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).
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 km².

2.1 General introduction to the Miombo ecoregion

Miombo woodlands cover two-thirds of the Sudan-Zambezian phytoregion (circa. 2.7 million km²) (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).
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.

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

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of species</th>
<th>Notes on species and use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuelwood, poles, tools, handcrafts</td>
<td>34 different species (Mgumia et al., 2017).</td>
<td>Sclerocarya birrea, Adansonia digitata, Uapaca kirikiana, Parinari curatellifolia, Strychnos cocculoides, Anisophyllea boehmii, Azanza garckeana, Flacourtia indica, among others.</td>
</tr>
<tr>
<td>Fruits</td>
<td>83 known indigenous fruit species (Kadzere et al., 1998).</td>
<td></td>
</tr>
<tr>
<td>Medicine</td>
<td>At least 32 different species are used in health care (Mgumia et al., 2017).</td>
<td>Roots, leaves, bark, seeds of different species.</td>
</tr>
<tr>
<td>Fodder</td>
<td>9 species (Mgumia et al., 2017).</td>
<td></td>
</tr>
<tr>
<td>Mushrooms</td>
<td>34 edible species have been identified in Tanzania;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>60 in Malawi (FAO, 2000);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25 species in Zambia (Pegler and Pearce, 1980).</td>
<td></td>
</tr>
<tr>
<td>Wild meat (including insects)</td>
<td>At least 20 species of rodents eaten (Malaisse, 1982).</td>
<td>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).</td>
</tr>
<tr>
<td></td>
<td>31 species of edible caterpillars found in Zambia alone (De Foliart, 1999).</td>
<td></td>
</tr>
</tbody>
</table>

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).
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-Pérez 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.
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.

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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
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. 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.

3 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.
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; Piarce, 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.
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.
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.
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 (Manyanhare 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 hotspots 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.
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

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


Table 3. Nationally determined threats to Miombo woodlands

<table>
<thead>
<tr>
<th>Convention</th>
<th>Angola</th>
<th>DRC</th>
<th>Malawi</th>
<th>Mozambique</th>
<th>Tanzania</th>
<th>Zambia</th>
<th>Zimbabwe</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNFCCC</td>
<td>Long-term use of Miombo for charcoal production has had negative consequences for the ecosystem.</td>
<td>Charcoal production has had negative impacts on Miombo.</td>
<td>Firewood and charcoal production: with population pressure, demands will increase on Miombo woodlands.</td>
<td>Miombo woodlands experiencing late bush fires.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNCCD</td>
<td>Shifting cultivation and fuelwood harvesting are the main threats to Miombo.</td>
<td>Charcoal production has cleared forests and left behind low-quality woodlands.</td>
<td>Firewood harvesting and charcoal production cause degradation and deforestation in Miombo.</td>
<td>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.</td>
<td>Regenerative capacity of Miombo under stress and this could lead to negative impacts for dependent communities.</td>
<td>Deforestation for tobacco curing and harvesting of other NTFPs.</td>
<td></td>
</tr>
</tbody>
</table>

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)

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

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 CO2 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 trypanosomiasis 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).
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 CO₂ 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

<table>
<thead>
<tr>
<th>Country</th>
<th>UNFCCC</th>
<th>UNCCD</th>
<th>CBD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>INDC/NDC</td>
<td>NAPA</td>
<td>National Communication</td>
</tr>
<tr>
<td>Angola</td>
<td>Miombo covers 45.4% of total land area</td>
<td>Miombo and savannah highlighted as main forest types</td>
<td>Miombo highlighted as open forests with socio-economic importance in terms of woodfuels, construction, medicinal plants and NWFPs</td>
</tr>
<tr>
<td>DRC</td>
<td>N/A</td>
<td>Miombo not highlighted, but savannahs in the southern part, which indirectly highlights Miombo</td>
<td>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</td>
</tr>
<tr>
<td>Malawi</td>
<td>Forestry sector mentioned; no clear reference to Miombo</td>
<td>Placed under the blanket of forests</td>
<td>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</td>
</tr>
<tr>
<td>Country</td>
<td>UNFCCC</td>
<td>UNCCD</td>
<td>CBD</td>
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</tr>
<tr>
<td></td>
<td>INDC/NDC</td>
<td>National Communication</td>
<td>National Biodiversity Strategy and Action Plans (NBSABs)</td>
</tr>
<tr>
<td>Mozambique</td>
<td>No explicit mention of Miombo or forestry sector</td>
<td>No mention of Miombo, only savannahs are highlighted. Unclear if it covers Miombo</td>
<td>No direct mention of Miombo woodlands, but savannahs are highlighted as main vegetation classification, covering 70% of land area</td>
</tr>
<tr>
<td>Tanzania</td>
<td>Forestry sector mentioned; no clear reference to Miombo</td>
<td>No direct mention of Miombo. Woodlands and savannahs are highlighted as being under threat from deforestation</td>
<td>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</td>
</tr>
<tr>
<td>Zambia</td>
<td>Forestry sector; no specific reference to Miombo</td>
<td>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</td>
<td>Miombo described as the most extensive of five woodland types in Zambia</td>
</tr>
<tr>
<td>Zimbabwe</td>
<td>Reference to forestry sector</td>
<td>N/A</td>
<td>Miombo mentioned as the main woodland type, with clear distinctive description, separate from the general woodland or savannah descriptions</td>
</tr>
</tbody>
</table>
Table 6. Key references to food security from the Nationally Determined Contributions (NDCs)

<table>
<thead>
<tr>
<th>Angola</th>
<th>DRC</th>
<th>Malawi</th>
<th>Mozambique</th>
<th>Zambia</th>
<th>Zimbabwe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food security</td>
<td>Food insecurity remains a challenge</td>
<td>Improved co-management of capture fisheries also has strong potential to buffer food security and improve the climate resiliency of fishing-dependent communities</td>
<td>Under adaptation. Increase resiliency of agriculture, livestock and fisheries to guarantee adequate levels of food security and nutrition</td>
<td>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</td>
<td>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</td>
</tr>
</tbody>
</table>

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

Table 7. Resilience in the NDCs

<table>
<thead>
<tr>
<th>Malawi</th>
<th>Mozambique</th>
<th>Tanzania</th>
<th>Zambia</th>
<th>Zimbabwe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhance resilience of productive sectors, building of resilience, community resilience, enhance people’s resilience to the negative impacts of climate change</td>
<td>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</td>
<td>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</td>
<td>To promote conservation/climate smart agriculture activities leading to adaptation benefits and enhancing climate resilience, especially in rural areas</td>
<td>Enhance resilience of all sensitive socio-economic sectors to improve the national adaptive capacity. Building resilience in managing climate-related disaster risks</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Angola</th>
<th>DRC</th>
<th>Malawi</th>
<th>Mozambique</th>
<th>Tanzania</th>
<th>Zambia</th>
<th>Zimbabwe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wood energy</strong></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

- **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**

<table>
<thead>
<tr>
<th>Restoration</th>
<th></th>
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</tr>
</thead>
</table>

- **Commitments to reforestation. Several large-scale afforestation projects planned, including 50,000 ha to be planted in the next 10 years**

- **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**