tanzania, for instance, show that the Miombo woodlands contributed to 42 percent of household income in some areas (Njana *et al.*, 2013).

A CIFOR study (1999) suggests that 58 percent of the cash income is derived directly from the sale of honey, charcoal, fuelwood, wild fruits and vegetables. Tibuhwa (2013) found that mushroom collectors can earn $400-900 per year from harvesting in the Miombo woodlands (which is more than the gross national income of $340/year). A 2008 World Bank study moreover estimated that a quarter of a million honey producers were deriving an income from forests. Howell *et al.* (2008) has shown that the poorest households are the most dependent on collecting foods and other natural resources, arguing however that the absolute financial returns were small. Although income can vary considerably according to product and species, some products have been commercialized quite successfully – *Sclerocarya birrea* trees for the production of Amarula liqueur is just one example.

It is important to note that while there is a tendency to label the harvest of forest foods as unsustainable, this is very much species specific. Miombo, for instance, is characterized by the predominance of ectomycorrhizal mushrooms; several studies suggest that picking does not compromise future harvests (Egli, 2006; Norvell, 1995; Pilz *et al.*, 2003). It has been suggested that Miombo is the "mushroom kingdom of the world" (Campbell, 1996; Cunningham, 1996; Morris, 1987; Piearce, 1981; Harkonen *et al.*, 2003). Mushrooms are an important source of micronutrients and protein for rural people in the Miombo woodlands. Multiple studies show that the resource availability of these mushrooms is not affected by harvesting *per se*; they are instead compromised by intensive forest management and agriculture, which is expanding rapidly in the Miombo woodlands (Jew *et al.*, 2016). For those species that are vulnerable to overharvesting, measures such as appropriate and product-specific legislation (e.g. sustainable harvesting quotas) and the participatory domestication of certain tree species, for instance, can be considered.

Some researchers have concluded that biodiversity contributes to sustained ecosystem functioning in forests, which in turn generates the more direct ecosystem services of food (and other NWFPs) (Sircely and Naeem, 2012). Despite the range of species utilized, other studies contend that the principal component of biodiversity *directly* important for supporting household food security is the availability of particular species, rather than species richness *per se*, because of the specificity in regard to which species are used and which are not (Dembner, 1995; Gyan and Shackleton, 2005; Hanazaki *et al.*, 2009; Ingram *et al.*, 2012). The nutritive value of the species was

likely not taken into consideration in these studies, however (e.g. nutritional composition/properties relative to other foods).

Kimaro and Lulandala (2013) found that the Ngumburuni forest reserve in Tanzania was a more important source of NWFPs than the land area outside the reserve, as supplies of NWFPs in the forest reserve were higher. Ndangalasi *et al.* (2007) found that the extraction of NWFPs from two forest reserves in Tanzania and Uganda was important for livelihoods even when their exploitation was restricted by law. In addition, the use of NWFPs, especially close to village borders, was found to have negative impacts on forest structure and diversity, and the provisioning of ecosystem services (Ndangalasi *et al.*, 2007; Thapa and Chapman, 2010). This is likely to be the case across the Miombo ecoregion, but data on the exact contribution to national economies, for example, are not well documented. Indeed, data on consumption, production, resource availability, nutritional composition and market structure need to be improved for NWFPs to enable more tailored and appropriate policies, and to better inform private sector stakeholders who must also have a seat at the table in discussions on the sustainable management of the woodlands.

©FAO/S. Maina

2.6 Wood energy in Miombo woodlands

There is global recognition of the important role played by bioenergy in rural and urban livelihoods. In 2015, charcoal production in Africa was **31.7 million tonnes**, of which these **seven miombo countries produced about 6.5 million tonnes, (or 20%)**, according to FAOSTAT (2015). The figure is considerably higher when charcoal production figures from Tanzania and the DRC are added. The collection, distribution and trade of these fuels provide income and employment to millions of people, largely in informal settings. The Miombo woodlands of southern and eastern Africa, as in the rest of sub-Saharan Africa, form part of the epicenter of the global challenge of energy poverty, with the absolute numbers of the energy poor projected to increase through 2030.

Energy poverty is variously defined, but in this context it is regarded as the lack of access to electricity and an overreliance on traditional biomass fuels, but taking into account that there will be instances where these energy sources will be scarce and their supply intermittent (e.g. fuelwood, charcoal, dung, crop residues) for cooking, space heating, lighting, small-scale business and industry (IEA, 2014; GACC, 2014: IEA, 2010; Sovacool, 2012). In instances like these, the search for solutions like electricity supply requires urgent attention. This is in line with Sustainable Development Goal #7 whose objective is to ensure that by 2030, universal access to affordable, reliable and modern energy services will have been attained. Nowhere is this goal more elusive than in sub-Saharan Africa (SSA), where the absolute number of people reliant on biomass energy is projected to increase through 2030 (GEA, 2012; UN DESA, 2015). This demand cannot typically be met from alternative energy sources, at least in the short to medium term, but from the more pragmatic management of the production of and demand for wood biomass.

Feasible solutions for mitigating energy poverty are urgently needed. Energy poverty presents a complex socio-environmental challenge – it has enormous implications for climate (Ramanathan and Carmichael, 2008), environmental sustainability (Bailis *et al.*, 2015), and human health and well-being (Sovacool, 2012; Martin *et al.*, 2014) and is closely linked to food security. The negative impacts of energy shortages are often felt at household, village and collective scales, and in local, regional and global contexts. Despite this array of challenges, national policies in SSA have tended to ignore or downplay the contribution of woodfuel to woodland loss. Monitoring of charcoal movements remains underdefined and sporadic as the relevant national forestry institutions have not put the required emphasis on this aspect.

©FAO/T. Ranaivosoa

Wood is the major source of energy for close to 70 percent of rural communities in Sub-Saharan Africa including the Miombo countries (Matsika *et al.*, 2013). Studies conducted in Tanzania and Uganda showed that over 95 percent of rural households used fuelwood as their main source of energy (Njana *et al.*, 2013; Tabuti *et al.*, 2003). Kimaro and Lulandala (2013) and Brouwer and Falcão (2004) showed that in addition to the rural population, the urban households of Maputo in Mozambique are reliant on charcoal. Households are typically more dependent on fuelwood, whereas urban populations consume proportionally more charcoal (Kituyi *et al.*, 2001). Nkambwe and Sekhwela (2006) noted that the rural-urban transitional zone is often neglected in assessments of woody biomass use, as many inhabitants of these zones may depend directly on natural resources rather than employment from urban centres. Fuelwood is typically collected for subsistence purposes, and through fuelwood, energy security and associated nutritional security are linked to the availability of forest biomass in the developing countries (Kijazi and Kant, 2011). In addition to subsistence use, the fuelwood trade is an important source of income to rural communities in many areas (Openshaw, 2010; Aabeyir *et al.*, 2011). Literature shows that pristine forests, degraded forests and areas outside forests are regarded as important sources of fuelwood. In addition, a wide range of trees are used as fuelwood. In most communities, fuelwood from native tree species is regarded as more important than exotic species. The wide range of fuelwood species means that a forest with high species richness can provide valuable livelihood benefits for communities, even if the most valuable timber species have been exhausted.

Despite the importance of biomass energy resources from the Miombo woodlands, relatively little is known about how woodfuel and other forms of biomass are produced, managed, traded and consumed in the selected countries across the Miombo ecosystem (Angola, Democratic Republic of the Congo, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe). In addition, the extent to which these forms of energy contribute to the improvement of livelihoods at community level is unknown. But what is clear, is that the unsustainable harvesting of fuelwood from a given woodland or forest type, through selective harvesting, may lead to the loss of key species (Shackleton, 2015, Shackleton and Gumbo, 2010), and such species may be highly desired (for various purposes such as medicinal, construction, ecosystem balance), thereby changing the value of that forest type and reducing its capacity to contribute to local livelihoods as well as global goods and services (e.g. capacity to sequester carbon). Often mentioned but not fully accounted for in national energy budgets in SSA, is the link between biomass harvesting, production, incomes, food processing, cooking and warming, and climate change, which has of late been raising the spectre of a negative impact on the forests and livelihoods.

©FAO/S. Gallagher

©FAO/T. Babayev

Wood biomass is also harvested for use in rural industries (including food processing) such as pottery, edible oil production, beer brewing (McCall, 2001), fish smoking, and baking (ZERO, 1991; Sachetto, 2012). It is not easy to account for how much of this forest resource loss can be attributed to wood energy used in these rural industries, but data and information generated from tobacco production provide some insights. Tobacco production in Zimbabwe and Zambia has been noted as a major cause of deforestation and up to 10 times more aggressive than other causes of deforestation (Manyanhaire and Kurangwa, 2014; Sacchetto, 2012). Tobacco curing requires large quantities of fuelwood and estimates indicate that close to 43 m^3 of fuelwood (15 000 kg per year) are used to produce an average of 1 400 kg of cured tobacco (Scott, 2006). This translates to 300 000 hectares of indigenous forests cleared every year in Zimbabwe by new small-scale tobacco farmers (FAO, 2010; Musoni *et al.* 2013). Musoni and others (2013) indicate that 98.5 percent of energy is lost as a result of inefficient traditional barns and similar observations have been made in Malawi (Geist, 1999, Fraser and Bowles, 1986) and Tanzania (Siddiqui and Rajabu, 1996). This has prompted the industry to opt for massive tree planting instead, as well as the adoption of efficient barns such as the rocket barn.

As with tobacco curing, attempts have been made to provide energy-saving devices as well, but progress has been slow. Lately, concerted efforts have been made to adopt and use more efficient cook stoves in households (see Malawi Cookstove Market Assessment Report, 2013), with closer policy alignment as noted in Zambia's Ministry of Mines, Energy and Water Development (2014).

The fuelwood species harvested, and the severity of the impacts of fuelwood collection on biodiversity and the provision of other ecosystem services are unclear, except where there is clear felling followed by agricultural activities as can happen in charcoal production areas. It should be noted that fuelwood can be collected from secondary forests and fallow, and additionally as waste from timber sourced from native, primary forests. Grundy *et al.* (1993) found that in Zimbabwe, local people mainly used riverside areas and Miombo woodlands as sources of construction wood, whereas newly cleared land with remnant trees was seen to have very little relevance for construction purposes. Some notable aspects include:

- FAO (2017) reported that the importance of natural forests as sources of fuelwood was greatest in Africa.
- Some fuelwood trees are also used for other purposes (Hicks *et al.*, 2014). As such, the impact of fuelwood harvesting is often less severe than assumed, as fuelwood is typically collected as dead wood material or as fallen branches (Ektvedt, 2011; Nagothu, 2001; Matsika *et al.*, 2013; Tabuti *et al.*, 2003b). Dovie *et al.* (2004) noted that the decreased availability of dead wood may lead to increased tree felling.
- In Malawi in 1996, less than 50 percent of fuelwood and charcoal was sourced from natural woodlands, with nearly 40 percent originating from open areas, including farmlands, the roadside, grassland and urban areas (Openshaw, 2010), while in Zimbabwe, Grundy *et al.* (1993) reported that 55 percent of respondents collected their fuelwood mainly from Miombo woodland or riverine areas.
- Commercial woodfuel collection has led to the depletion of preferred woodfuel species in many areas in the Miombo woodlands, especially when linked to urban markets where "wet' wood may be in demand.
- Felling trees for charcoal production is regarded as a major threat (comparable with the extraction of firewood) to natural woodlands outside parks and reserves (Naughton-Treves *et al.*, 2007).
- Woodlands are a potentially important source of income for the rural poor (Vedeld *et al.*, 2007). As noted in Tesfaye *et al.* (2011), although the generally low market value of NWFPs often limits the income derived from these products, the resource will have been harvested anyway.
- When compared with other forest products, it is more difficult to estimate the role of protected forests as sources of fuelwood, because extraction in these forests is often regulated or restricted. Illegal collection of fuelwood from protected forests may take place, particularly when alternative sources of fuelwood have been depleted (Matsika *et al.*, 2013; Nagothu, 2001; Fousseni *et al.*, 2012).

Specific tree species are usually preferred as fuelwood, while species of inferior quality may be used when the preferred species are not available (Natuhara *et al.*, 2012; Kituyi *et al.*, 2001). More research is required on the correlation between access to energy and changes in cooking practices and dietary choices (e.g. skipping meals, avoiding "fuel-demanding" foods [Want *et al.*, 2011; Sunderland *et al.*, 2013]).

2.7 Forest biodiversity and environmental values of the Miombo woodlands

The rich biodiversity of the Miombo woodlands requires proper management. In terms of plant diversity alone, they are home to 8 500 higher plants (Frost, 1996). Close to 54 percent of these are endemic to the woodlands alone (Rodgers *et al.*, 1996). Mittermeier *et al.* (2003) classify Miombo woodlands as one of five global biodiversity hotpots due to their irreplaceable endemism. Consequently, a range of protected areas including national parks, game controlled areas and forest reserves have been established across the Miombo countries.

At a continental level the Miombo acts as a buffer zone (Tanzania, DRC, Zambia), protecting the biodiversity values of the ecologically important adjacent rain forests. For example, by absorbing population pressure, the Miombo woodlands buffer the remaining areas of the Guinea-Congolian forest (Gombe and Mahale Mountain national parks in western Tanzania).

A wealth of literature attests to the importance of ecosystem services (ES) from the Miombo woodlands to the livelihoods of the poor (Ryan *et al.*, 2016; Dewees *et al.*, 2010; Cavendish, 2000; Chidumayo and Gumbo, 2010), but questions remain about how this relationship is being altered by environmental and social changes (Eriksen and Watson, 2009). As the woodlands are now being integrated into global markets, capital and global land-use systems, the demand for their biological resources is going to increase accordingly, e.g. commercial timber (Lambin *et al.*, 2011). Jew *et al.* (2016) and Syampungani *et al.* (2009) estimate that nearly 100 million people are dependent on the Miombo woodlands for their goods and services.

Biodiversity in Miombo woodlands is being lost as the woodlands are converted to species-poor farmlands and plantations (Sileshi *et al.*, 2007). Currently, the Miombo woodlands are regarded as the last agricultural frontier in an era of land scarcity (Deakin *et al.*, 2016; Searchinger *et al.*, 2015). Meanwhile, climatic, atmospheric and other environmental changes may alter the growth rates of woodland flora, impacting species composition and productivity. These changes will result in trade-offs and conflicts between the beneficiaries of different ES, some of which may impact on the drivers of change.

©FAO/Z. Auntony

3 ENVIRONMENTAL DEGRADATION IN MIOMBO WOODLANDS

©FAO/S. Maina

3.1 Environmental degradation and its causes

Continuous deforestation and forest degradation in Miombo woodland areas are leading to a decline in the provisioning of forest resources such as fruits and medicinal plants, with severe consequences for those communities most dependent on forest resources (the aged, poor, women and children in particular) (Akinnifesi *et al.*, 2006). Millions of hectares were lost between 1990 and 2015, the majority of which were Miombo woodlands (Chirwa *et al.*, 2008), with a loss of 9 and 8 million hectares in Tanzania and Zimbabwe respectively (Table 2).

Although there is no concrete evidence or detailed data available on the deforestation rate and total area lost for Miombo woodlands alone, the authors of this paper identified threats to Miombo woodlands on a national level through a screening of the national reports to the three Rio conventions (UNFCCC, UNCCD and CBD) (Table 3). Identified threats include i) collection of firewood and charcoal production; ii) poor farming practices and overgrazing; and iii) fire – all resulting in the decline of the regenerative capacity of the woodlands.

Table 2. Total land area, forest area and forest loss between 1990 and 2015

	Total land area (1 000 ha)	% forest land (2015)	Forest loss in ha (1990-2015)
Angola	124 670	46.4 (57 856 000 ha)	3 120 000
DRC	234 486	65 (152 578 000 ha)	7 785 000
Malawi	9 428	33.4 (3 147 000 ha)	749
Mozambique	78 638	59.1 (37 940 000 ha)	5 438 000
Tanzania	88 580	57.1 (46 060 000 ha)	9 860 000
Zambia	74 339	71.3 (48 635 000 ha)	4 165 000
Zimbabwe	38 685	36.4 (14 062 000 ha)	8 102 000

Source: FAO Global Forest Resources Assessment (2015) and World Bank (2014)

Table 3. Nationally determined threats to Miombo woodlands

Convention	Angola	DRC	Malawi	Mozambique	Tanzania	Zambia	Zimbabwe
UNFCCC	Long-term use of Miombo for charcoal production has had negative consequences for the ecosystem	Charcoal production has had negative impacts on Miombo	Firewood and charcoal production: with population pressure, demands will increase on Miombo woodlands				
UNCCD						Miombo woodlands experiencing late bush fires	
CBD		Shifting cultivation and fuelwood harvesting are the main threats to Miombo	Charcoal production has cleared forests and left behind low-quality woodlands	Firewood harvesting and charcoal production cause degradation and deforestation in Miombos	Poor farming practices and overgrazing have negatively affected Miombo woodlands. These woodlands are being cleared for biofuel crop farming, e.g. jatropha, sugar cane and palm oil	Regenerative capacity of Miombo under stress and this could lead to negative impacts for dependent communities	Deforestation for tobacco curing and harvesting of other NTFPs

Some studies identified that the main driver of deforestation and degradation in the Miombo woodlands is conversion to agricultural land (Bond *et al.*, 2009; Campbell *et al.*, 2007). This is not surprising, given the steep population growth experienced from 1950 till today (Table 4), with populations having more than tripled.

Projections from the United Nations Population Division estimate that population growth will continue to rise at an alarming rate. The question remains how this population growth will influence the landscapes and the Miombo woodlands in particular. Will the Miombo woodlands still be sufficiently healthy and sustainable in 2030, 2050 and 2100 to continue to provide goods and services?

Table 4. Population growth trends across selected countries in the Miombo ecoregion (thousands)

	1950	2015	2030	2050	2100
Angola	4 355	25 022	39 351	65 473	138 738
DRC	12 184	77 267	120 304	195 277	388 733
Malawi	2 954	17 215	26 584	43 155	87 056
Mozambique	6 313	27 978	41 437	65 544	127 648
Tanzania	7 650	53 470	82 927	137 136	299 133
Zambia	2 317	16 212	25 313	42 975	104 869
Zimbabwe	2 747	15 603	21 353	29 615	40 263

Source : UN DESA, 2015

There has been an increased resolve to address the links between rural poverty and environmental degradation in the developing world. Particular emphasis has been placed on improving the livelihoods of the rural poor (Scoones, 2009), which in turn would help conserve the environment. However, the relationship between rural households and environmental change is not clearly understood. A lack of physical and economic data is one of the main factors limiting an understanding of the relationship between poverty and the environment (Duraiappah, 1998; Cavendish, 2000).

Continuous pressure on land for fast-growing cities is having a major impact on the Miombo woodlands, particularly in terms of increased charcoal production to meet the growing demand in urban and peri-urban areas. Liyama *et al.* (2014) estimated that for SSA, the land needed to meet charcoal production in 2015 was 1.6 million ha of forests per year; and by 2050 the area needed to meet the demand would be 4.4 million ha. These figures are alarming, as the impact on Miombo woodlands and other forests will be devastating, unless sustainability measures are implemented.

Drivers of global environmental change – namely changes in land-use, climate, biogeochemical cycles and biological diversity, including forests – continue to impact negatively on local communities who depend on these resources. Forests act as a source of carbon dioxide through deforestation and degradation, as well as sinks through afforestation or avoided deforestation. With better management and growth, their role in the mitigation of greenhouse gas emissions can be enhanced.

Miombo woodlands are increasingly at risk from human-induced pressures that remove woody species, deplete soil nutrients, promote runoff, decrease biomass, and alter micro-climates (Solbrig and Young, 1992; Meyer and Turner, 1997; Turner, 1997; Ojima *et al.*, 1994). There exist a wide variety of driving factors to the deforestation of Miombo woodlands. These include agricultural expansions, timber and wood extraction, fire, landscape fragmentation, spread of second growth forests, invasion by new species and spread of pathogens, increased CO_2 and climate change. The deforestation may have a severe negative impact on maintaining critical ecological connections. The patterns of change are spatially heterogeneous, often characterized by strong interactions among different drivers, and have both large-scale and remote effects that play out through ecological cascades over long timescales. As a consequence, most Miombo woodlands are on a trajectory to becoming altered ecosystems, with the degree of alteration dependent on the intensity and duration of the current human-induced pressures.

The Miombo woodlands are changing in spatial extent as well as in the quality of their attributes. Widespread change has been driven by shifting and small-scale sedentary cultivation, resulting in huge forest loss (Geist *et al.*, 2009; Luoga *et al.*, 2002), which alters the biodiversity of the woodlands. Driven by selective harvesting of key species, degradation in the Miombo is linked to woodland use. Selective harvesting follows a different approach to the management of woodland use, one that is more closely allied to current practice and requirements of local users. As with most forest systems, harvesting in the Miombo woodlands should be viewed as part of forest management, the impacts of which the system should be able to sustain. Studies have shown that harvesting intensity has a strong impact on the diversity of organisms.

Harvesting is acknowledged as contributing to tree mortality through disturbance, is largely anthropogenic, and when combined with natural processes, can have a profound impact on forest ecosystems, community structure and processes, as well as its species richness (Attiwill, 1994). Harvesting is part of disturbance ecology – it determines the variability in the extent, severity and frequency of disturbances that maintain the structural heterogeneity of forests. This heterogeneity creates habitat variability, which is fundamental for species diversity and ecosystem processes (*ibid*). Most components of biodiversity can be protected, and ecosystem resilience secured, when forest management maintains the key characteristics of natural habitats by imitating the repeatability, severity, and extent of natural disturbance events (Drever *et al.*, 2006).

The lack of infrastructure and prevalence of deadly diseases such as malaria and trypanosiomiasis limit extensive clearance for cultivation, livestock farming and settlements (Scholes *et al.*, 1996) but lately, extensive mining rights have led to new frontiers in the demand for forest products, which are leading to overharvesting. In addition, the types and intensity of land use are changing due to changes in the socio-economic, political and technological development of the region (Nduwamungu, 2001). More specifically, the emergence and growth of urban markets for forest products have led to unprecedented clearing or degradation of woodlands for firewood, charcoal, timber and industrial cultivation of tobacco (World Bank, 1990; Misana *et al.*, 1996). Further, wood is harvested for food-processing activities such as brick beer brewing (millet and sorghum), bakeries, brick making, fish smoking and drying (preservation of fish and meat), roasting and parboiling (e.g. as part of the processing of edible caterpillars).

While the amounts of energy used vary across the Miombo countries where these activities are carried out, certain tree species are used more frequently for their desired characteristics such as colour or taste. This can lead to the depletion of such tree resources as well as the degradation of the forest.

Timber is a source of income for communities living in or near tropical dry forests, although there are *competing explanations* regarding the level of its importance. Apart from direct local uses, such as construction (Grundy *et al.*, 1993; Vermeulen *et al.*, 1996), timber is harvested for domestic and international markets. Godoy (1992) noted that due to the perceived high value of timber trees, tropical dry forests have typically been valued based on standing timber biomass, which overlooks the value of forests in terms of other ecosystem services. Income from timber can be particularly important as a safety net during periods of stress. A study undertaken by Njana *et al.* (2013) in villages adjacent to protected Miombo woodlands in Tanzania, found that a variety of livelihood strategies, including lumbering, were undertaken periodically to cope with food insecurity. The value of traded commercial timber species often forces forest policy and management to avoid forests without commercial timber species, which then leaves such forests open to exploitation for other uncategorized tree species.

One of the many important traits found in Miombo woodlands is their regenerative capacity, despite the general perception that charcoal production and slash and burn lead to their loss (Syampungani *et al.*, 2016). Natural regeneration after cutting typically follows within relatively few years (Dewees, 2013; Dewees *et al.*, 2011), provided that the area is left undisturbed during the recovery period. It is estimated that Miombo woodlands harvested for charcoal production can recover fully within 20 years (Kalaba *et al.*, 2013). The problem is that the recovery period is often interrupted, leading to continuing degradation and, ultimately, the disappearance of the Miombo woodlands. While the amounts of energy used vary across the Miombo countries where these activities are carried out, certain tree species are used more frequently for their desired characteristics such as colour or taste. This can lead to the depletion of such tree resources as well as the degradation of the forest.

3.2 Climate change impacts and variability

The IPCC forecasts an increase in average temperatures for most parts of sub-Saharan Africa (IPCC, 2007 and IPCC, 2013), but warns of a rapid change in the occurrence and predictability of climatic variability. According to these reports, many parts of the region have experienced an increase in temperature of between 1 and 2 °C from 1974 to 2005, while the rest increased from 0.2 to 1 °C during the same period. The reports project a further increase in temperature of between 3 and 4 °C by 2080 under the "no-action" scenario. Rising temperatures, changing precipitation regimes and changes in the amount of carbon dioxide are expected to affect phonology, composition, structure, distribution, succession processes and community dynamics in the following ways, which will affect the flow of ecosystem goods and services and, in particular, the ability of the ecosystem to support economic development and well-being sustainably.

It is estimated that woodfuels contribute 7 percent of GHG emissions worldwide, and 34 percent in Africa (Whiteman, 2015). The impact may not be easy to attribute given the various pathways that wood is brought into the energy mix and the lack of comprehensive monitoring of the woodfuel value chain by national forestry institutions. For example, firewood is often harvested as dead wood (a product of other forest uses) (May-Tobin, 2011), with the impact felt at point of use, while charcoal production will have different impacts from harvesting and kilning. Other sources of wood energy, such as offcuts from concessions and plantations, are often not factored into the use chain.

However, and as noted by the FAO's 2015 Global Forest Resources Assessment, total forest area in the world declined by 3 percent, from 4 128 Mha in 1990 to 3 999 Mha in 2015 (FAO, 2015). Of interest for this study is woodland loss in the Miombo ecosystem, which is nested in tropical forests where the rate of decline was estimated to be 5.5 M ha yr^{-1} between 1990 and 2015 (Keenan *et al.*, 2015; Sloan and Sayer, 2015). Tropical forests (Miombo included) cover about 13 percent of the world's land area – about 2 billion ha (Butler, 2014) – and contain an estimated 25 percent of the carbon in the terrestrial biosphere (Bonan, 2008). Often their loss and degradation are a major driver of CO_2 fluctuation caused by land-use changes, including the harvesting of biomass for use as energy (Bonan, 2008; Pongratz *et al.*, 2014).

©FAO/S. Maina

The overall challenge for the Miombo woodlands is human poverty. Livelihoods in this landscape are dependent on the Miombo and its natural resources. The degradation of the Miombo ecosystem will exacerbate rural poverty and delay its eradication. The main causative factors of degradation of the Miombo ecosystem are the unsustainable use of resources, including forest fires, poaching and deforestation; a lack of community involvement in forest management; inequitable access to forest resources; and inadequate information about resources, their use and management. The key threats to the Miombo ecosystem are the loss of woodland cover and the resulting changes in hydrology. Over 70 percent of the Miombo ecoregion is under small-scale agriculture, and farmers are highly dependent on natural resources. Clearance of woodland for agriculture, timber products and woodfuel interrupts the nutrient cycle, increases the likelihood of soil erosion and interrupts the hydrological and climatic balances of the region. These processes have a negative impact on biodiversity, the high-carbon nature of the ecosystem, and the sustainability of local livelihoods. Some evidence of climate change often mentioned for the Miombo woodlands includes increasing food insecurity in eastern southern Africa and extreme weather events such as flooding, compounded by increasing forest loss and degradation.

Pienaar *et al.* (2015) found from pollen records that one of the main Miombo species, *Brachystegia spiciformis* Benth, underwent a retraction of 450 km in the southern part of the ecoregion (South Africa) over the past 6 000 years, indicating that this could have been triggered by shifts in temperature and precipitation. Pienaar *et al.* (2015) further suggest that Miombo woodlands in Zimbabwe and Mozambique would retract by between 30.6 percent and 47.50 percent respectively by 2050. These predictions are a cause for concern.

3.3 Responses in NDCs and Rio conventions

Forests are important carbon pools which continuously exchange CO_2 with the atmosphere, due to natural processes and anthropogenic activities. Lately, it has been noted that forests can help mitigate climate change and simultaneously assist humanity to adapt and cope with climate change effects. Over the years, under the UNFCCC, countries were required to commit to promote sustainable management of sinks and reservoirs of all GHGs, including biomass, forests and other ecosystems. This would be done through countries promoting SFM, afforestation and reforestation as well as renewable energy. Under this section the study seeks to explore whether Miombo woodlands, which contribute to 75 percent of forest cover in the region, are highlighted in the national reports of the selected Miombo countries (Angola, DRC, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe). These countries have actively engaged, participated in and responded to international initiatives on climate change and related forestry issues. Table 5 shows that these countries have been party to, and provided national reports to the UNFCCC, UNCCD and CBD conventions.

Reports provided to these conventions focus to a great extent on the status of the forests and the actions that member countries will implement or plan to implement to either protect their forests or address forest loss. The nationally determined contributions (NDC), based on a willingness to demonstrate national efforts to address climate change issues, provide strong and transparent domestic foundations upon which to pursue a path to decarbonization (Boyd *et al.*, 2015). Further, the NDCs focus on the likelihood of achieving the goals in the context of current policy and economic trends. The NDCs encompass mitigation measures and unconditional and conditional measures for the reduction of GHGs. All countries are committed to stabilizing their emissions, and contributing to climate change mitigation by 2030. But, as with many developing countries including those with Miombo woodlands, the NDCs submitted reflect national circumstances (see Table 4) and the actioning of these are subject to the availability of finance and other support which these countries do not seem to have. The reports reviewed for the seven countries mention the forestry sector in general, but not necessarily the Miombo woodlands, except in the case of Angola's NDC. This could be due to the classification systems used in these countries as well as the historical dominance of savannahs in vegetation reporting.

Another area in which the study sought to understand whether Miombo woodlands were recognized in national reports, was under National Adaption Programmes of Action (NAPA). Of the seven countries, only six (excluding Zimbabwe) have NAPA plans (see Table 5). As with the NDCs, only the forestry sector in these countries is mentioned as a major part of the proposed action plans. Under national communication reports from the UNFCCC, Miombo woodlands are extensively covered as the dominant woodland, except in the case of Mozambique. Under UNCCD's national action programmes, Miombo is only explicitly mentioned under Zambia and it is assumed that the rest of the countries categorize these woodlands under the forestry sector. Similarly, under the National Biodiversity Strategy and Action Plans (NBSAPs), the Miombo woodlands are explicitly referred to under Malawi, Tanzania and Zambia and it can be assumed that the other countries chose to plan with the sector in mind and not a woodland type. These NBSAPs make strong reference to Miombo woodlands as biodiversity hotspots, with Mozambique, for example, emphasizing Miombo as being part of several of the Aichi Biodiversity Targets.

In Table 6 the NDC reports and their link or reference to food security and nutrition are reviewed. Miombo woodlands provide a myriad of foods ranging from mushrooms and edible caterpillars to fruits, but the NDCs include these under agricultural produce, with fisheries and livestock also mentioned. In addition, countries like Zambia and Zimbabwe refer to climate smart agriculture, which may result in direct benefits for forests. Clearly the contribution of forest foods to food security has not been factored into policy and planning. The enormous potential that Miombo woodlands hold for contributing to food and nutrition security is again not explicitly represented. The question remains why Miombo has not received more attention at the national level across strategies, policies, plans, etc. Data on the Miombo that have been collected have not been systematically analysed.

Table 7 refers to NDCs and resilience, an important aspect for climate change responses. Currently the global focus is on the resilience perspective, as it appeals to the notion of sustainable and dynamic development (Folke, 2006; Kremen and Ostfeld, 2005) and the Miombo woodlands have not been left out of the discussion (Gonçalves *et al.*, 2017; Ribeiro *et al.*, 2016; McNicol *et al.*, 2015; Dewees, 2013, Syampungani, 2009; Chidumayo, 1997). For the Miombo countries, the resilience perspective, the focus on the interplay between periods of change, and the associated dynamics across temporal and spatial scales make this approach appropriate in our understanding of Miombo. All the national reports address this issue and make reference to enhancing resilience in mitigation and adaptation right across all the countries – aspects which are also inherent in management approaches to the Miombo. While forests are not mentioned, let alone Miombo, it is assumed that in view of the key role played by forests in climate change mitigation and adaption and the many initiatives promoting this, the resilience referred to here will address the dominant forest type, i.e Miombo. Resilience read together with Tables 7 and 8 conveys the importance of Miombo woodlands. As already noted, the bulk of the biomass used for energy comes from the Miombo by its sheer coverage in the region. Thus, in Table 8, the reference to enhancing the production of energy correlates well with the Miombo.

Both Malawi and Zambia refer to sustainable forest management (SFM) in their NDCs. Malawi highlights the need to better promote SFM and Zambia intends to develop a programme on SFM as part of its mitigation priorities.

Table 5. References to Miombo woodlands across national reports to the UNFCCC, UNCCD and CBD Conventions

Country	UNFCCC			UNCCD	CBD
	INDC/NDC	NAPA	National Communication	National Action Programmes	National Biodiversity Strategy and Action Plans (NBSABs)
Angola	Miombo covers 45.4% of total land area	Miombo and savannah highlighted as main forest types	Miombo highlighted as open forests with socio-economic importance in terms of woodfuels, construction, medicinal plants and NWFPs	N/A	N/A
DRC	N/A	Miombo not highlighted, but savannahs in the southern part, which indirectly highlights Miombo	Miombo mentioned as one of the major ecological zones in Katanga province. Miombo highlighted as part of the "savane boisee" in the south, covering 19% of the total land area. Other savannah types are highlighted, but elsewhere in the country, so there is a clear distinction	Miombo is highlighted as being part of the vegetation cover	Miombo mentioned as one of 11 forestry habitats, and with a potential for more protected sites. Miombo covers 34% of the country, with only 7% protected
Malawi	Forestry sector mentioned; no clear reference to Miombo	Placed under the blanket of forests	Miombo dominates the natural forests and contributes to firewood and conversion to charcoal. But with population pressure little is available also because of fires, and droughts	No direct mention of Miombo. Woodlands are highlighted, with low recovery capacity due to short rainy seasons, wood extraction for charcoal, etc	No mention of Miombo. Woodlands highlighted as being under pressure from charcoal production

Country	UNFCCC			UNCCD	CBD
	INDC/NDC	NAPA	National Communication	National Action Programmes	National Biodiversity Strategy and Action Plans (NBSABs)
Mozambique	No explicit mention of Miombo or forestry sector	No mention of Miombo, only savannahs are highlighted. Unclear if it covers Miombo	No direct mention of Miombo woodlands, but savannahs are highlighted as main vegetation classification, covering 70% of land area	No reference to Miombo, only savannah with trees highlighted	Miombo woodlands highlighted as a critical ecosystem. Miombo highlighted as part of three targets (5, 11, 12 as part of the justification)
Tanzania	Forestry sector mentioned; no clear reference to Miombo	No direct mention of Miombo. Woodlands and savannahs are highlighted as being under threat from deforestation	A detailed description of the geographical location of Miombo woodlands and climate change impacts on Miombo woodlands: scenarios include Miombo woodlands becoming more closed woodlands and evergreen forests	No direct mention of Miombo, but of woodlands which are under threat owing to increased land degradation and encroachment, mainly due to charcoal production	Miombo mentioned with regard to the importance of the volume of trees they contain and their high biodiversity levels
Zambia	Forestry sector; no specific reference to Miombo	Miombo highlighted as most important vegetation type and source of charcoal. 50% of the Miombo will be affected by climate change. Climate change is jeopardizing the regeneration of Miombo	Miombo described as the most extensive of five woodland types in Zambia	Miombo highlighted as the main land cover, with almost 42% of the country covered by this woodland type	Miombo mentioned as covering almost 40% of Zambia. The regenerative capacity of Miombo is under stress, with a negative impact on communities, biodiversity and the national economy
Zimbabwe	Reference to forestry sector	N/A	Miombo mentioned as the main woodland type, with clear distinctive description, separate from the general woodland or savannah descriptions	No direct mention. Woodlands are highlighted as the main vegetation type and source of fuelwood	Miombo is a globally recognized centre of high plant diversity

Table 6. Key references to food security from the Nationally Determined Contributions (NDCs)

Angola	DRC	Malawi	Mozambique	Zambia	Zimbabwe
Food security highlighted as one of the key sectors affected by climate change	Food insececurity remains a challenge	Improved co-management of capture fisheries also has strong potential to buffer food security and improve the climate resiliency of fishing-dependent communities	Under adaptation. Increase resilience of agriculture, livestock and fisheries to guarantee adequate levels of food security and nutrition	Guaranteed food security through diversification and promotion of Climate Smart Agricultural (CSA) practices for crop, livestock and fisheries production including conservation of germplasm for land races and their wild relatives	Climate change adaptation in agriculture sector a priority. E.g. CSA offers mitigation opportunities and sustainable agro-forestry based adaptation and management practices. The sector thus has multiple benefits, and Zimbabwe foresees Greenhouse Gas (GHG) emission reductions whilst improving agricultural productivity and enhancing national food security

Only countries with references to food security in their NDCs were included in the table.

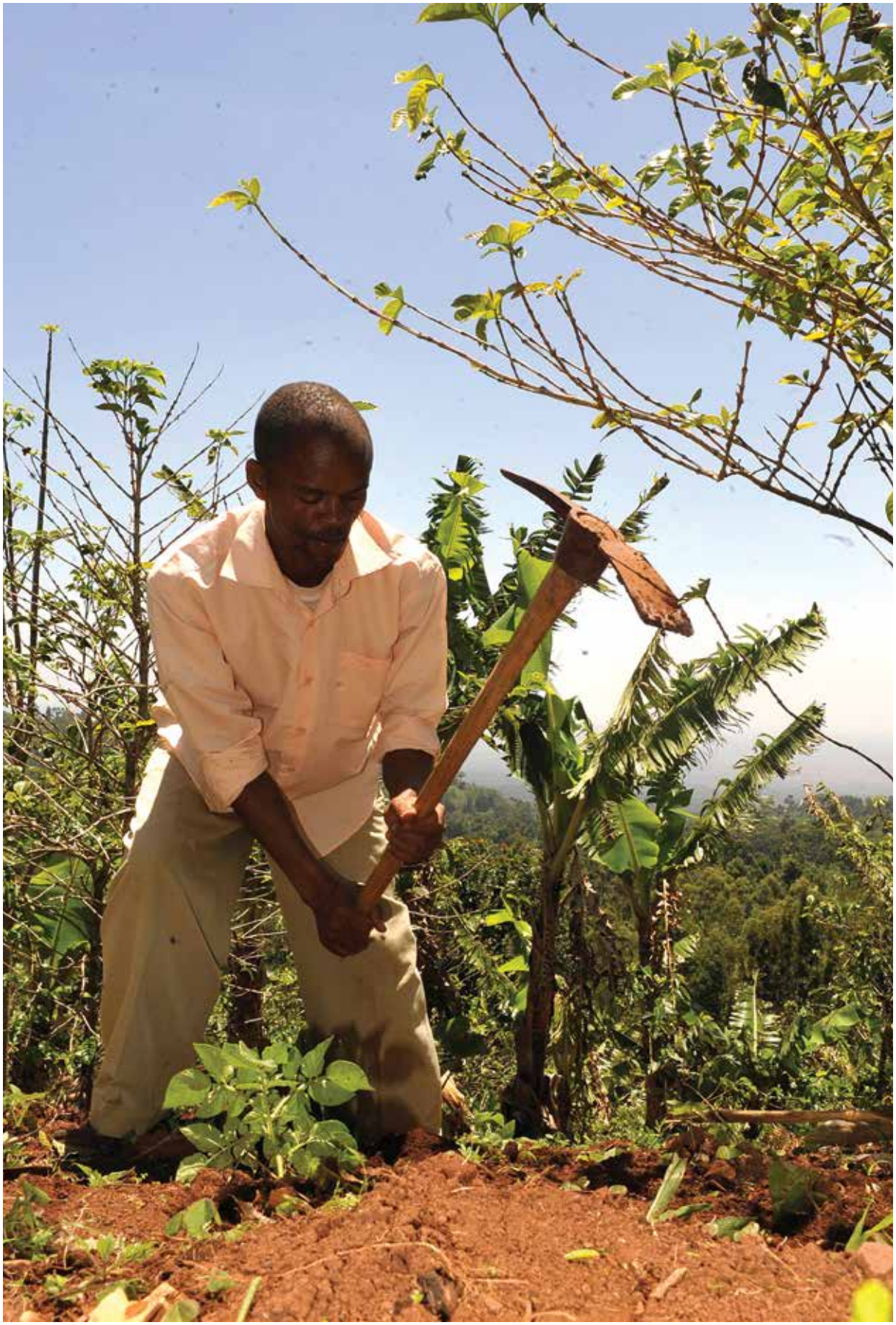
Table 7. Resilience in the NDCs

Malawi	Mozambique	Tanzania	Zambia	Zimbabwe
Enhance resilience of productive sectors, building of resilience, community resilience, enhance people's resilience to the negative impacts of climate change	The National Climate Change Adaptation and Mitigation Strategy identifies adaptation and the reduction of climate risk as a national priority and presents eight strategic actions aimed at creating resilience and reducing climate risk in the communities, ecosystems and national economy	The national climate change strategies aim to, among other things, enhance adaptive capacity to climate change, thereby ensuring long-term resilience; resilience of ecosystems to climate change; and enhanced participation in climate change mitigation activities to contribute to international efforts while ensuring sustainable development	To promote conservation/climate smart agriculture activities leading to adaptation benefits and enhancing climate resilience, especially in rural areas	Enhance resilience of all sensitive socio-economic sectors to improve the national adaptive capacity. Building resilience in managing climate-related disaster risks

Only countries with references to resilience in their NDCs were included in the table.

Table 8. References to wood energy and restoration in the NDCs

Angola	DRC	Malawi	Mozambique	Tanzania	Zambia	Zimbabwe
Wood energy						
Reducing demand for firewood to reduce deforestation Power generation from renewable sources; and reforestation	Harvesting of firewood highlighted as driver of deforestation	Promote sustainable production of fuelwood by establishing woodlots, plantations and forest management Promote use of biomass briquettes as a substitute for firewood and charcoal	Conservation and Sustainable Use of the Energy from Biomass Energy Strategy (2014 to 2025)	Enhancing efficiency in woodfuel utilization	Sustainable charcoal production to include improved kilns	Majority of rural energy demand met from firewood, candles and paraffin. Potential to focus on implementation of cleaner initiatives
Restoration						
Commitments to reforestation. Several large-scale afforestation projects planned, including 50 000 ha to be planted in the next 10 years	No references	Upscale afforestation, reforestation and forest conservation and protection of catchments Promote sustainable production of fuelwood by establishing woodlots, plantations and forest management Implement conservation agriculture and agroforestry practices	Reduce soil degradation and promote mechanisms for the planting of trees for local use	Enhancing carbon sinks through forest conservation, afforestation and reforestation Mangrove and shoreline restoration programme	Forest enhancement, including natural regeneration and afforestation. Restoration of natural habitats. Regeneration of abandoned land from disturbed forests (firewood collection, charcoal production and timber harvesting), afforestation and reforestation Promote CSA practices through conservation agriculture, agroforestry	Climate Smart Agriculture (CSA) and sustainable agroforestry-based adaptation and management practices



©FAO/S. Maina

4 INTERVENTIONS TO REDUCE ENVIRONMENTAL DEGRADATION IN MIOMBO WOODLANDS

©D. Gumbo

Due to their biodiversity, contribution of valuable resources to sustainable livelihoods and resilience to climate change, Miombo woodlands need to be managed. Although the Miombo countries are committed to the pragmatic adoption and implementation of sustainable forest management, this is subject to some barriers, which are addressed across the Miombo countries.

4.1 Key considerations

Change in the Miombo is inevitable. Such change is expected to affect the supply of energy and biodiversity resources, and thereby the ability of the Miombo to meet future livelihood demands. The key aspects are briefly described below.

Tree species composition and forest productivity are central to the productivity of woodlands. Community- and ecosystem-level processes will influence specific tree demographic processes that will enable the woodland to meet livelihood needs (Kobe, 1996). This will ensure, among other things, that biodiversity values of the woodland are safeguarded, while offtakes for energy are met and forests and carbon stocks are maintained. It is important, for several reasons, to understand how future interventions can facilitate and ensure better woodland condition, and hence tree performance, with direct impacts on improving livelihoods.

Critical aspects:

1) Biodiversity is important in delivering a range of ecosystem services and in maximizing the achievement of the primary objectives of a wood energy supply programme (McMullin *et al.*, 2012). Biodiversity and its conservation in general have values beyond the side benefits of forestry interventions. Woodland fragmentation, which is noted all over the Miombo, can have additional impacts on the provision of ecosystem services – as fragmentation increases, the capacity of the woodland to supply energy-based tree species will decline. Miombo woodlands are home to around 8 500 recorded plant species (Dewees *et al.*, 2011; Frost, 1996). Together with Mopane, Miombo is one of five ecosystems noted as being global biodiversity hotspots requiring conservation or restoration due to their irreplaceable endemism (Mittermeier *et al.*, 2003).

2) Woodlands such as the Miombo that have a relatively high species richness provide a wider range of tree species and NWFPs. As noted by Njana *et al.* (2013), the well-being of local communities can depend on the diversity of tree and shrub species with different functions, such as fuelwood, construction materials, wild food, medicinal plants and other important products. In addition, there may be several species that are used for the same purpose, as in the case of energy, that may increase the value of the forest as a source of materials for use in meeting livelihood demands. Thus, loss of species richness may not denote actual loss of utilization value (Brown *et al.*, 2011).

3) Wild foods, fuel, fodder and thatch grass were found to be the most important NTFPs, with wild foods and fuelwood comprising 70 percent of forest income on average (Vedeld *et al.*, 2007).

4) Different forest tree species are used as timber. Forests with high species diversity often host numerous timber tree species which are used as firewood. Timber from areas with high numbers of species with timber utility is used for a greater variety of purposes (Njana *et al.*, 2013; Vermeulen *et al.*, 1996). Miombo woodlands in Tanzania provided a total of 42 timber tree species, of which 18 were used for construction poles, and 18 were used for timber (Njana *et al.*, 2013). Working in the dry Miombo woodlands of Zimbabwe, Vermeulen *et al.* (1996) found that of 81 species occurring in the study area, the local people use 44 species for construction, of which 14 species were particularly favoured.

5) The overharvesting of targeted and often favoured tree species may degrade habitats, triggering a decline in abundance that may potentially impact the long-term provision of food products. Harvesting is likely to cause changes to the structure, function and composition of ecosystems, which may in turn affect other ecosystem services, such as regulating services (Nasi *et al.*, 2011). In terms of wood energy, the overharvesting of those species favoured for charcoal-making may also affect the woodlands, thereby affecting sustainability.

6) McGregor (1995) found that abundance of species varied with forest degradation: some species decreased while others favouring disturbed habitat increased. In addition, the vulnerability of particular species to harvesting varies, with some species remaining abundant or even prospering in heavily exploited secondary forests, while others need intact forests to remain viable (Nasi *et al.*, 2011).

7) Several studies show that protected forests are important sources of forest materials for local communities across the Miombo, but management rules of access limit the use (Thapa and Chapman, 2010; Kimaro and Lulandala, 2013; Fousseni *et al.*, 2012; Ndangalasi *et al.*, 2007).

8) Timber processing also generates fuelwood in the form of offcuts and waste. The importance of farmland trees as sources of fuelwood typically increases with distance to natural forests (Kituyi *et al.*, 2001; Ndayambaje *et al.*, 2013).

4.2 An example of a value chain analysis of woodfuels from Miombo woodlands

Given the vast amounts of woodfuels produced and transported daily across the Miombo ecosystem, this section presents an example of a value chain analysis for the woodfuels derived from the woodlands. 'Value chain' refers to the full range of activities required to bring a product (or service) from conception through the different phases of production to delivery to the final consumers. So, producers, processors and traders are an important part of the value chain. In terms of wood energy, it is a known fact that rural producers are the initiators of such a value chain. Studies on woodfuel have started to integrate value chain analysis over the past years, while recognizing the related social and environmental issues that often go beyond those of rural production and subsistence use, involving commercial supply, urban role-players and wider ecosystems (Bailis, 2009; Kambewa *et al.*, 2007; Ribot, 1998). For fuelwood, the value chain starts where the tree grows. It then goes through a process of cutting, drying and possible carbonization. From there it is packaged and transported to local and regional markets, where it is purchased and consumed by households and businesses. Poor households may not be able to participate in or benefit from participation in value chains unless they have access to and the ability to use (and accumulate) certain assets effectively (McKay, 2009). Market linkage projects often seek to build or strengthen weak assets. Assets may be substitutable and it may be possible to design interventions to compensate for weak or non-existent assets. Market channels for urban supply vary from direct sales by producers to consumers, to indirect chains that involve intermediaries and/or wholesalers and retailers who organize the sales to consumers.

Value chain interventions offer a range of ancillary benefits and services that build human and natural capital. Beneficial value chain participation tends to be linked to strong levels of natural capital where natural capital includes size of landholding, access to water, type of tree, and level of productivity. Low natural capital may lead poor producers to participate as wage labourers in value chain activities. A lack of access to land often means that poor people participate as workers, leading to increased human capital with increasing employment opportunities (Mitchell and Shepherd, 2006). Improved access to credit and income from value chain participation can lead to increased natural capital.

The major groups of role-players involved in the woodfuel value chain are producers (natural capital), transporters (financial), traders, wholesalers, retailers, consumers (service) and (traditional and official) authorities (social capital).

Studies on the benefits of supply chain participation suggest that a producer's assets are a critical factor in their ability to participate in and benefit from formal markets. Assets can be seen through three lenses. First, identifying pre-existing assets is important for evaluating the likelihood of a producer benefiting from a trading opportunity. Second, understanding the gap between available assets and those necessary to successfully benefit in a particular market in the long term is critical to designing the upgrading strategy. Finally, assets themselves are an indicator of poverty and thus a useful metric for evaluating and monitoring the impact of value chains on poverty.

Production of fuelwood

Woodfuel can be sourced from a number of places, including natural forests, trees on farms, plantations, residues from forest harvesting, salvage harvesting (sick or damaged trees) and silvicultural thinning (FAO, 2010b). The main role-players involved at this level are specialized woodcutters, small-scale rural industry operators, community members, farmers and formal and informal authorities. Producers are the primary role-players in terms of the number of income-generating opportunities created and this is a low-cost activity. Formal and informal authorities exercise control over tree resources and any forms of commercialization. Local traditional authorities often provide access to land; government officials control official land including the use of low-cost labour and movement of materials, but not pricing. Regulatory tools regarding woodfuel extraction can constitute producer or trader taxes, licences, permits, fees and imposing minimum harvestable tree diameters or restrictions on certain tree species (Namaalwa *et al.*, 2009).

Charcoal production and processing

The process of charcoal production starts with the movement of wood from the area of harvesting to a more central place where cross-cutting and packaging to the required sizes and amounts are done. The main role-players are often the same people involved in production or specialized wood-processing groups where use is made of inefficient traditional charcoal-production techniques such as earth mound kilns. In addition, the same systems are used by illegal charcoal producers. Two types of charcoal makers are generally distinguished: (1) rural citizens, mostly farmers, who produce charcoal as a by-product of transforming forestlands into farmlands (Hulusjö, 2013), and; (2) specialized producers, urban or rural citizens working in groups who are moving around, following production frontiers. In the latter group, one is likely to find individuals obtaining official permits to make charcoal, but often some of the sites where they make such charcoal are never inspected to ensure compliance. Sometimes it is urban merchants who hire woodcutters to produce the charcoal (Ribot, 1998). Charcoal production for commercialization, nowadays, is mainly an activity executed by men (Gumbo *et al.*, 2013). Transportation varies from head-loading, bicycles and motorcycles, to donkey carts, cars, pick-up trucks, lorries and large trucks. Modes of transport depend on the distances to be covered and the financial means of the traders. Transporters, or traders, are often men, mostly urban-based, who travel around production zones to collect woodfuel or travel to a village after being contacted by producer groups (FAO, 2010). These transporters are expected to have conveyance certificates to move charcoal, but often do so without any certificates, which is part of the illegal activities associated with the value chain.

Distribution and retail

Wholesalers can be characterized into two groups: those with their own transport and those that hire transportation. Wholesalers without their own transportation pay a fixed price for a truckload before organizing further sales, directly, or via retailers. Retailers buy fuelwood and charcoal from the wholesaler. Sales are either organized via depots or directly to markets and semi-industrial consumers. Retailers buy fuelwood and charcoal from the wholesaler and repack the product in smaller quantities for sale in the different neighbourhoods. Retailers resell at specialized woodfuel markets, common markets, at roadsides in local neighbourhoods or in small kiosks. Their clients are generally the poorer urban citizens who cannot afford to buy an entire bag of charcoal.

Consumption

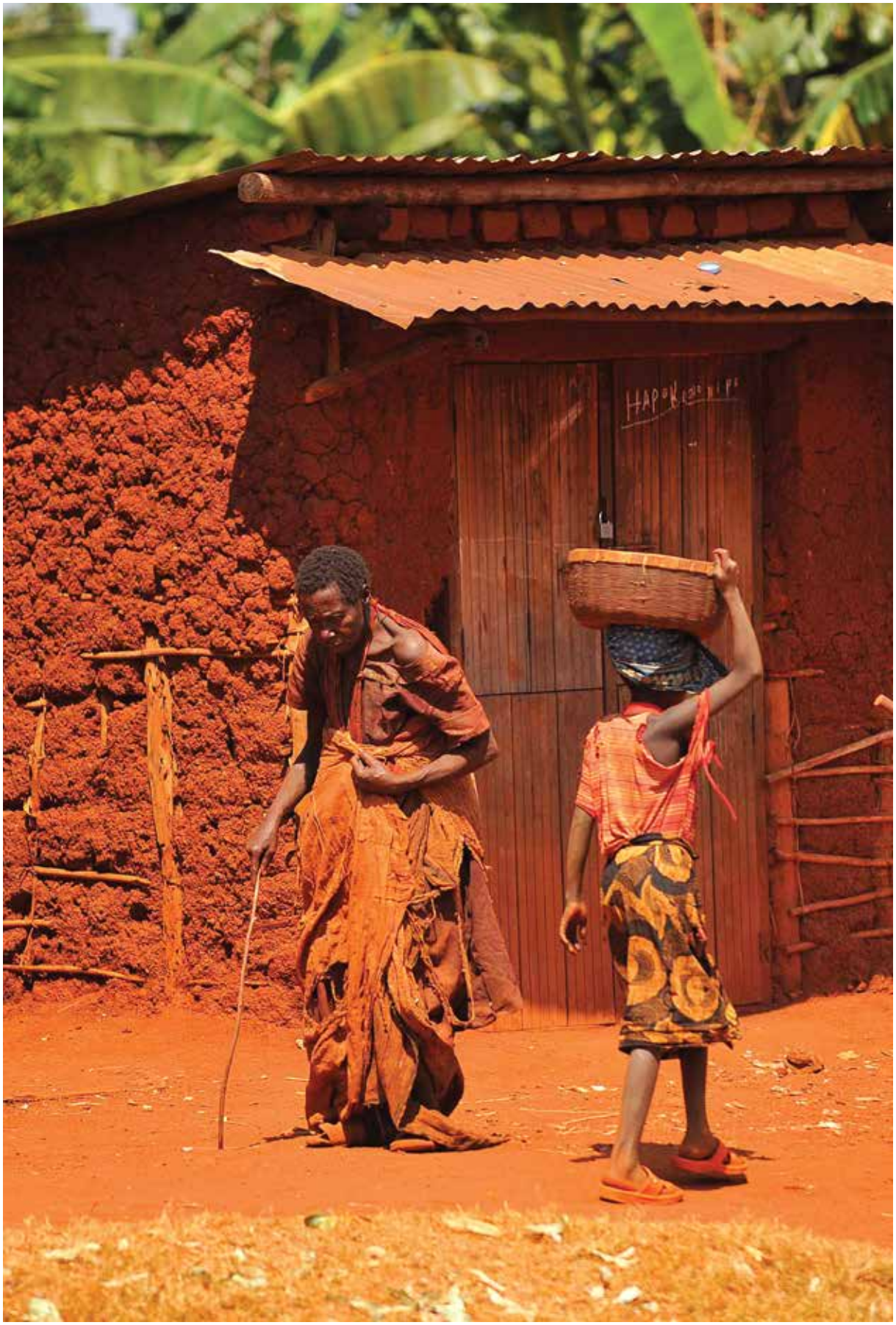
Households are the main consumers of woodfuel for cooking, followed by small-scale rural industries, the agroprocessing sector which includes baking, drying, smoking and parboiling, and the services sector (IEA, 2006), which includes businesses such as bakeries, breweries, restaurants, brick makers and aluminium forgers. At a household level, energy choice is part of a complex decision-making process influenced by the size of the household, area of residence, availability of fuel, income, education, available labour, cultural preferences and oil price, which may cause increased demand for woodfuel (Maconachie *et al.*, 2009; Masera *et al.*, 2000).

Charcoal production has also been reported as a driver for continuation of the deforestation process when timber harvesting is no longer profitable (Ahrends *et al.*, 2010). Although the availability of net biomass could be sufficient on a national scale, most studies reported pressures at local scales that contribute to resource depletion of peri-urban tree sources (Openshaw, 2011).

The contribution of charcoal production to deforestation and degradation in Sub-Saharan Africa is estimated at about 14 percent of total deforestation (Luoga *et al.*, 2000), and woodfuel production has been shown to be an important cause of forest degradation (Chidumayo and Gumbo, 2013). However, the reality is that the impacts of woodfuel production on forests are quite diverse as it is location-specific and mostly temporal. Therefore, understanding the role of fuelwood and charcoal as drivers affecting forests is a prerequisite to tailoring appropriate measures (Kissinger *et al.*, 2012; May-Tobin, 2011).

Lately, notice has been taken of issues pertaining to indoor pollution resulting from the combustion of biomass (such as dung, charcoal, wood or crop residues). Globally, approximately 50 percent of all households and 90 percent of rural households utilize solid fuels for cooking or heating and the Miombo countries are not an exception. In SSA, women responsible for preparing meals, and the young children they care for, are most severely exposed to indoor air pollution. Data from Africa for the past 10 years show that biomass fuel smoke was associated with high levels of household air pollution and symptoms and impaired lung function were associated with exposure to biomass fuel smoke and poverty. In addition to direct adverse health effects, inefficient burning of biomass fuel is a contributor to adverse environmental and climate change effects by degradation of forests and greenhouse gas emissions and these factors are increasingly recognized as independent risks for adverse health outcomes. Across most of the countries in the Miombo region, the Global Alliance for Clean Cookstoves (GACC) formed in 2010 and committed to fostering "the adoption of clean cookstoves and fuels in 100 million households by 2020", is working with the national governments and other stakeholders to save lives, improve livelihoods, empower women, and combat climate change.

©FAO/R. Faidutti



©FAO/S. Maina

5 CHALLENGES TO SUSTAINABLE MANAGEMENT OF THE MIOMBO WOODLANDS

©FAO/S. Maina

5.1 Existing barriers to the sustainable management of the Miombo woodlands

Existing challenges and hindering factors related to the sustainable management of the Miombo woodlands are reviewed below.

Lack of an enabling policy environment

The Miombo woodland countries are plagued by weak governance and inadequate enforcement of natural resource management policies, rules and regulations at the local level and this emanates from a poor history of policy development in the forestry sector. Until recently, forestry management was based on top-down government approaches which focused on the introduction of new and alien technologies. This was characterized by the establishment of village woodlots, the planting of fast-growing species, and the demarcation of protected forest areas for revenue generation, from which local people were often excluded. Indigenous species, local agroforestry systems, and traditional resource management practices, as well as institutions for communal forest stewardship, were often ignored. In many Miombo countries, for example, huge areas of Miombo were gazetted as forest reserves, but no institutions were established or developed to manage the areas. Consequently, no tradition of management *per se* was developed and the focus remained on regulation and revenue generation for the state.

Although forest resources play a crucial role in local livelihoods and contribute significantly to national economies, the forestry sector is generally marginalized in the national policy arena and budgeting process, with limited resources to support sustainable management, develop appropriate technical information and enforce regulations (Barany *et al.*, 2004; Mlay *et al.*, 2003). Forestry spending needs to be mobilized in the face of many competing priorities such as health, education, transport and agriculture. The national extension service is primarily for agriculture, and only tackles forestry issues in an ad hoc manner. Lack of resources means that the forestry

establishments are unable to implement forest policies effectively, have limited capacity for regulation, and provide limited services to smallholders and communities.

Unsustainable management of Miombo woodlands

The greatest barrier to adoption of production practices that are biodiversity friendly and promote ecosystem resilience, is poor understanding of the Miombo woodlands compounded by limited individual and institutional capacity at national and local levels. The Miombo woodlands' ecology, silviculture and management potential are yet to be better understood (Ryan *et al.*, 2016). As these woodlands are located on some of the poorest soils in Africa, they have the unique problem of a low inherent productivity. Because of this low productivity, returns to active management will generally be low, thus providing few incentives to actively manage the forests. It is noted, however, that the woodlands are characterized by a good regenerative capacity (Jew *et al.*, 2016; Ryan *et al.*, 2016; Symapugani *et al.*, 2009), but that unsustainable management inhibits the woodlands from recovering naturally. Nevertheless, for the rural poor, the woodlands need to be managed for multiple outputs, which poses further challenges in terms of the management structures required.

Limited willingness and ability to pay for and access to energy-efficiency technologies

Rural and urban households in the selected countries depend on wood biomass for energy, but in doing so, use inefficient technologies such as the three-stone fire or *mbauala*. Those making charcoal use inefficient traditional earth mound kilns. Information on more efficient technologies is available, but may not be accessible to these households, or the same households may not have extra cash or willingness to invest in the best technologies. The development of a vibrant local economy is further complicated by inadequate access to credit facilities. Currently, the available credit facilities are tied to agroproduction in the form of cash crops (tobacco and cotton). There is less investment in woodfuel energy enterprises as well as a general lack of credit facilities in rural areas.

Inadequate awareness and information

There is inadequate knowledge, capacity and policies in the Miombo countries to deal with adaptation to climate change (in terms of climate change issues and possible adaptation or mitigation interventions). Due to low levels of research, there is insufficient knowledge available on how a changing climate will alter key characteristics of the woodlands, such as distribution, phenology, population structure and species composition; or how these factors will interact to influence productivity, regenerative capacity and flow of other ecosystem benefits.

High poverty levels

The rural populations in the Miombo countries experience high levels of poverty that are compounded by low margins for investing in active management of the Miombo woodlands. Owing to the low income of most rural households, cash constraints push decisions towards rapid woodlands exploitation options. While woodlands are quite important for subsistence products, they are less important for cash income. Because of their locations, trees in the rural areas are felled for cash. Under these circumstances, communities demonstrate a strong tendency to discount the future as the need to secure their immediate survival is greater than that of ensuring conservative use. Households needing to secure cash often choose to over-use and, if necessary, deforest the Miombo.

5.2 Knowledge and information gaps

Despite the vast body of literature available on the functions of Miombo woodlands, there are still significant gaps in the existing knowledge that hinder SFM and, particularly, proper policy formulation on Miombo woodlands.

The main gaps centre around:

- Incomplete data and information on the extent of Miombo woodland coverage. References to Miombo cover all highlight that it amounts to around 2.7 million km^2. There are, however, no precise data at country level reporting how many hectares are covered by the woodlands. The woodlands are often reported as savannah or simply forests. There is a strong need to map the Miombo woodlands properly to better account for them in inventories, policies and strategies.
- The full value of Miombo woodlands in terms of their economic, social and environmental benefits at community and national levels is not well captured in the existing literature. There are estimates of some of the economic gains from NTFPs from case studies, however there are no comprehensive overviews available to gain a full understanding of the magnitude of the Miombo woodlands and their importance to rural livelihoods and national economies.
- Availability and quality of data. Data on Miombo woodlands have been collected and processed for more than 40 years. Although there is a vast body of data available on the Miombo woodlands, often at country level, particularly from Tanzania, Zambia and Mozambique, few regional studies have been conducted on these woodlands. The need for additional data is always present, but it is perhaps more important to focus on the analysis of existing data first – to fully understand the gaps in the existing data and to gain an understanding of what future research should be focused on.

©FAO/S. Maina

©FAO/P.N. Chitembwe

6 CONCLUSIONS AND KEY MESSAGES

©FAO/S. Maina

Miombo woodlands play a significant role in sustaining the livelihoods of millions of rural and urban poor in southern Africa. The numerous goods and services they contribute include a vast array of NTFPs (fruits, mushrooms, medicines, insects, fodder, woodfuels, etc.).

The woodlands are under threat from ever increasing populations in need of more agricultural land, over-use of resources and unsustainable management. There is an urgent need to identify proper measures for improving the management, restoration and monitoring of the woodlands to ensure provision of goods and services in particular relating to food security, nutrition and wood energy.

Promoting improved regional collaboration across the Miombo ecoregion could play a significant role in sharing best practices across SFM, food security, nutrition and wood energy in Miombo woodlands.

This paper served as background document for a workshop on SFM in Miombo woodlands held in Harare from 30 to 31 August 2017, which brought together key stakeholders from six Miombo countries (Angola, Malawi, Mozambique, Tanzania, Zambia and Zimbabwe). The workshop discussed the need for improved regional collaboration across the Miombo ecoregion. It was concluded that there is scope for a regional programme on SFM in Miombo woodlands focusing on sharing of best practices, improving data and data analysis on Miombo woodlands, harmonization of policies, to name but a few.

Key messages

Nutritionally-rich, resilient and biodiverse food system

- Forests and trees, if managed sustainably, are an important source of resilience for rural people in the Miombo woodlands, supporting households to absorb and recover from climatic or economic calamities and contributing to resolving the underlying causes of food insecurity, undernutrition and poverty by providing nutritious edible products and woodfuel for cooking in addition to conserving biodiversity and water resources, buffering extreme weather conditions and preventing land degradation and desertification.
- NWFPs add vital micro- and macronutrients to local diets and contribute to diversified food systems.
- Miombo woodlands contribute significantly to household and national economies.
- A resilient system and multipurpose and participatory tree management will enhance the adaptive capacities of communities.

Knowledge gaps remain

- Current data bases referring to the value of the Miombo must be analysed and used as evidence to improve policy-making.
- Miombo woodlands may be dominant (spatially), but they have not been addressed as a single unit as part of the region's forests. They form part of the overall forestry strategies and no specific mention in the conventions does not suggest that their importance is underplayed.
- Their importance needs to be revisited and promoted based on the evident and intricate link between energy, livelihoods, food and nutrition security and woodland status.
- The contribution of the Miombo woodlands to food security and nutrition (fruits, mushrooms, berries, edible insects) is invaluable, yet more data are needed on consumption of these foods and degree to which they contribute to diets, resource availability, market structure pertaining to key products as well as their nutritional composition.
- A need was identified for information and awareness campaigns on the nutritional benefits of Miombo foods to support intergenerational transmission of knowledge combined with dissemination of nutrient-rich and "energy-smart" cooking practices.

Need for more sustainable management and capacity development

- The management of Miombo will require some changes in management structures, especially in providing benefits emerging from trade in forest products to local managers.
- Local forest managers should play a greater role in allocating resources for feedstock for charcoal production.
- There is a need for training/capacity building in livelihood diversification and development of value-added NTFPs (e.g. processing techniques, Miombo labelling scheme).
- The low productivity of the Miombo means that a close look should be taken at enabling passive and assisted regeneration (restoration) and/or "rewilding" (e.g. indigenous/native plant species) should be explored.

The way forward

The importance of the Miombo woodlands is well documented in literature through case studies, however regional information is patchy and not comprehensive. Lack of comparable quantitative data at national and regional levels has hindered the development of appropriate policies and programmes. The question that emerges is whether the goods and services provided by Miombo woodlands can continue to sustain lives, livelihoods and nourish future generations in the context of a changing climate, an unprecedented loss of biodiversity and increasing pressures from agriculture and a growing population.

Many projects over the years as well as high-quality scientific articles, papers and reports have suggested numerous ways to approach the best management of the woodlands. Some have been more successful than others. Perhaps never before has the prospect of climatic change been so great, requiring efforts that transcend boundaries and take stock of "what works" in facing these challenges. Moreover, after years of declining food insecurity, 2016 marked an increase in global hunger (now affecting 815 million); conflict – often associated with the depletion of natural resources and exacerbated by climate-related shocks – was deemed a major factor driving this trend. Building resilience and sustainably managing natural resources can provide "insurance" against these shocks, providing long-lasting benefits for lives and livelihoods. There is a need to better understand previous approaches, gaps, needs and findings from the vast body of literature as well as the numerous projects by development partners and governments.

The next step forward from this publication is thus to conduct a follow-up study revising all existing data on the woodlands, to map their importance properly as reflected in national economies and trade across the ecosystem, their position in policies and strategies and above all their importance and value to rural communities. Such an analysis can demonstrate best practices from the past as well as highlight the gaps and what future programmes should focus on. Given the vast amount of data available, the study would also identify new and different ways of analysing the data. This would avoid any new collection of data that have already been identified, collected and analysed in the past. The study would result in the creation of a Miombo woodlands database and a scientific paper to highlight the findings. The study would seek collaboration from all interested stakeholders, particularly from the Miombo network. The expected result of the analysis would be to identify the true value of the woodlands. This would allow policy-makers to integrate Miombo woodlands into policies and strategies and create more awareness of the significant role they play.

A number of the Miombo countries have made pledges to the Bonn Challenge to restore a significant number of hectares prior to 2020 and 2030. The DRC has committed 8 million hectares by 2020, more specifically in the Katanga province where most of their Miombo woodlands are found. Malawi has committed 4.5 million hectares by 2030. These pledges will require concerted efforts, coordination and funding. Most of these pledged hectares will be in or near Miombo woodlands. It would therefore be crucial that the suggested platform seek to understand these pledges, and particularly how the Miombo ecosystem can be part of it. Given the natural regenerative capacity of the Miombo woodlands, there are vast opportunities for the woodlands to restore themselves at very low cost.

The final step in the suggested approach would be to create a platform for Sustainably Managed Miombo Woodlands that would liaise strongly with existing initiatives such as the Miombo network to explore synergies and identify complementary areas to work on. The platform would seek to address the following key issues in particular:

- Support countries in reviewing existing data on Miombo woodlands. Build on existing Miombo research and development and create a strong regional platform for improved collaboration across the Miombo ecoregion.
- Analyse the true value of Miombo in household and national economies.
- Support countries in integrating Miombo woodlands into relevant policies (e.g. climate change, forests, land use, biodiversity, tenure, etc.) and in harmonizing policies favouring sustainable management of the Miombo woodlands.
- Build capacity in SFM in Miombo woodlands and NWFPs and support countries in the restoration of Miombo woodlands.
- Develop a transboundary programme across the Miombo ecoregion to i) create an enabling environment for integrated landscape management; ii) enhance sustainable forest value chains and diversification of livelihoods; and iii) improve forest inventories, creation of a regional Miombo database and establishment of a centre of excellence on Miombo woodlands.

Feedback

This publication seeks to provide an overview of the vast body of research relating to Miombo woodlands. Any feedback and suggestions on improving this overview are most welcome.

The publication seeks to stimulate future discussions and development of programmes in the Miombo ecosystem. The authors and FAO would welcome any feedback and suggestions on how to better collect, analyse and manage the available information, particularly in view of strengthening the management of these unique woodlands.

Please send any feedback on this publication to Zuzhang Xia, FAO Forestry Officer, at Zuzhang.Xia@fao.org

REFERENCES

Agustino, S., Mataya, B., Senelwa, K. & Achigan-Dako, G.E. 2011. *Non-wood forest products and services for socio-economic development. A compendium for technical and professional forestry education*. The African Forest Forum, Nairobi, Kenya. 219 pp.

Akinnifesi, F.K., Kwesiga, F., Mhango, J., Chilanga, T., Mkonda, A., Kadu, C.A.C., Kadzere, I., Mithofer, D., Saka, J.D.K., Sileshi, G., Dhliwayo P. & Swai, R. 2006. Towards developing the miombo indigenous fruit trees as commercial tree crops in Southern Africa. *Forests, Trees and Livelihoods* 16:103-121.

Attiwill, P.M. 1994. The disturbance of forest ecosystems—the ecological basis for conservative management. *Forest Ecology and Management*. 1994; 63: 247–300. doi: 10.1016/0378-1127(94)90114-7.

Bailis, R., Drigo, R., Ghilardi, A. & Masera, O. 2015. The carbon footprint of traditional woodfuels. *Nature Climate Change*. DOI: 10.1038/NCLIMATE2491.

Balint, P.J. & Mashinya, J. 2009. CAPFIRE during Zimbabwe's national crisis: local impacts and broader implications for community-based wildlife management. *Society and Natural Resources*, 21: 783-796.

Barnes, F.B., Openshaw, K., Smith, K.R. & van der Plas, R. 1994. *What makes people cook with improved biomass stoves? A comparative international review of stove programs*, World Bank Technical Paper Number 242, Energy Series, Washington, D.C, 1994.

Bhaskar V., Wildburger C. & Stephanie M. (eds). 2015. *Forests, trees and landscapes for food security and nutrition.* A global assessment report, IUFRO World Series Volume 33. Vienna, Austria.

Bond, I., Chambwera, M., Jones, B., Chundama, M., Nhantumbo, I., Izidine, S. & Gumbo, D. 2009. *REDD+ in dryland forests: issues and prospects for pro-poor REDD in the Miombo woodlands of southern Africa*. Synthesis report. International Institute for Environment and Development, London. Pp. 73.

Boyd, R., Cranston, Turner J. & Ward, B. 2015. *Tracking intended nationally determined contributions: what are the implications for greenhouse gas emissions in 2030?* Policy Paper August 2015. London: ESRC Centre for Climate Change Economics and Policy, Grantham Research Institute on Climate Change and the Environment.

Campbell, B.M. 1987. The use of wild fruits in Zimbabwe, *Food and Nutrition*, 12:38-44.

Campbell, B.M., Angelsen, A., Cunningham, A., Katerere, Y., Sitoe, A. & Wunder, S. 2007. *Miombo woodlands – opportunities and barriers to sustainable forest management*. Center for International Forestry Research. http://www.cifor.org/Miombo/docs/Campbell_BarriersandOpportunities.pdf

Chidumayo, E.N. 1997. Woodfuel and deforestation in Southern Africa – a misconceived association, *Journal of Renewable Energy Development*, Vol. 10 No. 2, pp. 2-3.

Chidumayo, E.N., Gambiza, J. & Grundy, I. 1996. Managing miombo woodland. Chapter 7. In *The Miombo in Transition: woodlands and welfare in Africa.* Ed. Campbell, B. Pp. 175-193.

Chidumayo, E.N. & Mbata, K.N. 2002. Shifting cultivation, edible caterpillars and livelihoods in the kopa area of Northern Zambia. *Forests, Trees and Livelihoods* Vol. 12 (3): 175-193

Chirwa, P.W., Syampungani, S. & Geldenhuys, C.J. 2008. The ecology and management of the Miombo woodlands for sustainable livelihoods in southern Africa: the case for non-timber forest products. *Southern Forests 2008*, 70(3): 237-245.

Clarke, J., Cavendish, W. & Coote, C. 1996. Rural households and miombo woodlands: use, value and management. Chapter 5. In *The Miombo in transition: woodlands and welfare in Africa*. Ed. Campbell, B. Pp. 101-135.

Clauss, B. 1992. *Bees and beekeeping in the North Western Province of Zambia: report on a beekeeping survey*, Forest Department-IRDP. Mission Press, Ndola, Zambia.

Corvinus, F. & Mapoko M. 2000. Mid-term Prorammate Evaluation. PROBEC, Harare Counsell, S. 2009. *Forest Governance in Africa*. Occasional paper No 50. Governance of Africa's Resources Programme. South African Institute of International Affairs.

Dewees, P.A. 2013. *Bouncing back: forests, trees and resilient households*. Working Paper prepared for the International Conference on Forests for Food Security and Nutrition, Rome, May 13 to 15, 2013.

Dewees, P., Campbell, B., Katerere, Y., Sitoe, A., Cunningham, A.B., Angelsen, A. & Wunder, S. 2011. *Managing the miombo woodlands of southern Africa: Policies, incentives, and options for the rural poor*. Washington DC: Program on Forests (PROFOR). Pp. 77.

Drever, C.R., Peterson, G., Messier, C., Bergeron, Y. & Flannigan, M. 2006. Can forest management based on natural disturbances maintain ecological resilience? *Canadian Journal of Forest Research*. 2006; 36:2285–2299. doi: 10.1139/x06-132.

Egli, S., Peter, M., Buser, C., Stahel, W. & Ayer, F. 2006. Mushroom picking does not impair future harvests - Results of a long-term study in Switzerland. Biol. Conserv. 129, 271–276.

ETC. 1993. *Estimating woody biomass in Sub-Saharan Africa*. ETC (UK) Ltd, in collaboration with Newcastle Polytechnic and Reading University, World Bank, Washington, DC (1993).

FAO. 2001a. *Farming systems and poverty. Improving farmers' livelihoods in a changing world*. Pp. 407.

FAO. 2001b. http://www.fao.org/geonetwork/srv/en/metadata.show?currTab=simple&id=1255

FAO. 2001c. *Non-wood forest products in AFRICA: a regional and national overview*, by Walter, S. Rome, Italy.

FAO. 2009. *Bees and their role in forest livelihoods. A guide to the services provided by bees and the sustainable harvesting, processing and marketing of their products*, by Radbear, N. Rome, Italy.

FAO. 2010a. *Global forest resources assessment, Country Report Zimbabwe*, Forestry Department Food and Agriculture Organization of the United Nations, Rome, 2010, www.fao.org/docrep/014/am325e/ am325e.pdf

FAO. 2010b. *Criteria and indicators for sustainable wood-fuels*. FAO Forestry Paper. Rome: FAO.

FAO. 2011. Save and grow: A policymaker's guide to the sustainable intensification of smallholder crop production. Rome: FAO.

FAO. 2013. *Implementing the non-legally binding instrument on all types of forests*. Rome, Food and Agriculture Organization of the United Nations.

FAO. 2014. *The state of the world's forest genetic resources*. Rome, Italy. http://www.fao.org/3/a-i3825e.pdf. Accessed September 7, 2017.

FAO. 2017. *The charcoal transition: greening the charcoal value chain to mitigate climate change and improve local livelihoods,* by J. van Dam. Rome, Food and Agriculture Organization of the United Nations.

Folke, C. 2006. Resilience: the emergence of a perspective for social-ecological systems analyses. *Global Environmental Change* 16(3):253-267.

Fraser, A.I. & Bowles, R.C.D. 1986. *The use of wood by the tobacco industry in Malawi*, International Forestry Science Consultancy, Edinburgh, UK. (Forestry).

Frost, P. 1996. The ecology of Miombo woodlands. In: B. Campbell (ed.) *The Miombo in Transition: Woodlands and Welfare in Africa*, pp. 11-57. Center for International Forestry Research.

Garrity, D., Dixon, J. & Boffa, J.M. 2012. Understanding African Farming Systems. Science and Policy Implications. *Food Security in Africa: Bridging research and practice*. Sysdne, 29-30 November 2012. Pp. 55. http://aciar.gov.au/aifsc/sites/default/files/images/understanding_african_farming_systems_report_for_aifsc_conference.pdf

Geist, H.J. 1999. Global assessment of deforestation related to tobacco farming, *Tobacco Control*, (8): 18- 28. http://www.forces.org/assorted/tob-dev.htm.

Geist, H.J., Chang, K.T., Etges, V. & Abdallah, J.M. 2009. Tobacco growers at the crossroads: towards a comparison of diversification and ecosystem impacts, *Land Use Policy*, Vol. 26, pp. 1066-1079.

Gonçalves, F.M.M., Revermann, R., Gomes, A.L., Aidar, M.P.M., Finckh, M. & Juergens, N. 2017. Tree species diversity and composition of Miombo woodlands in South-Central Angola: A chronosequence of forest recovery after shifting cultivation. *International Journal of Forestry Research* Volume 2017, Article ID 6202093, 13 pp. https://doi.org/10.1155/2017/6202093

Government of Zimbabwe. 1985. *Geographical extent of vegetation types, estimates of total and accessible areas surviving in 1984 and their growing stock increment*. (Cited in Millington and Townsendl) (1985).

Holden, S. 1991. Edible caterpillars – a potential agroforestry resource? *Food Insects Newslet*., 4: 3-4.

Hosier, R.H., Katarere, Y., Munasirei, D.K., Nkomo, J.C., Ram, B.J. & Robinson, P.B. 1986. *Zimbabwe: Energy planning for national development*. Beijer Institute, Stockholm, Sweden; Scandinavian Institute of African Studies, Uppsala, Sweden (1986).

IPCC: Climate Change 2007: Synthesis Report. *In* Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Edited by Pachauri R.K., Reisinger A. Geneva: IPCC; 2007.

Jew, E.K.K., Dougill, A.J., Sullu, S.M., OÇonnell, J. & Benton, T.G. 2016. Miombo woodland under threat: Consequences for tree diversity and carbon storage. *Forest Ecology and Management* 361 (2016), pp.144-153.

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*. Volume 35, Issue 2: 159-82.

Kokwe, M. 2012. *Forest management practices with potential for REDD+ in Zambia*. NIRAS and Forestry Department, Lusaka Zambia.

Kremen, C. & Ostfeld, R.S. 2005. A call to ecologists: measuring, analysing, and managing ecosystem services. *Frontiers in Ecology and the Environment* 3(10):540-548

Liyama, M., Neufeldt, H., Dobie, P., Njenga, M., Ndegwa, G. & Jamnadass, R. 2014. The potential of agroforestry in the provision of sustainable woodfuel in sub-Saharan Africa. *Current Opinion in Environmental Sustainability* 2014, 6:138-147.

Lowore, J. 2006. *Miombo woodlands and rural livelihoods in Malawi*. Center for International Forestry Research. Pp 18.

Luoga, E.J., Witkowski, E.T.F. & Balkwill, K. 2002. Harvested and standing stocks in protected and communal Miombo Woodlands of Eastern Tanzania, *For. Ecol. Manage*, Vol. 164, pp. 15-30.

Malambo, F.M. & Syampungani, S. 2008. Opportunities and challenges for sustainable management of Miombo woodlands: the Zambia perspective. *Working papers of the Finnish Forest Research Institute* 98: 125-130.

Manyanhaire, I.O. & Kurangwa, W. 2014. Estimation of the impact of tobacco curing on wood resources in Zimbabwe, *International Journal of Development and Sustainability*, Vol. 3 No. 7, pp. 1455-1467.

Mayes, M.T., Mustard, J.F. & Melillo, J.M. 2015. Forest cover change in Miombo woodlands: modelling land cover of African dry tropical forests with linear spectral mixture analysis. *Remote Sensing of Environment* 165: 203-2015.

McCall, M. 2001. Brewing rural beer should be a hotter issue. *Boiling point*, 47. Rugby, ITDG.

McNicol, I.M., Ryan, C. M. & Williams, M. 2015. How resilient are African woodlands to disturbance from shifting cultivation? *Ecological Applications*, Vol. 25 (8): 2330–2336.

Mickels-Kokwe, G. 2006. *Small-scale woodlands based enterprises with outstanding economic potential: the case study of honey in Zambia*. CIFOR, Bogor, Indonesia.

Mika, L. & Tahwa, J. 2001. Wood burning stoves of Zimbabwe, *ProBEC Special Focus on Zimbabwe Newsletter*, February 2001.

Millington, A., Townsend, J., Kennedy, P., Saull, R., Prince, S. & Madams, R. 1989. *Biomass assessment – wood biomass in the SADC region*. Earthscan Publications, London (1989).

Missanjo, E., Thole, G.K., Mtambo, C. & Chisinga, O. 2014. Evaluation of natural regeneration and tree species diversity in Miombo woodlands in Malawi. *J Biodivers Manage Forestry* 3:3.

Mittermeier, R.A., Mittermeier, C.G., Brooks, T.M., Pilgrim, J.D., Konstant, W.R., da Fonseca, G.A. & Kormos, C. 2003. Wilderness and biodiversity conservation. *Proceedings of the National Academy of Science* 100: 10309–13.

Musoni, S., Nazare, R., Manzungu, E. & Chekenya, B. 2013. Redesign of commonly used tobacco curing barns in Zimbabwe for increased energy efficiency, *International Journal of Engineering Science and Technology* (IJEST), Vol. 5 No 3, pp. 609-617.

Njana, M.A., Kajembe, G.C. & Malimbwi, R.E. 2013. Are miombo woodlands vital to livelihoods of rural households? Evidence from Urumwa and surrounding communities, Tabora, Tanzania. *Forest, Trees and Livelihoods*, 2013. Vol. 22, No. 2, 124-140.

Norfolk, S. & Cosijn, M. 2013. Towards the legal recognition and governance of forest ecosystem services in Mozambique.

Norvell, L. 1995. Loving the chanterelle to death? The 10 year chanterelle project. McIlvanea 12, 6–25.

Pailler, S., Naidoo, R., Burgess, N.D., Freeman, O.E. & Fisher, B. 2015. Impacts of community-based natural resource management on wealth, food security and child health in Tanzania. *PLoS ONE* 10(7): e0133252. https://doi.org/10.1371/journal.pone.0133252.

Peckam, J. 1993. *The value of indigenous fruit-bearing trees in Miombo woodland areas of South-Central Africa*. RDFN Paper 15c.

Pienaar, B., Thompson, D.I., Erasmus, B.F.N., Hill, T.R. & Witkowski, E.T.F. 2015. Evidence for climate-induced range shift in *Brachystegia* (Miombo) woodland. *South African Journal of Science*. Volume 111 (Number 7/8): 1-9.

Pilz, D., Norvell, L., Danell, E., Molina, R. 2003. Ecology and Management of Commercially Harvested Chanterelle Mushrooms. Gen. Tech. Rep. PNW-GTR-576. Portland OR: Department of Agriculture, Forest Service, Pacific Northwest Research Station, pp. 1–83.

ProBEC. 2010. *Progress report on the portable clay stove production in Zambia*. Programme for Basic Energy and Conservation. http://www.probec.net/fileuploads/fl12082010073420_2010_PROGRESS_REPORT_ON_CLAY__STOVE_PRODUCTION_IN_ZAMBIA.pdf.

Ribeiro, N.S., Syampungani, S., Matakala, N.M., Nangoma, D. & Ribeiro-Barros, A.I. 2015. Miombo woodlands research towards the sustainable use of ecosystem services in southern Africa. Chapter 19. pp 475-491. In *Biodiversity in ecosystems – Linking structure and function*. EDs

Rodgers, A., Salehe, J. & Howard, G. 1996. The biodiversity of Miombo woodlands. Box 2.1. p. 12. In Frost, P. 1996. The ecology of Miombo woodlands. In: B. Campbell (ed), *The Miombo in Transition: Woodlands and Welfare in Africa*, pp. 11-57. Center for International Forestry Research.

Ryan, C.M., Pritchard, R., McNicol, I., Owen, M., Fisher, J.A. & Lehmann, C. 2016. Ecosystem services from southern African woodlands and their future under global change. *Phil. Trans. R. Soc.* B 371: 20150312.

Sacchetto, C. 2012. *Impact of tobacco-growing on deforestation*. Document prepared for UNITAB and FETRATAB, pp. 21-25.

Saka, John & D. Msonthi, Jerome. 1994. Nutritional value of edible fruits of indigenous wild trees in Malawi. Forest Ecology and Management. 64. 245–248. 10.1016/0378-1127(94)90298-4.

Scoones, I. 2009. Livelihoods perspectives and rural development, The Journal of Peasant Studies, 36:1, 171-196, DOI: 10.1080/03066150902820503

Scott, P. 2006. *Development of rocket tobacco barn for small holder farmers in Malawi*, www.aprovecho.org/lab/rad/rl/stove-design/doc/17/raw (accessed 28 July 2014).

Siddiqui, K.M. & Rajabu, H. 1996. Energy efficiency in current tobacco curing practice in Tanzania and its consequences, *Energy*, Vol. 21. No. 2, pp. 141-45.

Siiskonen, H. 2007. The conflict between traditional and scientific forest management in the 20th century Finland. *Forest Ecology and Management*. 2007; 249:125–133. doi: 10.1016/j.foreco.2007.03.018.

Sileshi, G., Akinnisfesi, F.K., Ajayi, O.C., Chakeredza, S., Kaonga, M. & Matakala, P.W. 2007. Contributions of agroforestry to ecosystem services in the Miombo eco-region of eastern and southern Africa. *African Journal of Environmental Science and Technology* Vol. 1 (4), pp. 068-080.

Sunderland, T.C.H, Harrison, S.T. & Ndiye, O. 2004. Commercialization of non-timber forest products in Africa: history, context and prospects. In Sunderland and Ndiye (eds). 2004. *Forest products, livelihoods and conservation: case studies of NTFP system*, Volume 2 Africa. CIFOR.

Syampungani, S. 2009. *Vegetation change analysis and ecological recovery of the Copperbelt Miombo woodlands of Zambia* [Ph.D. thesis]

Syampungani, S., Chirwa, P.W., Akinnifesi, F.K., Sileshi, G. & Ajayi, O.C. 2009. The Miombo woodlands at the cross roads: Potential threats, sustainable livelihoods, policy gaps and challenges. *Natural Resources Forum* 33 (2009) pp. 150–159.

Syampungani, S., Geldenhuys, C.J. & Chirwa, P.W. 2016. Regeneration dynamics of Miombo woodland in response to different anthropogenic disturbances: forest characterisation for sustainable management. *Agroforestry Systems*. Volume 90, Issue 4: 563-576.

Syampungani, S., Tigabu, M., Matakala, N., Handavu, F. & Oden, P.C. 2017. Coppicing ability of dry miombo woodland species harvested for traditional charcoal production in Zambia: a win-win strategy for sustaining rural livelihoods and recovering a woodland ecosystem. *Journal of Forestry Research*. Volume 28: Issue 3: 549-556.

Termote, C., Raneri, J., Deptford, A. & Cogill, B. Assessing the potential of wild foods to reduce the cost of a nutritionally adequate diet: An example from eastern Baringo District, Kenya. Food and Nutrition Bulletin. 2014. doi:10.1177/156482651403500408

UN. 2008. United Nations General Assembly. Non-legally binding instrument on all types of forests. Sixty-second session. Agenda item 54. http://www.un.org/en/ga/search/view_doc.asp?symbol=A/RES/62/98

UN DESA. 2015. *World population prospects*. The 2015 revision. Key findings and advance tables. Department of Economic and Social Affairs. Population Division. Pp. 66.

Vinceti, B., Termote, C., Ickowitz, A., Powell, B., Kehlenbeck, K. & Hunter, D. 2013. The contribution of forests and trees to sustainable diets. *Sustainability* (5): 4797-4824; doi:10.3390/su5114797.

Vinya, R., Syampungani, S., Kasumu, E.C., Monde, C. & Kasubika, R. 2011. *Preliminary study on the drivers of deforestation and potential for REDD+ in Zambia*. A consultancy report prepared for Forestry Department and FAO under the national UN-REDD+ Programme, Ministry of Lands and Natural Resources, Lusaka, Zambia.

ZERO. 1991. *A business of rural small-scale bread, beer and brick making industries*. Working Paper 21, Zimbabwe Environment Research Organization.

ISBN 978-92-5-130423-5

9 789251 304235

I8852EN/1/03.18

www.fao.org