

G:ENESIS



FOR THE WORLD BANK

**PAPER I: Research and Management of Miombo
Woodlands for Products in Support of Local
Livelihoods**

December 2007



5/12/2007: VERSION 2

Authors: C.M. Shackleton
 J.M. Clarke

Genesis Analytics (Pty) Ltd

2nd Floor, No 3 Melrose Square, Melrose Arch, Johannesburg
South Africa, 2196.

Post to: Suite 3, Private Bag X1, Melrose Arch, Johannesburg, South Africa, 2076.

Tel: +27 11 214 4080, Fax: +27 11 214 4099

www.genesis-analytics.com

TABLE OF CONTENTS

1. INTRODUCTION	1
1.1. What is <i>miombo</i>	1
1.2. Landuse patterns in <i>miombo</i>	1
1.3. Local livelihoods and resource use	5
1.4. Purpose of this paper	6
1.5. Approach	8
2. EXISTING USE AND MANGEMENT OF <i>MIOMBO</i>	9
2.1. Woody resources	9
2.1.1. Fuelwood/charcoal	10
2.1.2. Construction timber	13
2.1.3. Wood for handles and implements	14
2.2. Non wood products	15
2.2.1. Medicinal plants	15
2.2.2. Beehives and other products from bark	17
2.2.3. Wild fruits	17
2.2.4. Wild leafy vegetables	19
2.2.5. Wild mushrooms	20
2.2.6. Edible insects	20
2.2.7. Bushmeat	20
2.2.8. Fodder for livestock	21
2.3. Service functions of woodlands	22
2.3.1. Shade	22

2.3.2. Cultural and spiritual benefits	23
2.3.3. Land and nutrients for arable production	23
3. EMERGING THEMES IN THE MANAGEMENT OF <i>MIOMBO</i> WOODLAND	24
3.1. Support for indigenous practices and institutions	25
3.2. Management through fire and grazing	26
3.3. Promoting regeneration and increased productivity	28
3.3.1. Woody plants	28
3.3.2. Non-timber products	30
3.4. Silvicultural systems	30
3.4.1. Clear felling	30
3.4.2. Coppice with standards	31
3.4.3. Cutting cycles in <i>miombo</i>	31
3.4.4. Selective cutting	32
3.5. Systems and practices for multiple use	33
3.6. Domestication	34
3.7. Substitution	35
4. CONCLUSIONS	36
5. REFERENCES	41

1. INTRODUCTION

1.1. WHAT IS *MIOMBO*

Miombo woodlands (hereafter referred to as *miombo*) cover a vast area of south and central Africa. Stretching from the northernmost tip of South Africa up to Tanzania, and from Mozambique in the east to Angola in the west, they cover approximately 3.2 million km² (Scholes & Biggs 2004). They are the most widespread fire-adapted, closed-canopy woodlands in southern and central Africa. Whilst comprising of several sub-types, the defining characteristic of *miombo* is its occurrence on nutrient poor soils and the dominance of three woody plant genera, namely *Brachystegia*, *Julbernardia* and *Isoberlinia*, with an under storey of grasses and herbs. The density and biomass of the woody and herbaceous layers is dependent upon local patterns of rainfall, grazing, fire and use by humans. The overall appearance of the *miombo* changes seasonally in response to the marked concentration of rainfall into only 5 - 7 months of the year, which results in most of the woody layer being deciduous and the herbaceous layer dying back in the dry season. More detailed descriptions of *miombo* and how it is differentiated from other savanna or forest types are provided by Huntley (1982), Chidumayo (1993) and Frost (1996).

1.2. LANDUSE PATTERNS IN *MIOMBO*

Given their enormous expanse, it is not surprising that *miombo* is home to between 45 and 50 million Africans across seven countries, over 80 % of which are rural dwellers. These resident populations obtain the majority of their livelihood needs directly or indirectly from the goods and services provided by *miombo*. This includes cropping, grazing, collection and sale of a variety of woodland resources, as well as benefits from the ecological services such as water provision, nutrient cycling, and carbon sequestration, and cultural and spiritual value from places and species in the *miombo*, for rural and urban dwellers. Consequently, there is large spatial and temporal variation in land use patterns and practices, which require that

generalizations are treated with caution (Campbell *et al.* 1997). Nonetheless, the primary land use patterns are those of the rural sector inscribed by small-scale farmers in pursuit of their livelihoods. This has resulted in a landscape mosaic of rural dwellings and arable fields within the background matrix of *miombo* woodland which has been opened up to a greater or lesser extent. Small-scale arable cropping systems are around the homestead and fields for staple carbohydrate sources (maize and cassava), intercropped with groundnuts, vegetables and fruit trees, and sometimes tobacco or cotton as a cash crop. Large and small domestic stock are maintained under free-range conditions around the dwelling and within the surrounding *miombo*. Besides animal fodder, the surrounding *miombo* is used for the collection of multiple natural resources for energy, construction, nutrition, medicine, decoration and cultural or spiritual needs. Interspersed into this small-farmer dominated mosaic are a range of protected areas and eco-tourism initiatives that seek to minimise human impacts on *miombo* and maximise biodiversity (especially of large mammals) and ecosystem services, and forestry enterprises harvesting *miombo* hardwoods as well as plantation timber. An assessment of the Zambezi basin in 2000 indicated that overall, approximately 90 % of the *miombo* was relatively untransformed by urbanization or monoculture agriculture (Scholes & Biggs 2004). The Global Landcover 2000 assessment indicated less than 9 % of the *miombo* as under permanent cultivation whilst recognizing that the small-scale and shifting nature of cultivation in many countries makes such estimates difficult and hence somewhat inaccurate (Scholes & Biggs 2004).

The composition and structure of *miombo* at any time or place is thus largely determined by the intensity and duration of the different land uses and practices (which themselves are influenced by local rainfall and soil types (Wilson 1990, Frost 1996, Campbell *et al.* 1997, 2002)), which override the inherent relationship of woody plant biomass and basal area with rainfall evident for relatively undisturbed *miombo* (Frost 1996, Banda *et al.* 2006). In areas of low intensity use, *miombo* is approximately 8 – 20 m tall with more-or-less 100 % canopy cover, and a well established herbaceous layer and a low biomass of domestic or wild animals. In contrast, intensively used areas have a dispersed canopy of largely isolated trees of favoured species in fields or homesteads, between which is a scrubby bush land of harvested but coppicing stems, and large numbers of grazing animals. In this respect they present a stark contrast to more intact *miombo*, with a different physiognomy, structure and biomass. Several authors have contrasted the structure of old and regrowth *miombo* at a number of sites (Trapnell 1959, Strang

1974, Guy 1981, Chidumayo 1993, 2002, Luoga *et al.* 2002, Banda *et al.* 2006). Whilst the precise values for the different attributes differ widely between the studies (reflecting differences in climate, soil, landscape position and human impacts), the qualitative trends are similar (Table 1). The attributes of regrowth stands are generally intermediate between these two extremes. There is typically a gradient of use intensity radiating out from major transport routes or human settlements (Vermeulen 1996, Chidumayo 2002, Luoga *et al.* 2002, Schwartz & Caro 2003, Malimbwi *et al.* 2005), and hence a change in *miombo* structure with distance away from nodes of human activity.

It is noteworthy that although human use inevitably alters the appearance and size class profile of *miombo*, and potentially the productivity, several studies have shown that there has been no significant decrease in woody plant species richness (Vermeulen 1996, Malimbwi *et al.* 2005, Banda *et al.* 2006), although some have (Mwase *et al.* 2007).

Attribute	Lightly used/old growth	Heavily used/1 st regrowth
Woody plant density	High	Low
Coppice density	Low	High
Stem height	Tall (12 – 20 m)	Short (2 – 4 m)
Basal area	High (\pm 7 – 25 m ² /ha)	Reduced (3 – 15 m ² /ha)
Above ground woody biomass	High (50 – 90 t/ha)	Reduced (20 – 50 t/ha)
Peak herbaceous biomass	Low (\pm 2 t/ha)	Highly variable
Woody plant species richness	Relatively similar (although species identities might differ)	
Herbaceous species richness	Relatively similar (although species identities might differ)	

Table 1: Contrasts in the general attributes of intensively and lightly used *miombo*

Source: Extrapolated from data sources at different sites from Trapnell (1959), Strang (1974), Chidumayo (1993, 2002), Frost (1996), Vermeulen (1996), Banda et al. 2006)

1.3. LOCAL LIVELIHOODS AND RESOURCE USE

The millions of people resident in *miombo* engage in a range of livelihood strategies, but most are directly dependent on *miombo* for land and the products on it for home consumption and for income generation. At any one site several hundred species are used, across two dozen or more resource types supplying energy, nutritional, construction, fibre, medicinal and livestock needs. The importance of different resources or species varies from place to place, as measured by either the proportion of households using them, volumes extracted or monetary value. But more often than not, resources used by > 80 % of households include fuel wood or charcoal, construction timber, wild fruits and honey (Luoga *et al.* 2000, Lynam *et al.* 2003, Bwalya in prep.). Medicinal plants have been found to be extremely important elsewhere, but most livelihood surveys exclude them because of the difficulty in quantifying so many different species and plant parts (leaves, bark, roots). Similarly, water quantity and quality is a key resource supplied by *miombo*, but has never been included in valuation studies of *miombo* products.

Recently there have been some attempts to value the contribution of *miombo* resources to local livelihoods. This is fraught with methodological challenges (Campbell & Luckert 2002, Gram 2001, Vedeld *et al.* 2004), such as what resources are included and which excluded (especially fodder), how to deal with the absence of farm-gate prices, whether or not collection time or costs of labour are deducted, depreciation functions of vehicles and equipment used in harvesting, and so on. Consequently, many findings are not directly comparable to one another. Moreover, none of the studies have considered the contribution of environmental services to livelihoods, such as water yield, water quality, pollination, nutrient cycling, and the like. Nonetheless, the results are informative, especially if one refrains from comparing the different studies. For example, Cavendish (2000) reported results from two sites in Zimbabwe, on what he described as the boundary between *miombo* and mopane woodlands. In an extremely detailed survey every three months for two years of all livelihood income (cash, gifts, in-kind) he found that income from the *miombo* resources (excluding gold panning) constituted approximately one-third of total household accruals. Adding in returns from livestock, cropping and craft sales, increased this by a further 11 %, providing a total of over 40 % of all livelihood sources coming from *miombo* and land cleared of most trees. Campbell *et al.* (2002) conducted a similar exercise in another region of Zimbabwe, also on the transition between

miombo and mopane woodlands. They reported that gross returns from *miombo* goods were 12.6 % of total livelihood accruals. With cropping and livestock included this jumped to 73.8 %. The draft report by Bwalya (in prep.) reports on a survey of 435 households sampled at eight sites throughout Zambia (therefore *miombo* and non-*miombo* localities). The draft analysis indicates that approximately 40 % of total livelihood accruals come from forest resources (cash and consumption), and agriculture comprises 37 %. The national value of charcoal and fuel wood to the GDP is approximately ten times greater than the contribution of commercial logging. Also in Zambia, Mutamba (in prep.) compared the contribution of *miombo* resources to local livelihoods in communities close to major markets, and those well divorced. At both sites *miombo* resources contributed by far the greatest proportion to total incomes (cash and consumptive), approximately 54 %, and was higher at the accessible site because of the income derived from trade in *miombo* products. Lynam *et al.* (2003) used a range of innovative ranking procedures to index relative value of different sites and resources to two villages in Mozambique, one of which (Nhanchururu) is located in *miombo*. The community provided a list of 26 basic needs required for an adequate standard of living and life, of which many of the most important ones were from *miombo* products or services, namely housing (1st), food (2nd), water (3rd), fuel wood (6th) and sleeping mats (12th). The first four mentioned here were rated higher than schooling, employment or livestock. The food component included crops, wild and cultivated fruits, and wild foods. The various landscapes around the village were also rated in terms of their contribution to different livelihood strategies of cropping, livestock and collection of non-timber forest products (NTFPs). Thereafter a botanical inventory was conducted in each landscape. Subsequent statistical analysis indicated a significant correlation between the community ranking and the number of resources per landscape.

1.4. PURPOSE OF THIS PAPER

It is clear from the above that close to ten percent of all people on the African continent obtain significant value from *miombo* woodlands in the form of goods and services in support of their livelihoods. The *miombo* plays a major role in shaping the livelihood options available to them, and the magnitude of income streams they secure. Simultaneously, the actions of local populations shape the *miombo*, changing its structure and relative composition, enhancing the flow of selected

goods and services, and constraining others. Support to rural people from government agencies and NGOs throughout the *miombo* takes relatively little cognisance of this intimate relationship between rural people and their surroundings. Conventional support structures and extension agencies focus on western models of agriculture, livestock husbandry and forest practice. Knowledge regarding the production rates and sustainable harvesting levels of most *miombo* products is vested in local communities and currently little documented. Conventional research and extension has focused on a few species of high value for external markets, with yield tables underpinned by a timber production paradigm. Yet these species and products represent only a small proportion of the total standing value, and form a minor component of peoples' livelihoods. Consequently, the purpose of this paper is to synthesise existing knowledge on the production and management of the, up till recently, ignored products from *miombo* that are used to support and build local livelihoods of the *miombo* dwellers. In time, such a paradigm shift may require a total reconsideration of terminology and conventional classifications of *miombo* types so that they are based on local knowledge and uses (e.g. Wong *et al.* 2007). By definition, such a synthesis will be limited and incomplete because (i) there are so many different products and species, and (ii) there has been relatively little research to date regarding what have been seen by conventional research and management agencies as products of little value or concern. Indeed, Campbell and Byron (1996) commented over a decade ago that "surprisingly little research has investigated possible silvicultural tools", especially as related to the context of small-scale farming endeavours and rural livelihoods, and yet relatively little has been done in the intervening years. But with increasing commitment globally to devolution of forest policies and management to local level (e.g. Turyahabwe *et al.* 2007), including in the *miombo* region (e.g. Kowero *et al.* 2003), it is important that the necessary first steps are taken. In making the first attempt, we hope to stimulate interest for those who will come after as well as identify gaps for immediate research. We approach the task by presenting an overview of current use and management practices, and secondly use this as the basis for assessing the growing body of technical and practical recommendations emerging from research and project based work on improved management of *miombo* in communal lands. At the end these are brought together in a suite of conclusions and research considerations.

1.5. APPROACH

The broad approach to compiling this paper was to review relevant literature identified via: key word search on the Scopus and Science-Direct international databases, author name search for people known to be relatively active in *miombo* research, and personal contacts to researchers for less accessible literature. In all instances we placed emphasis on locating information from 1990 onwards, although not confined to that period. Our assumption was that key information available prior to 1990 would have been covered in a few important synthesis works of the mid 1990s, namely Chidumayo (1993) and Campbell (1996). Once literature was identified from any of the above sources, a secondary search was instigated of the reference list in each of the sources.

2. EXISTING USE AND MANGEMENT OF *MIOMBO*

A considerable body of work has built up, much of it over the past decade or so, on the complex and diverse relationships between local inhabitants and the *miombo* woodlands on which their lives so closely depend. In this section we provide an overview of use and management practices, attempting to foreground features that form the basis for interventions aimed at improved management. In particular, we highlight the plethora of ways in which users manage both the supply of goods and services as well as demand for these resources.

In considering current management practices and uses it is necessary to recognise the significant variation across the region. Whether or not local communities (as a collective), households or individuals deliberately engage in activities to promote the growth and productivity of woodlands and individual trees depends very much on the local context, being influenced by aspects such as governance structures, availability of common pool resources, land availability for cropping, links for wider economy, population density, opportunity costs of labour and time, and relative wealth. Arnold & Dewees (1995) commented that as the relative abundance of common pool tree resources diminishes greater will be development and implementation of strategies to enhance local abundance and productivity, invested in private space around the homestead and arable fields. Thus, in reality there is a continuum of local management situations from the relatively passive (such as maintenance of existing trees in field) to the relatively active (such as seeking out, digging up and transplanting a seedling of a desirable from the wild into the home space). Generally, the greater the pressure on the resource, the greater the incentive to develop active management practices.

2.1. WOODY RESOURCES

Woody resources typically comprise the most significant value stream to local communities and households. Key products from woody plants include (i) fuel wood or charcoal, (ii) construction timber and (iii) wood for handles (axes, hoes, etc.). There are both gender and wealth related differences with respect to what *miombo* timber resources are considered as key (Abbot 1997, Fortmann *et al.*

1997, Lynam *et al.* 2003), but when the household is considered as the unit of analysis, most households make use of the above resources to some degree. There are other woody resources, but of less significance when measured by the proportion of people using them, or the volume of products extracted. These include browse for livestock, bark for laths, kindling, and walking sticks.

2.1.1.

FUELWOOD/CHARCOAL

Much has been written about fuelwood yield and harvesting approaches in *miombo*. It is the primary energy source throughout the region, for both rural and urban populations, other than the urban rich. Across the *miombo* as a whole wood production exceeds consumption, but there are nodes and local level situations where the opposite applies (van Jaarsveld *et al.* 2005). There are considerable trade networks moving the wood, or more usually the charcoal, from the rural areas to supply burgeoning towns (e.g. Campbell *et al.* 2003, Brouwer & Falcão 2004). Thus, it represents a source of cash income for many, and consequently, proximity to markets and transport routes is a significant factor in the harvesting levels and resultant impacts on *miombo* structure and productivity (Chidumayo 2002, Luoga *et al.* 2002, Malimbwi *et al.* 2005). Commercial demand also poses a challenge to local communities since entrepreneurs not necessarily resident in the rural community undertake much harvesting for markets, and these individuals do not participate in local management plans or objectives.

At the local level and for largely domestic use, there is little active management on the production side for fuelwood or charcoal. Traditionally and historically wood was in adequate supply in most areas, and so supply side management was not required. Three practices are common that served to augment supply, but in passive manner, namely (i) selective maintenance of particular trees when land was cleared for arable fields and homestead plots, (ii) nurturing of self-seeded recruits and (iii) planting and maintenance of live-fences.

On the demand side a number of strategies have been reported across various regions. These include:

Governance (such as harvest seasons for certain species, sacred or taboo species, sacred or taboo areas, harvesting permits, harvesting quotas), which is not within the ambit of this paper.

Selective harvesting. In areas or times when demand is low relative to wood availability, then harvesters generally demonstrate a degree of selectivity for places, type of wood, species and size classes. However, as demand increases, either domestic or commercial, the opportunity costs associated with selection increase, and so it decreases, resulting in more clear-fell harvesting. Selectivity for harvesting areas is usually based on (i) proximity, (ii) ease of access and (iii) amount of wood available at one site relative to another (Abbot 1997, Malimbwi *et al.* 2005).

Selectivity for type of wood refers to the marked preference for dead wood over live timber (Abbot & Lowore 1999, Luoga *et al.* 2000). Dead wood has a number of desirable traits relative to live wood, including that it is easier to harvest, drier and so can be used immediately, lighter to carry, and usually does not require permits or permission to collect. Annual yields of deadwood in *miombo* have not been determined. Luoga *et al.* (2002) recorded a standing stock of dead wood of $336 \pm 57 \text{ kg ha}^{-1}$ at Kitulanghalo Forest Reserve in Tanzania which had about 40 t ha^{-1} biomass. However, the forest reserve was harvested to some degree and thus these dry wood stocks cannot be viewed as representative of intact *miombo*. Frost (1996) present figures from three different sites, which range between 3 and 7 t ha^{-1} . Clearly there is need for yield studies from a number of sites throughout the *miombo*. In the drier savannas, Shackleton (1998) indicated that annual dead wood yield was approximately 1.7 % of standing biomass. When live wood is cut, it is usually dried for a few weeks before use (Abbot & Lowore 1999).

Selectivity for species is generally marked but diminishes as harvesting demand increases. Typical attributes of a species regarded as good for fuelwood or charcoal are medium to high wood density, low moisture content, long-lasting coals, low smoke yield, absence of thorns and absence of unusual fumes or smells (Abbot & Lowore 1999, Luoga *et al.* 2000). Highly regarded genera include *Acacia*, *Brachystegia*, *Combretum* and *Julbernardia*.

Selectivity for size is also marked, but is influenced by the end purpose for the wood and use of stoves. Collectors of fuelwood for household fires typically target branches and stems 3 – 8 cm diameter (Abbot & Lowore 1999). Harvesters who have stoves, or for charcoal and commercial reasons will include larger stems and branches (Abbot & Lowore 1999, Abbot & Homewood 1998). Smaller kindling of < 2 cm diameter is collected opportunistically.

Individual tree management and harvesting. Having selected the place, species and size of tree to harvest, the harvester can then influence its regrowth in terms of how it is cut as well as the height.

Rarely are whole trees cut because they are too large, and it takes to time to fell them and cut the wood into manageable sizes. The exceptions are when trees are cut for commercial charcoal production and for land clearance when establishing new fields. Thus, when cutting does occur it is usually of small stems or smaller branches of a large tree, i.e. pollarding. The tools used to cut also influence regrowth; a clean cut with a saw results in a greater number of regrowth coppice shoots, than a jagged cut from an axe.

Lastly, the greater the height at which the stem is cut, the greater the number of resultant coppice shoots (Chidumayo *et al.* 1996, Shackleton 2001, Luoga *et al.* 2004, Kaschula *et al.* 2005). Subsequent to cutting, the coppice regrowth can be managed according to conventional silvicultural practices, although rarely is. There will be a trade-off between number of coppice shoots maintained and subsequent height regrowth. The more coppice shoots that sprout from the cut stump, and maintained, the greater will be inter-shoot competition and the longer it will take for re-establishment of apical dominance. Thus, one would have many short and thin shoots for a longer period. If the number of coppice shoots is reduced, either by thinning, browsing or fire, then apical dominance will be re-established sooner, and height regrowth will accelerate. In such a situation there will be fewer shoots per cut stump, but longer and thicker. Consequently, the objectives of the local users, and the rotation period they would like to optimize would dictate whether or not coppice management is required and worthwhile (Shackleton 2001), relative to other demands and restrictions on their time. Regrowth rates are likely to be influenced by site characteristics (soil fertility, rainfall), but this has never been studied in *miombo*. Post-harvest management (fire, browsing, and coppice control) and species characteristics will also influence regrowth rates, but there is very little information in this regard. Regrowth rates for standard-sized poles (3 – 8 cm diameter, 2 – 4 m long/tall) were reported as approximately five years (Abbot & Lowore 1999) at a relatively moist site in Malawi. Luoga *et al.* (2004) reported higher coppice response from stumps in communal land compared to a nearby reserve. They attributed this to less competition in communal lands because of the thinning effects of tree harvesting.

In terms of supply side management key aspects affecting fuelwood and charcoal are largely those impacting the broader landscape, namely harvesting pressures, fire and browsing. Yield per unit area is highly variable because of differential harvesting rates and consequently biomass of harvestable timber per hectare. Relevant work has been done on the regeneration dynamics and growth rates of selected species, albeit mostly in controlled conditions (e.g. Boaler 1966, Ernst 1988, Chidumayo 1991, Munyanziza 1994, Munyanziza & Oldeman 1996). Such information would be useful in the event of the need to undertake projects on enrichment planting in stands of *miombo*, or plantations and nurseries.

Outside protected areas re-establishment rates have been determined for some sites. Clearly, a heavily harvested site will take longer to return to the pre-harvesting condition than will a lightly harvested site due to death or removal of rootstocks (Prins & Kikula 1996). Malimbwi *et al.* (2005) report on potential charcoal yield along a harvesting gradient between a major transport route and a protected forest reserve. Adjacent to the road the estimated yield was 1 bag (56 kg charcoal) per hectare, whereas 10 – 15 km away from the road the yield was 125 bags per hectare. They concluded that *miombo* forests in that region could be harvested for charcoal approximately every eight years and maintain the standing biomass at approximately 70 % of that in the protected site.

Overall, the seemingly robust re-establishment rates of *miombo* underlie its renowned resilience. This is largely because regrowth after harvesting is from cut stump coppice, root coppice and a large regeneration bank of suppressed saplings (Chidumayo 2004). Consequently, in shifting cultivation systems, the longer they have been cultivated the longer is the re-establishment period after abandonment because a greater proportion of the stumps, root-stock and suppressed seedling bank have been removed (Prins & Kikula 1996).

2.1.2.

CONSTRUCTION TIMBER

The dynamics around use and management of timber for construction purposes mirrors that of fuelwood or charcoal. Most households use construction timber to some degree, for housing and/or fencing. There is marked selectivity regarding the size and species used (Vermeulen 1996, Luoga *et al.* 2002), which imposes a degree of area selection regarding where best to harvest the right size and

species. Different species are required for different components of the construction. For example, Luoga *et al.* (2000) reported the key differences in species used for wall poles, beam poles, roofing poles, and withies.

There is both competition and complementarity in use of *miombo* trees for fuelwood and construction. Typically construction needs require thicker and longer poles than what is preferred for fuelwood (Luoga *et al.* 2002). Consequently, the bulk of construction timber is obtained via felling of the main stem, rather than lopping of branches or collection of deadwood as is the case for fuelwood. Felling of these larger pieces produces offcuts that can be used for fuelwood (Abbot & Lowore 1999). Another example of complementary use is the widespread practice of recycling timber as firewood, when the time comes to replace structures such as cattle kraals (Grundy *et al.* 1993). On the other hand, because construction timber is of larger diameters, if offtake is significant it can alter the size-class profile of the standing stock in favour of smaller stems (Abbot & Homewood 1998, Backéus *et al.* 2006), which if sustained over long periods would reduce the overall sustainable yield of fuelwood into the future.

2.1.3.

WOOD FOR HANDLES AND IMPLEMENTS

A surprising number of small household and agricultural implements are made from locally available *miombo* timber. These include pestles and mortars, kitchen spoons, bowls and stirrers, walking and fighting sticks, handles for hoes, axes and machetes, cattle ploughs and yokes, and musical instruments. Without these inputs, agricultural production and domestic processing would be constrained. In most places factory produced alternatives can be purchased, but their lesser quality and price deter use. Each implement differs in the need for woods of varying strengths, durability, flexibility, propensity to splinter, and even colour (Clarke *et al.* 1996). Consequently, there is marked selection for specific species for each type of implement. There is also an active market for these implements in tourist and craft shops, along with wood-carvings of animals and figurines (Sunderland & Ndoye 2004, Cunningham *et al.* 2005).

Most pieces will be made from wood collected after felling of a tree for construction timber, or removal or a single branch from the required species. The thicker branches are then used to make wooden utensils. Consequently, demand for wooden implements probably has relatively little impact on *miombo* structure and productivity. However, in areas frequented by tourists the demand for crafts of such household implements and carvings of animals can have significant impacts on local stocks of specific tree species (Cunningham *et al.* 2005) From a silvicultural perspective not much is done by local people to ensure an adequate supply of timber for wooden implements. In some areas selective retention and/or enrichment planting of key species in commons or fields might be considered worthwhile to ensure a stable size class structure for certain implements. Local co-ordination of users might be useful to ensure that when larger trees are felled for construction timber that the branches are available for other purposes other than just fuelwood. For species with high craft market value a suite of strategies are typically advocated, including (i) better governance systems (ii) education of the tourists on which woods to buy and which to avoid, and (iii) substitution of key species with faster growing ones.

2.2. NON WOOD PRODUCTS

2.2.1. MEDICINAL PLANTS

Use of plant material for physical and psychological ailments and spiritual rituals and observances is common (Brigham 1994, Cunningham 1996, Luoga *et al.* 2000), both through self-collection and use, as well as via traditional healers. In some areas there is also significant trade in medicinal plants, with rural collectors supplying traditional healers and markets serving urban areas. A variety of plants parts are used, including leaves, roots and bark.

Many studies have documented that historically harvesting of bark was generally regarded as sustainable. Traditional healers would take care to ensure that a single tree was not re-harvested until the scars of the previous harvest were healed, and that subsequent harvests were on different sections of the tree. In such a way mortality induced by bark harvesting was minimised. However, with both reduced stocks of trees due to land clearance and felling for other reasons,

along with increasing commercial demand for medicinal bark in expanding urban centres, the traditional care in harvesting is being undermined as less informed actors enter the stage to supply the urban markets. This includes export of material to large metropolises in neighbouring countries (Botha *et al.* 2004, Williams 2004). Consequently, rates of ring-barking are increasing, resulting in mortality of trees that are over-harvested. Twine (2004) showed that regrowth rate of bark was inversely proportional to the area removed. A number of interventions have been proposed in response to the increasing over-harvesting (e.g. Geldenhuys 2004, Mander 2004), albeit much of it concentrated in South Africa, neighboring the *miombo* region. Interventions include:

- Increased law enforcement, especially for listed endangered species.
- Working with harvesters and healers to promote sustainable practices and establish oversight institutions or associations.
- Working with communities to manage and police use of local resources.
- Cultivation of key species, at homesteads, enrichment planting, community nurseries or commercial nurseries.
- Substitution, of key species with more abundant ones, or of bark products with leaves.

Most of the options mirror those for supply-side responses to declines in favoured species for wood-carving in the region as outlined by Cunningham *et al.* (2005). The additional ones are simply to expand the harvesting area (Mandondo 2001), i.e. travel further afield or increase poaching from private, State or protected areas. Both these options become increasingly viable for harvesters as scarcity drives up prices obtained in urban markets. A further option, as mentioned above, is greater co-ordination between harvesters of different products. In this instance, felling of large trees for construction timber could potential yield significant amount of bark for local and/or commercial uses.

2.2.2. BEEHIVES AND OTHER PRODUCTS FROM BARK

Lynam *et al.* (2003) describe how bark is much sought after as a resource for making bee hives. However, they comment that usually harvesting is destructive, resulting in the death of the tree due to the removal of a large ring of bark from the central trunk. In contrast, Smith *et al.* (1996) describe the use of hollowed out logs as beehives in Tanzania. Various studies report on measures to reduce impact of bark hives, including promoting the use of bark from timber harvested for other purposes, and provision of “modern” beehives.

Dovie (2003) summarises a number of reports on the use of bark from *Adansonia* as a fibre for mats and ropes. He concludes that there is a distinct threat of over-harvesting as a result of urban demand, and that growth of commercial markets has attracted people with limited experience and knowledge resulting in poor harvesting practices.

2.2.3. WILD FRUITS

Miombo is known for its richness of tree species with edible fruits (Clarke *et al.* 1996). At a sub-continental scale of the whole region south of the Zambezi (including *miombo* and non-*miombo* regions), O'Brien (1988) demonstrated that the number of species with edible fruits increased with mean annual rainfall, as indexed as maximum monthly precipitation. The varied patterns of community phenology result in some species being found in fruit during almost every season, such that fruit production spans most of the year (Wilson 1990, McGregor 1995, Chidumayo & Frost 1996, Abbot 1997). This represents a significant source of nutrition including during the non-agricultural period. Indeed, peak consumption is during the dry season (Campbell 1987, Wilson 1990). This is particularly important for poor households (Wilson 1990, Abbot 1997, Mithöfer & Waibel 2003, Cunningham & Shackleton 2004) and children (Campbell 1987, Wilson 1990). Additionally, greater proportions of poor households engage in selling wild fruits than do wealthier households (McGregor 1995, Mithöfer & Waibel 2003, Shackleton & Shackleton 2006). The labour and economic analysis of Mithöfer & Waibel (2003) concluded that the returns to labour from collecting and selling wild fruits was significantly greater than that gained through livestock husbandry or arable production, a strong demonstration of the importance of wild resources in local livelihoods and the need for research and extension agencies to give wild

resources as much recognition to them as they do to arable and livestock production.

Many indigenous fruit species contain higher levels of vitamins and some minerals than domesticated species (Peters & O'Brien 1981, Fox & Norword Young 1982, Malaisse & Parent 1985, Saka & Msonthi 1994). The high regard for large-fruited species (such as *Adansonia*, *Azanza*, *Diospyros*, *Ficus*, *Partner*, *Sclerocarya*, *Strchynos*, *Uapaca* and *Ximenia*) means that they are selectively retained when woodland is cleared for fields or heavily cut for charcoal. This results in their relative abundance increasing, although absolute densities remain the same (Campbell 1987, McGregor 1995). Typically there is some localized planting of favoured species within the homestead area or the arable fields, or along the boundaries between fields (Deweese 1993, Grundy *et al.* 1993, Abbot 1997). This might be from transplanting seedlings, planting of truncheons, nurture of wildlings or deliberate discarding of fruit seeds in these areas (Mwambo 2000). Indeed, Cunningham & Shackleton (2004) suggest that the distribution and density of several favoured fruit species throughout the sub-continent are probably greater now than several millennia previously due to the actions of humans. Further, there is evidence that fruit trees retained within fields and around homes have fruit more frequently and have higher yields than those in woodlands, probably due to less competition (Chidumayo *et al.* 1996, Leakey *et al.* 2005a).

Several practices for managing or increasing fruit yield per tree have been documented. Seedlings or transplants within the homestead plot may be watered with waste water from domestic activities (Gerhardt & Nemarundwe 2006). Typically young trees are also protected from browsing, either because they are within the larger fenced homestead area, or individual trees may be protected via wire fencing, stacks of cement blocks, old tyres, thorn bushes and the like. Once trees are taller than browsing height such protection is removed and the tree receives little other care. Trees in arable fields will benefit from any application of fertiliser or manure that might occur. Rarely is there any systematic pruning or disease control. There is some suggestion that fruit set may be less than optimal due to reduced populations of key pollinators, especially bees, as *miombo* woodlands are fragmented and replaced by human-dominated landscapes. For example, Leakey *et al.* (2005b) suggest that the mean number of kernels in marula (*Sclerocarya birrea*) nuts is less than the potential maximum due to inadequate fertilization, either because of insufficient male trees (removed for fuelwood and carving) and/or pollinators. This requires investigation for other species, but if

substantiated, then the role of local households in honey production needs to be emphasized. So too the importance of maintaining adequate densities of male trees for dioecious species. Several authors have reported that removal of trees, especially male trees, has been, if not still, advocated by agricultural extension officers when clearing new fields and gardens (Campbell *et al.* 1991, Chivaura-Mususa *et al.* 2000, Shackleton *et al.* 2003). This needs to be addressed in the curricula of training institutions.

2.2.4.

WILD LEAFY VEGETABLES

Wild leafy vegetables are a significant component of rural peoples' diet throughout Africa, including the *miombo* region (Fleuret 1979, Malaisse & Parent 1985, Zinyama *et al.* 1990, McGregor 1995, Keller *et al.* 2006). Dozens of species are harvested, with marked regional variations. Predominant genera are *Amaranthus*, *Bidens*, *Chenopodium*, *Cleome*, *Corchorus*, *Cucumis*, *Momordica* and *Sonchus*. Many species are most abundant in disturbed sites (although not restricted to them), particularly at the edge of fields, and even amongst crops. In a conventional sense they are often viewed as agricultural weeds, but locals frequently retain them in the field or garden. Most commentators report that there is very little active management, but McGregor (1995) does note that some species are actively planted. As a food source they are richer in minerals and vitamins than domesticated crops, such that their role in food security and combating mineral deficiencies is beginning to be recognised (e.g. FAO 1988, Frison *et al.* 2006, Msuya *et al.* in press.). For example, *Amaranthus* typically has 200 % more vitamin A and carotenoids than cabbage and ten times more iron (Schippers 2000, Kruger *et al.* 2005). Moreover, they are relatively high yielding without much care and are better able than domesticated crops to survive periods of low rainfall. These advantages have also resulted in them being regarded as important safety-nets for times of household stress caused by unfavourable climate, economic situation or illness (Shiundu 2002, Barany *et al.* 2004). Yet overall, there is a strong perception in some areas that consumption of these vegetables is a sign of being backward, and once people are able to grow or purchase domesticated crops, they do so at the expense of these wild leafy vegetables (McGregor 1995, Weinberger & Swai 2006). The World Vegetable Centre regional office in Arusha is attempting to reverse such declines.

2.2.5. WILD MUSHROOMS

Mushrooms are also widely relished throughout the *miombo* region (Wilson 1990, Clarke *et al.* 1996). For example, Lowore *et al.* (1995) reported that locals used 26 species of edible mushrooms from communal lands around a village in Malawi, and McGregor (1995) found a similar number (21 species) at a site in Zimbabwe. Mushroom season is during the rains, usually from November until April, which coincides with the time when food stocks from agriculture are low. Mushrooms are mostly consumed fresh, but a portion of the harvest is preserved and stored for use throughout the year (Lowore *et al.* 1995). There is no active management of mushrooms, other than minimizing disturbance to termitaria, which is the site where several species are found. Some households dry freshly collected mushrooms for use in the dry season.

2.2.6. EDIBLE INSECTS

Edible insects are another important source of nutrition from *miombo* woodlands and the rest of sub-Saharan Africa (van Huis 2003). Whilst a wide variety of species are consumed, a small suite comprises the bulk of local intake (McGregor 1995, Cunningham 1996). The review by DeFoliart (1999) mentions that 65 species of insects are consumed throughout the DRC, 60 in Zambia and 40 in Zimbabwe. As with wild leafy vegetables, the consumption of insects has been undermined by western society's distaste and thus it is probably a declining practice (DeFoliart 1999). Historically, some active management practices were recorded (Wilson 1990, Cunningham 1996), but these rarely apply nowadays. Populations of many species are deemed to be declining as a consequence of fragmentation of the *miombo* woodlands.

2.2.7. BUSHMEAT

Another source of wild protein is obtained through hunting of small mammals, ranging from small rodents to small antelope (Wilson 1990, McGregor 1995). Larger species may also be trapped or hunted, but populations are very low in regions with high human population densities, and so the smaller species comprise

the bulk of the bushmeat intake. In some sub-Saharan countries wild animals constitute over 50 % of all animal protein consumed (Panayotou & Ashton 1992). In many countries it is also a form of recreation with young adolescents hunting small birds and rodents, before graduating to larger game as they mature into adulthood (McGarry & Kaschula in press). Once again, there is limited active management of these populations. Some rodent and bird species benefit from cereal crops in fields and stored around the homestead, as well as lower population densities of their natural predators (e.g. Caro 2001).

2.2.8.

FODDER FOR LIVESTOCK

Livestock play a critically important role in rural production systems and are valued for a wide range of economic and cultural purposes. *Miombo* woodlands provide the basis for extensive grazing as well as browse. The production of fodder in *miombo* is a complex interplay of a number of factors which can be managed individually or in tandem. The primary ones are rainfall, stocking rate, fire frequency and woody plant cover. There is a positive relationship between herbaceous production and rainfall, and a negative relationship with stocking rates, fire frequency and woody plant cover. The slope of these relationships is altered by site factors, most notably soil nutrient status.

Obviously rainfall cannot be managed by local farmers, but they can be opportunistic in their application of other management strategies in relation to the timing and amount of rainfall. For example, whether to burn before or after the spring rains will influence the heat of the fire and immediate post-fire rate of regrowth. Whilst stocking rate and woody cover influence herbaceous production, there is little active management of these variables towards that goal, other than in some areas a portion of land may be designated as reserve grazing for use in the dry season or during drought years. This, and the management of burning frequency and season, are the primary management tools used to actively manipulate fodder production. However, the interplay of fire characteristics with the other variables results in a multitude of potential combinations beyond the ambit of this review. There are several seminal works on fire in *miombo* or neighbouring savanna types, including Trollope (1984), Chidumayo *et al.* (1996), Desanker *et al.* (1997), and Mapuare (2001).

Throughout much of the *miombo* the main application of fire is in the late dry season; typically to stimulate an early flush of fodder for livestock. However, many fires are also simply accidental or negligent because at this time of the year the risk of runaway fires is extreme due to high air temperatures, low humidity and low moisture content of the litter and necromass. Thus, many areas are burnt annually or biennially, whether by design or accident, and any silvicultural management system needs to adapt to this. Burning at the end of the dry season usually results in relatively hot fires (depending on fuel-load, which is a function of the period since the last fire, and herbivore stocking rates) which result in greater mortality of woody stems than do cool fires. Frost (1996) provides a succinct flow diagram of the role of hot, cool and no fire in facilitating or retarding the regeneration of *miombo* after clearance for cultivation or heavily harvested for timber or charcoal.

The high fire frequencies combined with high stocking rates of domestic livestock results in many areas being dominated by less palatable grass species (Cauldwell *et al.* 1999). Thus, even if productivity is high, the nutrient content of these unpalatable species is low, resulting in sub-optimal growth rates and/or condition of domestic stock. However, meat production is rarely the primary reason that households keep livestock, and hence the slower growth rates or reduced adult mass is not an issue of concern to most households. They rather maintain their herds for a variety of goods and services, of which draught power, transport, milk, manure and savings are significant (Campbell *et al.* 2002). Draught power and manure are important inputs into the household arable production systems.

2.3. SERVICE FUNCTIONS OF WOODLANDS

2.3.1. SHADE

Shade is not a direct consumptive use of *miombo* trees, but is an important product that is appreciated by most households. Typically trees retained or planted in the homestead, home garden or arable fields are there primarily to provide fruit or spiritual reasons, but the resultant shade also provided is well appreciated. Workers in the fields rest under the shade of strategically placed trees during the heat of the day; the season-end harvest might be stored under the trees; specific crops might be planted within the shade relative to the non-shaded areas of fields or gardens; the leaf litter is used to enrich soils. The main species are both

indigenous and exotic fruit species, such as *Diospyros*, *Mangifera*, *Parinari*, *Uapaca*. Generally it is only high value species that are retained or planted in fields as this off-sets the negative impacts resulting from competition for light, water and nutrients.

2.3.2. CULTURAL AND SPIRITUAL BENEFITS

Most focus on use and management of *miombo* species has been on the utilitarian aspects, which belies the significant spiritual and cultural dimensions associated with particular species, places and vegetation types as described by Mandondo (1997). Some of these may be of significance to single households or clans, often differentiated by status within traditional structures. Others may be recognised and revered by communities. The maintenance and respect for burial sites and sacred areas can result in markedly lower rates of transformation than adjacent non-sacred areas (Byers *et al.* 2001), and presumably has biodiversity and ecosystem services benefits which spill out into neighbouring transformed landscapes (e.g. pollination services). However, there is some suggestion that these belief systems and values are being eroded with modernisation and migration of people into areas with which they have no ancestral ties (Byers *et al.* 2001).

2.3.3. LAND AND NUTRIENTS FOR ARABLE PRODUCTION

The arable production activities are intimately linked to *miombo*. All fields and gardens are established on land from which much of the *miombo* shrubs and trees were removed, other than perhaps useful fruit and cultural species. The *miombo* soils thus provide a nutrient source for arable production. This is often enhanced or maintained through collection and application of *miombo* leaf litter on the fields (Wilson 1990, Nyathi & Campbell 1993, McGregor 1995). The fences around fields and gardens are usually constructed using *miombo* timber, and the yolks for ploughs and handles of agricultural implements are also made from local timber. Thus, without these inputs from *miombo*, agricultural production would be diminished, or would have to be supported by importing commercial substitutes.

3. EMERGING THEMES IN THE MANAGEMENT OF *MIOMBO* WOODLAND

Section 2 has revealed the diversity of use practices in *miombo*, and has provided an overview of a wide range of active and passive resource management measures practiced by local users. Use and management practices, as we have seen, show considerable spatial and temporal variation, as well as intra-community specificity. The diversity of use, and the variability of use practices underscore the need for location specific interventions and the limitations of “one-size-fits-all” management prescriptions. Furthermore, the evidence of local agency points to the need for participatory approaches that acknowledge the primacy of users as managers and decision makers. This is in contrast to conventional technical wisdom, with its narrow single-product emphasis and a tendency to impose and prescribe rather than work with and assist. On the other hand there is a danger that valuable silvicultural expertise and research findings built up over more than a century be lost, as a result of the failure to effectively apply it in a communal land context, and a pendulum swing towards participatory forestry.

Although the importance of *miombo* woodlands to local livelihoods has long been recognised, it is only in the past two decades that the focus of research has been extended to look at improved management of woodlands in the context of community use. Prior to the 1980s, the focus of research was mainly on ways of managing woodlands for conservation and yields of valuable timber species, totally ignoring local livelihoods dependent upon the *miombo*. Fire management prescriptions and silvicultural systems for timber harvesting were developed through long-term trials and land use comparisons during this period. In this section, we provide a synthesis of literature on *miombo* silviculture, and attempt to better link the information to existing use and resource management practises. The section is organised to reflect broad categories of management.

3.1. SUPPORT FOR INDIGENOUS PRACTICES AND INSTITUTIONS

The lack of responsiveness on the part of external agencies to existing realities of local users, and a lack of appreciation of indigenous resource use and management practices, is a widespread constraint throughout the region. Emphasis is still placed on mono-cropping within commercially orientated systems. The benefits of woodlands and agroforestry systems are well appreciated by local households, but are undermined by those extension officers advocating single species systems. The role of trees in local livelihoods and production systems needs to be better addressed within the agricultural curricula throughout the region.

As described in Section 2 above, *miombo* in settled areas comprises a dynamic mosaic of woodlands and cleared and semi-cleared land used for homesteads, gardens and fields. The spatial and temporal heterogeneity of farming landscapes within the *miombo* zone plays a critical role in sustaining livelihoods, providing a variety of key resources, including grazing and woodland products (Scoones 1990, Campbell *et al.* 2002). It follows from this that silvicultural and other interventions aimed at improving the management of *miombo* need to look beyond the woodland, to the trees, and groups of trees, scattered within the farming landscape. Technocratic and top-down approaches to land reform, land use planning and villagisation often fail to encompass the age-old wisdom of selective clearing, resulting in wholesale land clearing with negative consequences for future resource availability (Grundy *et al.* 1993).

One of the foremost recommendations to emerge from *miombo* management studies and projects is the need for improved partnerships between local people and service agencies. Various projects in the region, both within *miombo* and other forest and woodland types, have shown the effectiveness of working with harvesters and users to promote sustainable practices and put in place or strengthen oversight institutions or associations (Kajembe *et al.* 2003, Geldenhuys 2004). The majority of existing resource use and management practices are mediated through institutions of governance underpinned by cultural and spiritual traditions. The challenge of improved resource management, therefore, relates directly to wider challenges of cultural change and the transformation of institutions of governance at local and national levels. Other papers in this series cover this topic in greater detail.

Throughout southern African savannas local communities are usually powerless to prevent harvesting by outsiders, especially where there is a high external demand

and good prices paid for a certain product in urban markets (Twine *et al.* 2003), as is the case for charcoal, medicinal plants and crafts. In such situations there is a need for local community control supported by traditional and conventional law enforcement agencies. Working closely with local policing or resource management institutions is recommended as a means to strengthen local controls and improve effectiveness of law enforcement.

3.2. MANAGEMENT THROUGH FIRE AND GRAZING

Optimising for grazing and wood products. Bush fires are an endemic characteristic of *miombo*, and have long been used as a management tool in southern Africa. Farmers use fire mainly to improve the quality of grazing within the woodland (Lowore & Abbot 1995). Late dry season fires are favoured, as this is the time when the grass is dry and unpalatable and the effects of fire are deemed to be most beneficial. Late dry season fires have however been shown to be damaging to trees, in particular young trees, than cooler fires early in the dry season or after the rains have begun (Chidumayo 1993). Late season fires burn at higher temperatures than fires after the end of the rains when there is still moisture in the grass and there is less dry leaf litter. Mortality of woody plant seedlings and coppice regrowth is therefore higher as a result of late dry season fires. For this reason, protection from fire during early stages of regrowth, and early season cool burns are usually recommended as a management tool for optimal timber production. As we have seen, however, *miombo* woodlands are valued for a wide range of goods and services, and management prescriptions need to take account of this. Given the interaction between the woody component and the grass layer, and the importance of both these products to local livelihoods, prescriptions are needed that seek to optimise productivity of both.

Managing woodlands for optimal production of grass, browse and wood products requires a balancing act that takes account of several dynamics. Opening up the canopy through felling trees or lopping branches increases the amount of available grazing. However, this also increases the risk of fires, and frequent fires can reduce grass growth. Species composition may also be adversely affected by removing tree cover, with less palatable grass species becoming dominant in cleared areas (Chidumayo *et al.* 1996). Removing tree cover also reduces availability of browse. Leaf flush in *miombo* woodlands coincides with the period of

lowest grazing productivity – the late dry season, and therefore potentially provides some protein to livestock at this time (Scoones 1990, Nyirenda 1995, Gambiza *et al.* 2000), although much is immobilised due to the high tannin content of many species.

Regenerating woodlands require a measure of reduced impacts from browsing and fire in order to promote growth of woody plants whilst they are still within fire and browsing height. On the other hand, livestock depend on access to grazing and browse in the woodlands, especially in the late dry season. The standard recommendation for regenerating woodlands is annual early burning, and a rotational grazing system that gives protection to coppice for at least the first growing season after cutting takes place (Chidumayo *et al.* 1996). Thereafter, high stocking levels are recommended as a way to both reduce the risk of late season fires and improve grazing. Grazing can even replace the need for early burning in woodlands, provided the regrowth is beyond the reach of livestock (Chidumayo *et al.* 1996).

Depending on the type of product required from the woodland, trees can be pollarded above two metres, so that the coppice is out of reach of livestock. Where there is need to cut below this level, a conventional coupe system could be introduced until effective institutional control; a year of cutting followed by a year of protection from grazing. Thereafter, regeneration and grazing can take place together until the next harvest. Where grazing pressure is insufficient to control the risk of late season burns or to remove the moribund layer of grass, a system of rotational early burning, or even late burning (which is more beneficial for herbage production) can be considered by local users. The latter, however, should be avoided in regenerating woodlands for at least 10-15 years after cutting (Chidumayo *et al.* 1996). Patch burning, traditionally practiced in *miombo*, is a practical way to provide a range of environments for production of grass and the regrowth of trees (Chidumayo *et al.* 1996, Forestry Department 1996). The removal of dry wood, grass and leaves from around tree seedlings and coppice regrowth before burning reduces damage to these vulnerable stages.

Fire and non-timber products The productivity of mushrooms is largely unaffected by fire. The main factor influencing availability is the density of tree rootstocks, and as we have seen, *miombo* rootstock is very resilient. Only after destumping do mushroom populations decline.

Many other non-timber forest products, are however, negatively affected by fire, and where these products are locally important, specific measures need to be taken to protect them. For example, in an area of Zambia where edible caterpillars of *Saturnidae* family are widely consumed, the local community, with support from service providers, adopted early burning to reduce the risk of late season fires that destroy the caterpillar eggs. Populations of caterpillars increased noticeably, an example of how technical knowledge, applied specifically, and placed in the hands of local communities can lead to improvements in resource availability. Fire also has negative impacts on herbaceous plants consumed by households, including leafy vegetables and the highly regarded *chikanda*, a tuber of a species in the Orchid family. Specific interventions to mitigate the effects need to be developed and local communities equipped to implement these, as in the example of the caterpillar eggs. Conversely, other species are well adapted to fires, such as bulbous medicinal herbs, and require periodic burning to promote flowering and regeneration.

3.3. PROMOTING REGENERATION AND INCREASED PRODUCTIVITY

3.3.1. WOODY PLANTS

The remarkable regenerating capacity of *miombo* is key to its ongoing productivity. After tree cutting there is rapid regeneration from coppice, root suckering and the large bank of suppressed saplings, known as suffrutices (Boaler 1966, Strang 1974, Chidumayo 1993). These forms of regeneration allow for much faster re-establishment than regeneration from seed, and provide a degree of protection from fire and grazing (White 1976, cited in Pearce, 1993). When conditions become favourable, such as after harvesting when the canopy opens up, and there is a measure of protection from fire and browsing, these suppressed saplings are able to rapidly increase their above ground biomass as a result of their already well established root systems.

Regeneration from coppice is influenced by a number of factors. Firstly, harvesting methods play an important role in stimulating or retarding coppice growth. A clean cut with a saw results in more vigorous coppicing than a jagged cut from an axe.

Certain species coppice better if the rim of the stump is nicked (Lowore & Abbot 1995). The height of cutting also influences coppicing. The greater the height at which the stem is cut, the greater the number of resultant coppice shoots (Shackleton 2001, Kaschula *et al.* 2005). Regrowth on stumps cut higher than one metre above ground will be better protected from fires and browsing animals (Lowore & Abbot 1995).

Subsequent to cutting, coppice regrowth can be managed according to conventional silvicultural practices, that is, thinning the number of shoots to enable those that remain to grow more vigorously. There is a trade-off between number of coppice shoots maintained and length and thickness of the shoots. The more shoots the greater the inter-shoot competition and the longer it will take for re-establishment of apical dominance. If the shoots are not thinned, there will be more shoots, but they will be shorter and thinner than if thinning took place. If the number of coppice shoots is reduced by thinning, browsing or fire, then apical dominance will be re-established sooner, and height growth will accelerate. In such a situation there will be fewer shoots per stump, but longer and thicker. Coppice thinning is seldom practiced by local users because of high mortality rates of shoots due to fire and browse, and because of the high demand for small diameter wood for various purposes (Abbot & Lowore 1995). If, however, large diameter poles are required by users then the conventional silvicultural approach of reducing to one or two shoots would be beneficial in most situations (Department of Forestry 1996). Thinning can be staggered to produce a range of sizes of small diameter stems on a continuous basis. The objectives of the local users, and the rotation period they would like to optimize would dictate whether or not coppice management is required and worthwhile, relative to the other demands and restrictions on their time. Regrowth rates are also influenced by site factors such as the amount of light available to the regenerating plants and soil moisture levels (Lowore & Abbot 1995). Fire and browsing pressure negatively affects rate of growth, especially in the first year after cutting. Trees cut during the dry season dormancy period regenerate better than those cut in the growing period. Some species regenerate better than others, and young healthy trees coppice better than old and senescent trees (Lowore & Abbot 1995).

The suppression of saplings is caused mainly by light competition; when canopy trees are felled the saplings begin to shoot up rapidly and contribute significantly to the stock of additional trees in the stand. Regrowth from coppice and the growth of suppressed saplings usually results in very high stocking rate in young regrowth.

For this reason, enrichment or replacement planting of seedlings is seldom practiced or required (Chidumayo *et al.* 1996). Enrichment planting is however a means to alter the species composition of the woodland, or to ensure regeneration of certain high value species (see below).

3.3.2. NON-TIMBER PRODUCTS

The need for further research into factors affecting fruit production was highlighted in Section 2. In general, the existing management of non-timber products is largely passive. There is therefore much scope for innovative and participative research approaches to seek ways to optimize productivity of these multiple resources and species, but it has to be within a framework of local users priorities, and an acknowledgement that not all resources can be optimized simultaneously. In promoting some, other may be negatively affected.

3.4. SILVICULTURAL SYSTEMS

Three basic silvicultural systems are commonly advocated for the purposes of harvesting *miombo* woodlands: complete coppice or clear cutting; coppice with standards; and selective cutting. Of these, selective cutting most closely resembles existing practices of local users (other than commercial charcoal production where clear felling is the norm) and is the most suitable for the provision of a wide range of wood and non-wood products. The other two systems are better suited to the production of larger dimension wood products, including commercial firewood, large poles and saw-timber.

3.4.1. CLEAR FELLING

Clear felling produces the highest rate of regrowth of the three systems, and is best suited to timber harvesting operations where there is little species selectivity and total volume is of greatest importance. This system is applicable, for example, when harvesting firewood for charcoal industries. Basically, all timber above a certain size is harvested, and the plot is completely cleared, save saplings and undergrowth. Regeneration is rapid, and can be managed according to the products required.

3.4.2. COPPICE WITH STANDARDS

The coppice with standards system, where selected trees are left to grow whilst others are clear cut, is better suited to the production of a range of timber products. It also has the advantage of retaining a portion of tree cover and protecting site from erosion and sun scorch (Department of Forestry 1996). The system is suitable for the production of timber from certain high value species that only comprise a portion of the woodland biomass. The high value timber species are left to grow until they reach maturity, whilst the other species are clear cut and the regeneration is managed to produce a range of small dimension wood products such as firewood and poles. The system has also been proposed for use by small-scale farmers, as a means to maximise the production of firewood and poles whilst retaining high value species that produce non-wood products and other services, such as fruit trees and trees with spiritual significance (Lowore & Abbot 1995).

3.4.3. CUTTING CYCLES IN *MIOMBO*

The standard silvicultural practice of rotational harvesting is recommended for both clear cutting and coppice with standards systems. The basic idea is to divide the woodland into enough blocks to allow for a continuous cutting cycle to be established; by the time the last block, or coupe is cut, the first is ready for re-harvesting. The number of felling coupes, then, is equal to the number of years it takes for the cut trees to regenerate and reach harvesting size, also known as the cutting cycle. Cutting cycles for *miombo* woodland are difficult to determine because of (i) site variation across the region, (ii) the wide range of species harvested, and (iii) the variety of products required. Cycles will also depend on the type of product to be harvested. Some general guidelines for certain products have however been developed from trials in different countries. Based on results from a relatively moist sites in Malawi, cutting cycle of between 3-5 years is recommended for the production of firewood and small poles, 10-15 years for medium sized poles and roofing struts, and 25 or more years for large poles and timber, and 40 or more years for saw log timber (Department of Forestry 1996, Abbot & Lowore 1999). Malimbwi *et al.* (2005) report on potential charcoal yield along a harvesting gradient between a major transport route and a protected forest reserve. Adjacent to the road the estimated yield was 1 bag (56 kg charcoal) per hectare, whereas 10 – 15 km away from the road the yield was 125 bags per hectare. They concluded

that *miombo* forests in that region could be harvested for charcoal approximately every eight years and maintain the standing biomass at approximately 70 % of that in the protected site.

3.4.4.

SELECTIVE CUTTING

Selective cutting follows a different approach to the management of woodland use, one that is more closely allied to current practice and requirements of local users. It is also the system widely practiced throughout the world in old growth indigenous forests with multiple age or size classes. Specific products or species, are harvested through felling, coppice thinning or lopping of branches. In its simplest form, harvesting under this system is not restricted to a single cutting period or areas (coupe) as is common with the other two systems, but is ongoing and takes place throughout the woodland, or the areas zoned for utilisation. Natural regeneration takes place through the usual means of coppice, sapling growth and reseedling, whilst those trees that were not cut continue to grow. Regeneration rates are linked to the extent of canopy clearing, hence the slower regeneration rates under this system compared to clear cutting and coppice with standards systems. Sustainability can be promoted through selectivity, i.e. if only certain types and sizes of wood are harvested from particular species, and trees are left to grow until they reach the required dimensions. This approach provides for harvesting of multiple products, and relies on simple observation for determining when re-harvesting can take place. This does away for need for information on harvesting intervals; information that is difficult to come by because of the wide range of products and variability of production rates.

A more formalised approach to selective cutting is to include forest zonation and a system of rotational cutting compartments as in the other two silvicultural systems. Zonation is used to segment the forest or woodland area into different categories of use and management, such as conservation areas, recreation areas and areas where harvesting takes place. Cutting cycles may be introduced for planning purposes and to guard against over exploitation, but are worked out for each species and product and according to a range of site variables.

In addition to harvesting for specific products, selective thinning may be practiced as management tool to remove dead and dying trees, and improve growth rates of

the remaining trees (Department of Forestry 1996). Pruning of unwanted branches is another management practice to aid growth and improve form of individual trees.

3.5. SYSTEMS AND PRACTICES FOR MULTIPLE USE

The emphasis of silvicultural systems is on wood products, traditionally timber, but recently extended to incorporate other wood products such as firewood and poles of various sizes (Lowore & Abbot 1995, Abbot & Lowore 1995). It has been proposed that coppice with standards and selective cutting systems be used as the basis for multiple use systems that include non-wood products, but information on trade-offs and how to manage these is still lacking. Likewise, very little research has been done on harvesting rates for non-wood products. Information is limited to a few studies that have looked at sustainable harvesting levels for certain products and species. Products that are seasonally available such as fruits do not require harvesting limits. Provided no damage is done to the trees during harvesting, the impacts from fruit removal seem small. Emanuel *et al.* (2005) modeled harvests of *Sclerocarya birrea* subsp. *caffra* at a site in South Africa, and concluded that 92 % of fruit could be harvested without impacting the size class profile of the *Sclerocarya* populations. Their review of the international literature indicated that very little work has been done internationally on impacts of fruit harvesting from indigenous trees, but of the few studies to date, most concluded a similar robustness, i.e. over 80 % of fruits can be harvested with seemingly little effect.

Harvesting of bark for various products including medicine, rope fibre and for making beehives can be highly destructive and result in increased tree mortality (Chidumayo *et al.* 1996). A number of methods for reducing the negative impact of bark harvesting have been proposed and tested, including: obtaining bark from woody material that has already been cut for other purposes, improved harvesting methods that prevent ring barking and reduce fungal infection; substitution such as the use of leaves to obtain medicinal products rather than bark, and the provision of timber beehives as an alternative to the use of bark for making beehives.

Improving co-ordination amongst harvesters has been recommended as a means to optimise use of different products, and prevent wastage in any given harvesting operation. For example, rope fibre can be obtained from coppice thinnings

harvested for roofing (Lowore & Abbot 1995), and the example cited above of obtaining bark for medicinal purposes from harvested timber.

3.6. DOMESTICATION

Enrichment planting in woodlands and the cultivation of useful tree species around homes and within fields and gardens is widely practiced. Propagation methods include nurturing of self-seeded individuals, direct seeding, planting from cuttings and truncheons, and nursery produced seedlings (Deweese 1993, Grundy *et al.* 1993, Abbot 1997). Research into the domestication and artificial propagation of *miombo* species has revealed that many are difficult to propagate using conventional seedling nursery and planting out techniques (Pearce 1993). High mortality rates and slow growth of seedlings has been linked to root damage in the nursery and during planting out, the absence of the required root symbionts, and the natural suffrutex habit that results in minimal above ground growth for the first 10-15 years of a seedlings life (Lees 1962, cited in Chidumayo 1993, Pearce 1993). Most of the work done in the region on propagation of *miombo* species relates to fruit trees. Propagation techniques for a range of high value indigenous fruit trees (*Parinari*, *Sclerocarya*, *Strychnos*, *Uapaca*) have been developed through field trials implemented by NGOs, forestry colleges and universities throughout the region (e.g. Maghembe *et al.* 1994, Prins & Maghembe 1994, Maghembe 1995, Mwabumba & Sitaubi 1995, Akinnifesi *et al.* 2006) and a new book is imminent (Roger Leakey pers. comm. 2007).

Recently Magingo & Dick (2001) reported successful propagation of two *miombo* species (*Brachystegia spiciformis* and *Pterocarpus angolensis*) via leafy stem cuttings, as a technologically simple and relatively inexpensive approach for propagation of clonal material. A more common form of vegetative propagation is planting of truncheons, often in the form of live fences (Clarke 1995). Certain species grow well from truncheons, including *Pterocarpus angolensis*, *Kirkia acuminata*, *Sclerocarya birrea* and species of the genera *Erythrina* and *Ficus* (Epstein 1992).

The misplaced emphasis placed by Forestry departments on tree planting, to the exclusion of improved management of existing resources, should not however, go without comment here. As we have noted, *miombo* species are extraordinarily

resilient and artificial propagation and establishment notoriously difficult. Returns to labour of protecting and managing existing resources far exceed those of woodlot establishment, which still forms the backbone of most rural forestry extension efforts. Furthermore, the planting and early care of tree seedlings is very labour intensive, at the busiest time in the agricultural calendar (Abbot 1997). So although there is a role for strategic interventions towards domestication of high value species, the current emphasis on tree planting by extension agencies needs to be reassessed.

3.7. SUBSTITUTION

Demand management is a natural response to increasing scarcity, and there are many examples from around the region of how local households curb their use of scarce resources (Chidumayo *et al.* 1996), some of which have already been highlighted in Section 2 above. Methods include improved protection of the resource, more conservative use, recycling, and substitution. Substitution is another important demand management strategy becomes more common with increasing scarcity. Ways to support and augment demand management practices are needed, for example through the provision of acceptable substitutes (such as *Eucalyptus* fence posts) or improved technology that reduces consumption (such as improved cook stoves). Potential substitutes for deriving medicinal ingredients currently obtained from bark, such as leaves or bark from coppice shoots needs urgent attention.

4. CONCLUSIONS

Traditionally, because of the low levels of use, high degree of selectivity, high rates of woodland regeneration, and respected and responsive community structures there was little need for conventional silvicultural sustainable yield regulation systems, or other external management interventions in *miombo* woodlands. In Section 2 we presented a summary of the range of ways in which local users of *miombo* actively or passively facilitate ongoing supplies of essential products through selective clearing, highly selective harvesting practices, seasonal, cultural and spiritual harvesting controls and a wide range of demand management measures. Studies have shown that woodland use and management practices are highly responsive to resource availability (e.g. Arnold & Dewees 1995, Campbell *et al.* 2002, Mutamba in prep.), suggesting that in many areas at least, there is still considerable scope to stay within sustainable harvesting limits merely through providing additional support to these practices. The advantages of such an approach are that minimal changes are required and therefore they are therefore more likely to succeed, and they have potential to strengthen local capacity for management through building on existing practices and institutions. There is a growing body of success stories from throughout the region, where local communities have been assisted to improve the management and productivity of their woodlands through small but effective changes to the status quo.

It follows that the type of support and intervention required will vary from place to place, and comprise a number of different elements, depending on the specific opportunities that exist there, and key constraints faced. Likewise, a step-wise sequential approach is advocated, beginning with the most obvious and pressing interventions, and progressing to more complex interventions as the situation demands. Where institutional change or support are unlikely or difficult, for example, planting of key tree or non-tree species on land allocated to households, such as in fields and near homes, is likely to be a better option than community-type initiatives.

Despite a fairly large body of literature calling for the introduction of conventional silvicultural systems for *miombo* management (Hofstad 1993, Werren 1995) backed up by technical recommendations from silvicultural systems trials, there are no reports of such practices having being successfully implemented within communal lands, which comprise the bulk of the *miombo* region. Whilst the principles and techniques of conventional silviculture have much to offer in terms of

improvements to current harvesting practices, the application of these to the complex social and multiple use systems that exist within communal lands has yet to be explored.

Current models and recommendations are limited to the harvest of a narrow range of wood products, and there are still very little known about multiple harvesting systems, trade-offs, complementarities and sustainable harvesting levels. Research agencies (with a couple of exceptions) seem to be stuck in a narrow technical paradigm focusing on a few resources and have failed to contextualize resource use within dynamic models and understanding of how people actually use and rely upon the *miombo* for their very existence. We have presented stark number in this report indicating the significance of *miombo* products to rural livelihoods, which constitute a compelling case for the broadening and reorientation of the silvicultural research agenda in the *miombo* region. Some illustrative examples include (i) up to one-third of livelihood incomes come directly from *miombo* products, (ii) the contribution of GDP to charcoal is almost ten times that derived from commercial high value timber, and (iii) the returns to labour from harvesting and sale of wild fruits are greater than those to either agriculture or livestock husbandry. There are many other examples beyond these, which service as a more than adequate rationale for greater attention to be directed at the full range of *miombo* products and species and the means to optimise production and reduce negative consequences of trade-offs. There is a need to make the resource users key stakeholders in the research and management processes. Adaptive, participatory research approaches need to become the norm (Sayer & Campbell 2004).

The very fact that *miombo* provides so many goods and services, and in significant amounts, to local livelihoods is also the primary management challenge for both local and government institutions. We have demonstrated above that there are both complementarities as well as competition in the supply of different resources. For example, complementarities include how the provision of construction timber also makes available wood for implement handles and fuelwood; maintenance of trees for fruits in arable fields provides litter as fertiliser; the thinning process resulting from continuous harvests results in faster regrowth rates. On the other hand competition is evident in managing for increased woody cover, which results in decreased forage production; harvests of large rings of bark for bee-hives results in tree mortality meaning other products from that tree cease; burning for fodder production impact on woody plant recruitment. Research and management needs

to seek avenues to enhance complementarities and minimise competition. This will require extensive local stakeholder consultation and participation because the relative “importance” of different goods and services differs between communities (Lynam *et al.* 2003).

Whilst recognising that local residents engage in a range of passive and active approaches to enhance the sustainability and productivity of key *miombo* resources, much of this is at the household scale. Traditional management approaches at a larger scale, for tracts of *miombo* and land around villages, are eroding in many areas with modernisation, growing resource commercialisation increasing human population densities, and increasing vulnerability to external shocks and stresses. Commercialisation is particularly virulent as in many instances it involves outsiders supplying urban areas. Outsiders may have little interest in long term measures to minimise any decline in resource productivity. Although the wider social and economic drivers of resource use and management have not been the focus of the preceding sections of this paper, their overriding significance needs to be acknowledged. Unless local residents have adequate governance and enforcement structures and mechanisms the most likely long-term scenario is one of declining resource supply and increasing vulnerability, irrespective of resource management know-how. Recent innovations in developing institutional alternatives to common property regimes, many of which are in transition to open access systems, need further attention (Kowero *et al.* 2003).

Control of resources by local communities also requires that they undertake basic monitoring of trends in resource supply and use, and when necessary adjust local regulations to meet the needs of local users but in a sustainable manner. Typically, rural resource users do monitor in an informal fashion and thus are well aware of changes and trends in the supply of key resources. But this individual monitoring is rarely institutionalised, and so there is no collective response when trends are discerned. Once again, this requires that functional and effective governance structures are in place.

The usefulness of any research programme aimed at facilitating informed and sound management options for *miombo* can be measured to some extent by the degree to which it is based on a dynamic understanding of what constitutes “a livelihood” for most *miombo* dwellers, and how such livelihoods evolve and adapt in response to a number of macro and micro drivers. A research and management approach seeking to prescribe static and mechanistic activities to provide a

prescribed volume or amount of a particular good *ad infinitum* will be outdated before it has even commenced. A number of modeling initiatives have been developed over the last few years from the qualitative or conceptual to the quantitative (Campbell & Byron 1996, Gambiza *et al.* 2000, Campbell *et al.* 2000, 2002), providing varied insights into the dynamic nature of livelihoods, and the primary drivers. In terms of overall livelihood vulnerability, the seminal work of Campbell *et al.* (2002) showed that the three major drivers were the state of the macro economy and people's links to it, rainfall, and the effectiveness of community institutions. Relative to these three, all other variables were negligible. The first two are beyond the control of local people and management agencies, but research can assist in developing and demonstrating approaches and policies to minimise adverse livelihood impacts in times of low rainfall or poor macro economic performance. The third one is definitely locally based and is within the hands of local people and communities.

It is telling that only in the last couple of decades has there be meaningful and systematic research conducted on the nature and dynamics of rural livelihoods in the *miombo* region (Campbell 1996, Campbell *et al.* 2002). Only now are integrated portrayals of livelihoods and their adaptability emerging, providing the impetus for greater understanding of traditional silvicultural approaches and thereby identifying potential synergies with conventional ones. But whatever this picture and understanding may be, it is already being clouded by the inexorable progress of climate change and ravishes of HIV/AIDS. Much of the *miombo*, already characterised by strong seasonality of rain which limits options during the dry season, will get warmer and even drier, although some areas may become wetter (Scholes & Biggs 2004). In those areas that will become drier, farmers and foresters will face further limitations to agricultural and *miombo* productivity, potentially undermining existing livelihood options and exacerbating vulnerability, especially of the poorer sectors of rural society. It is important that current and near-term future silvicultural research and intervention programmes immediately begin to take this into account. One avenue requiring thorough investigation is the potential for carbon credit payments through avoided deforestation. Indeed, greater understanding of the flows and value of all ecosystem services is required, facilitating improved examination of trade-offs between different land uses, and hence the context within which evaluation of new silvicultural practices and approaches can be gauged.

In overall conclusion, this paper has shown that despite there being a significant amount of ecological and silvicultural research from the *miombo* region it is of narrow content and geographic focus. Only in the last decade or two has there been a growing contextualization of management orientated research towards user needs. Whilst this shift is to be welcomed, and this review attempts to collate such work, it is readily apparent that enormous knowledge gaps remain to be addressed. Yet it is abundantly clear, that the greatest gains are likely to be in the realm of institutions, governance and co-operation rather than silvicultural guidelines. But for those agencies involved in silvicultural research a welcome shift to examine the growth rates and responses to harvesting of a wider suite of species and products would be welcomed, including non-timber species. Key focus products and species for such a research efforts should be those most used by rural communities rather than just high value timber species. At the habitat or community level, the impacts of current management systems and harvesting practices on biodiversity of all taxonomic groups, and trade-offs with the delivery of other ecosystem goods and services would be informative.

5. REFERENCES

Abbot, P.G. 1997. The supply and demand dynamics of *miombo*: an analysis of household responses. LTS International, Penicuik.

Abbot, P.G. & Lowore, J.D. 1995. Productivity of some *miombo* woodlands of Malawi – initial results from the establishment of silvicultural trials. In: Lowore, J., Abbot, P.G., & Khofi, C.F. (eds) 1995. Management of *miombo* by local communities. Proceedings of a workshop for technical forestry staff. Forest Research Institute of Malawi and University of Aberdeen.

Abbot, J.I.O. & Homewood, K. 1998. A history of change: causes of *miombo* woodland decline in a protected area in Malawi. *Journal of Applied Ecology*, 36: 422-433.

Abbot, P.G. & Lowore, J.D. 1999. Characteristics and management potential of some indigenous firewood species in Malawi. *Forest Ecology & Management*, 119: 111-121.

Akinnifesi, F.K., Kwesiga, F., Mhango, J. Chilanga, T., Makonda, A., Kadu, C.A. & Kadzere, I., Mithofer, D., Saka, J.D., Sileshi, G., Ramadhani, T. & Dhliwayo, P. 2006. Towards development of *miombo* fruit trees as a commercial tree crops in southern Africa. *Forests, Trees & Livelihoods*, 16: 103-121.

Arnold, J.E.M. & Dewees, P.A. (eds). 1995. Tree management in farmers' strategies. Oxford University press, Oxford. 287 pp.

Backéus, I., Pettersson, B., Strömquist, L. & Ruffo, C. 2006. Tree communities and structural dynamics in *miombo* (*Brachystegia-Julbernardia*) woodland, Tanzania. *Forest Ecology & Management*, 230: 171-178.

Banda, T., Schwartz, M.W. & Caro, T. 2006. Woody vegetation structure and composition along a protection gradient in a *miombo* ecosystem in western Tanzania. *Forest Ecology & Management*, 230: 179-185.

Barany, M., Hammett, A.L., Stadler, K.M. & Kengeni, E. 2004. Non-timber forest products in the food security and nutrition of smallholders afflicted by HIV/AIDS in sub-Saharan Africa. *Forest, Trees & Livelihoods*, 14: 3-18.

Boaler, S.B. 1966. The ecology of *Pterocarpus angolensis* DC in Tanzania. Overseas Research Publications, 12. London.

Botha, J., Witkowski, E.T.F. & Shackleton, C.M. 2004. Market profiles and trade in medicinal plants in the lowveld, South Africa. *Environmental Conservation*, 31: 1-9.

Brigham, T. 1994. Trees in the rural cash economy: a case study from Zimbabwe's communal areas. MA thesis, Carleton University, Ottawa.

Brouwer, R. & Falcão, M.P. 2004. Woodfuel consumption in Maputo, Mozambique. *Biomass & Bioenergy*, 27: 233-245.

Bwalya, S.M. in prep. The contribution of dry forests to rural poverty reduction and to the national economy, Zambia. Accessed at CIFOR website, 18 May 2007.

Byers, B.A., Cunliffe, R.N. & Hudak, A.T. 2001. Linking the conservation of culture and nature: a case study of sacred forests in Zimbabwe. *Human Ecology*, 29: 187-218.

Campbell, B.M. 1987. The use of wild fruits in Zimbabwe. *Economic Botany*, 41: 375-385.

Campbell, B.M., Bradley, P. & Carter, S.E. 1997. Sustainability and peasant farming systems: observations from Zimbabwe. *Agriculture & Human Values*, 14: 159-168.

Campbell, B.M. & Byron, N. 1996. *Miombo* woodlands and rural livelihoods: options and opportunities. In: Campbell, B.M. (ed.). *The miombo in transition: woodlands and welfare in Africa*. CIFOR, Bogor. pp. 221-230.

Campbell, B., Clarke, J.M. & Gumbo, D.J. 1991. Traditional agroforestry practices in Zimbabwe. *Agroforestry Systems*, 14: 99-111.

Campbell, B.M., Costanza, R. & van den Belt, M. 2000. Introduction, overview and synthesis. *Ecological Economics*, 33: 341-351.

Campbell, B.M., Jeffery, S., Kozanayi, W., Luckert, M.K., Mutamba, M. & Zindi, C. 2002. Household livelihoods in semi-arid regions: options and constraints, CIFOR, Bogor. 153 pp.

Campbell, B.M. & Luckert, M.K. 2002. Uncovering the hidden harvest: valuation methods for woodland and forest resources. Earthscan, London. 262 pp.

Campbell, B.M., Vermeulen, S.J., Mangono, J.J. & Mabugu, R. 2003. The energy transition in action: urban domestic fuel choices in a changing Zimbabwe. *Energy Policy*, 31: 553-562.

Caro, T.M. 2001. Species richness and abundance of small mammals inside and outside an African national park. *Biological Conservation*, 98: 251-257.

Cauldwell, A.E., Zieger, U., Bredenkamp, G.J. & Bothma, J. du P. 1999. The response of grass species to grazing intensity in the *miombo* woodlands of Chibombo district of the Central Province, Zambia. *South African Journal of Botany*, 65: 311-314.

Cavendish, W. 2000. Empirical regularities in the poverty-environment relationship of rural households: evidence from Zimbabwe. *World Development*, 28: 1979-2003.

Chidumayo, E.N. 1991. Seedling development of the *miombo* woodland tree *Julbernardia globiflora*. *Journal of Vegetation Science*, 2: 21-26.

Chidumayo, E.N. 1993. Responses of *miombo* to harvesting: ecology and management. SEI, Stockholm. 132 pp.

Chidumayo, E.N. 2002. Changes in *miombo* woodland structure under different land tenure and use systems in central Zambia. *Journal of Biogeography*, 29: 1619-1626.

Chidumayo, E.N. 2004. Development of *Brachystegia-Julbernardia* woodland after clear-felling in central Zambia: evidence of high resilience. *Applied Vegetation Science*, 7: 237-242.

Chidumayo, E.N. & Frost, P.G. 1996. Population biology of *miombo* trees. In: Campbell, B. (ed.). *The miombo in transition: woodlands and welfare in Africa*. CIFOR, Bogor. pp 59-71.

Chidumayo, E.N., Gambiza, J. & Grundy, I. 1996. Managing *miombo* woodland. In: Campbell, B.M. (ed). *The miombo in transition: woodlands and welfare in Africa*. CIFOR, Bogor. pp 175-194.

Chidumayo, E.N. & Kwibisa, L. 2003. Effects of deforestation on grass biomass and soil nutrient status I *miombo* woodland, Zambia. *Agriculture, Ecosystems & Environment*, 96: 97-105.

Chivaura-Mususa, C., Campbell, B.M. & Kenyon, W. 2000. The value of mature trees in arable fields in the smallholder sector, Zimbabwe. *Ecological Economics*, 33: 395-400.

Clarke J. 1995 Building on indigenous natural resource management: forestry practices in Zimbabwe's communal lands. Zimbabwe Forestry Commission, Harare. 55pp.

Clarke, J., Cavendish, W. & Coote, C. 1996. Rural households and *miombo* woodlands: use, value and management. In: Campbell, B. (ed.). *The miombo in transition: woodlands and welfare in Africa*. CIFOR, Bogor. pp 101-135.

Cunningham, A. 1996. Saturnid subsidy: cash and protein from edible caterpillars of Zambesian woodlands. In Campbell, B.M. (ed). *The miombo in transition: woodlands and welfare in Africa*. CIFOR, Bogor. pp 107-108.

Cunningham, A. 2004. Medicinal plants in *miombo* woodland: species, symbolism and trade. In: Lawes, M.C., Eeley, H.A., Shackleton, C.M. & Geach, B.S. (eds). *Indigenous forests and woodlands in South Africa: policy, people and practice*. University of KwaZulu-Natal Press, Pietermaritzburg. pp. 166-167.

Cunningham, A., Campbell, B., Belcher, B. & Achdiawan, R. 2005. Ecological footprints: carving, sustainability and scarcity. In: Cunningham, A., Belcher, B. & Campbell, B. (eds). *Carving out a future: forests, livelihoods and the international woodcarving trade*. Earthscan, London. pp. 199-228.

Cunningham, A.B. & Shackleton, C.M. 2004. Use of fruits and seeds from indigenous and naturalized plant species. In: Lawes, M.C., Eeley, H.A., Shackleton, C.M. & Geach, B.S. (eds). Indigenous forests and woodlands in South Africa: policy, people and practice. University of KwaZulu-Natal Press, Pietermaritzburg. pp. 603-626.

DeFoliart, G.R. 1999. Insects as food: why western attitudes are important. Annual Review of Entomology, 44: 21-50.

Department of Forestry, 1996. Forestry Extension Kit for Field workers in Malawi. Government of Malawi/ UNDP 5th Country Programme, Lilongwe, Malawi

Desanker, P.V., Frost, P.G.H., Justice, C.O. & Scholes, R.J. (eds.) 1997. The *miombo* network: framework for a terrestrial transect study of land use and land cover change in the *miombo* ecosystems of central Africa. IGBP rep. No. 41, Stockholm, Sweden.

Deweese, P.A. 1995. Trees on farms in Malawi: private investment, public policy and farmer choice. World Development, 23: 1085-1102.

Dovie, D.B.K. 2003. Rural economy and livelihoods from the non-timber forest products trade: compromising sustainability in southern Africa. International Journal of Sustainable Development & World Ecology, 10: 247-262.

Epstein, S. 1992. Raising trees from seeds and cuttings. Zimbabwe Forestry Commission, Harare. 39pp.

Emanuel, P.L., Shackleton, C.M. & Baxter, J.S. 2005. Modelling the sustainable harvest of *Sclerocarya birrea* subsp. *caffra* fruits in the South African lowveld. Forest Ecology & Management, 214: 91-103.

Ernst, W.H. 1988. Seed and seedling ecology of *Brachystegia spiciformis*, a predominant tree component in *miombo* woodlands in South Central Africa. Forest Ecology & Management, 25: 195-210.

FAO. 1988. Traditional food plants. FAO Food & Nutrition Paper no. 42. Rome. 593 pp.

Flueret, A. 1979. The role of wild foliage plants in the diet: a case study from Lushoto, Tanzania. *Ecology of Food & Nutrition*, 8: 87-93.

Fortmann L, Antinori C, Nabane N (1997) Fruits of their labours: gender, property rights and tree planting in two Zimbabwe villages. *Rural Sociology*, 62: 295-314

Frison, E.A., Snith, I.F., Johns, T., Cherfas, J. & Eyzaguirre, P.B. 2006. Agricultural biodiversity, nutrition and health: making a difference to hunger and nutrition in the developing world. *Food & Nutrition Bulletin*, 27: 167-179.

Frost, P. 1996. The ecology of *miombo* woodlands. In: Campbell, B. (ed.). *The miombo in transition: woodlands and welfare in Africa*. CIFOR, Bogor. pp. 11-58.

Fox, F.W. & Norwood Young, M.E. 1982. *Food from the veld: edible wild plants of southern Africa*. Delta Books, Cape Town.

Gambiza, J., Bond, W., Frost, P.G.H. & Higgins, S. 2000. A simulation model of *miombo* woodland dynamics under different management regimes. *Ecological Economics*, 33: 353-368.

Geldenhuys, C.J. 2004. Meeting the demand for *Ocetea bullata* bark. In: Lawes, M.C., Eeley, H.A., Shackleton, C.M. & Geach, B.S. (eds). *Indigenous forests and woodlands in South Africa: policy, people and practice*. University of KwaZulu-Natal Press, Pietermaritzburg. pp. 517-550.

Gerhardt, K. & Nemarundwe, N. 2006. Participatory planting and management of indigenous trees: lessons from Chivi district, Zimbabwe. *Agriculture & Human Values*, 23: 231-243.

Gram, S. 2001. Economic valuation of special forest products: an assessment of methodological shortcomings. *Ecological Economics*, 36: 109-117.

Grundy, I.M., Campbell, B.M., Balebereho, S., Cunliffe, R., Tafangenyasha, C., Fergusson, R. & Parry, D. 1993. Availability and use of trees in Mutanda Resettlement Area, Zimbabwe. *Forest Ecology & Management*, 56: 243-266.

Guy, P.R. 1981. Changes in the biomass and productivity of woodlands in the Sengwa Wildlife Research Area, Zimbabwe. *Journal of Applied Ecology*, 18: 507-519.

Huntley, B.J. 1982. Southern African savannas. In: Huntley, B.J. & Walker, B.H. (eds). *Ecology of tropical savannas*. Springer-Verlag, Heidelberg. pp. 101-119.

Hofstad, O. 1993. Woodland management practices in Zimbabwe. In: Pearce, G.D. and Gumbo, D.J. (eds.) *The Ecology and Management of Indigenous forests in Southern Africa*. Proceedings of an International Symposium, Victoria Falls, Zimbabwe, 27-29 July 1992.

Kajembe G.C. Monela, G.C and Mvena Z.S.K 2003. Making community-based forest management work: A case study of Duru-Haitema village forest reserve, Babati, Tanzania. In: Kowero, G. Campbell, B.M. & Sumaila, U.R. (eds) *Policies and governance structures in woodlands of southern Africa*. CIFOR, Bogor. 438 pp.

Kowero, G. Campbell, B.M. & Sumaila, U.R. (eds) 2003. *Policies and governance structures in woodlands of southern Africa*. CIFOR, Bogor. 438 pp.

Kaschula, S.A., Twine, M.C. & Scholes, M.C. 2005. The effect of catena position and stump characteristics on the coppice response of three savanna fuelwood species. *Environmental Conservation*, 32: 76-84.

Keller, G.B., Mndiga, H. & Maass, B.L. 2006. Diversity and genetic erosion of traditional vegetables in Tanzania from the farmer's point of view. *Plant Genetic Resources*, 3: 400-413.

Kruger, M., N. Sayed, M. Langenhoven & Holing, F. 2005. *Composition of South African foods: vegetables and fruit*. Medical Research Council, Pretoria.

Leakey, R.R.B., Shackleton, S.E. & du Plessis, P. 2005a. Domestication potential of marula (*Sclerocarya birrea* subsp. *caffra*) in South Africa and Namibia. 1. Phenotypic variation in fruit traits. *Agroforestry Systems*, 64: 25-35.

Leakey, R., Pate, K. & Lombard, C. 2005b. Domestication potential of marula (*Sclerocarya birrea* subsp. *caffra*) in South Africa and Namibia: 2. Phenotypic variation in nut and kernel traits. *Agroforestry Systems*, 64: 37-49.

Lowore, J.D & Abbot, P.G. 1995. Initial regeneration of *miombo* woodland under three silvicultural systems. In: Lowore, J., Abbot, P.G., & Khofi, C.F (eds). Management of *miombo* by local communities. Proceedings of a workshop for technical forestry staff. Forest Research Institute of Malawi and University of Aberdeen.

Luoga, E.J., Witkowski, E.T.F. & Balkwill, K. 2000. Differential utilization and ethnobotany of trees in Kitulanghalo Forest Reserve and surround communal lands, eastern Tanzania. *Economic Botany*, 54: 328-343.

Luoga, E.J., Witkowski, E.T.F. & Balkwill, K. 2002. Harvested and standing wood stocks in protected and communal *miombo* woodlands of eastern Tanzania. *Forest Ecology & Management*, 164: 15-30.

Luoga, E.J., Witkowski, E.T.F. & Balkwill, K. 2004. Regeneration by coppicing (resprouting) of *miombo* (African savanna) trees in relation to land use. *Forest Ecology & Management*, 189: 23-35.

Lynam, T., Cunliffe, R., Mapaure, I. & Bwerinofa, I. 2003. Assessment of the value of woodland landscape function to local communities in Gorongosa and Muanza districts, Sofala province, Mozambique. CIFOR, Bogor. 111 pp.

Maghembe, J.A. 1995. Achievements in the establishment of indigenous fruit trees of the *miombo* woodlands of southern Africa. In: Maghembe, J.A., Ntupanyama, Y. & Chirwa, P.W. (eds). Improvement of indigenous fruit trees of the *miombo* woodlands of southern Africa. ICRAF, Nairobi. pp. 39-49.

Maghembe, J.A., Kwesiga, F., Ngulube, M., Prins, H. & Malaya, F.M. 1994. Domestication potential of indigenous fruit trees of the *miombo* woodlands of southern Africa. In: Leakey, R.R.B. & Newton, A.C. (eds). Tropical trees: the potential for domestication and the rebuilding of forest resources. IUFRO, London. pp. 220-229.

Magingo, F.S.S. & Dick, J.M. 2001. Propagation of two *miombo* woodland trees by leafy stem cuttings obtained from seedlings. *Agroforestry Systems*, 51: 49-55.

- Malaisse, F. & Parent, G. 1985. Edible wild vegetable products in the Zambezian woodland area: a nutritional and ecological approach. *Ecology of Food & Nutrition*, 18: 43-82.
- Malimbwi, R.E., Zahabu, E. & Monela, G.C. 2005. Charcoal potential of *miombo* woodlands at Kitulangalo, Tanzania. *Journal of Tropical Forests Science*, 17: 197-210.
- Mander, M. 2004. An overview of the medicinal plant market in South Africa. In: Lawes, M.C., Eeley, H.A., Shackleton, C.M. & Geach, B.S. (eds). *Indigenous forests and woodlands in South Africa: policy, people and practice*. University of KwaZulu-Natal Press, Pietermaritzburg. pp. 440-445.
- Mandondo, A. 1997. Trees and species as emotion and norm laden components of local ecosystems in Nyamaropa communal land, Nyanga district, Zimbabwe. *Agriculture & Human Values*, 14: 353-372.
- Mandondo, A. 2001. Use of woodland resources within and across villages in a Zimbabwean communal area. *Agriculture & Human Values*, 18: 177-194.
- Mapaure, I. 2001. The influence of elephants and fire on the structure and dynamics of *miombo* woodland in Sengwa Wildlife Research Area, Zimbabwe. PhD thesis, University of Zimbabwe, Harare. 254 pp.
- McGarry, D.K. & Kaschula, S. in press. Child's play? The consumption of wild foods by vulnerable rural children in South Africa. *Ecology of Food & Nutrition*
- McGregor, J. 1995. Gathered produce in Zimbabwe's communal areas: changing resource availability and use. *Ecology of Food & Nutrition*, 33: 163-193.
- Mithöfer, D. & Waibel, H. 2003. Income and labour productivity of collection and use of indigenous fruit tree products in Zimbabwe. *Agroforestry Systems*, 59: 295-305.
- Msuya, J., Weinberger, K., & Mamiro, P. in press. Iron, Zinc and alpha-carotene potential of indigenous vegetables in Tanzania. *African Journal of Food & Nutritional Sciences*

Munyanziza, E. 1994. *Miombo* trees and mycorrhizae: ecological strategies and a basis for afforestation. PhD thesis, Wageningen University, Wageningen.

Munyanziza, E. & Oldeman, R.A. 1996. *Miombo* tree: ecological strategies and management. *Ambio*, 25: 454-458.

Mutmaba, M. in prep. Farming or foraging? The composition of rural livelihoods in Mafulira and Kabompo districts, Zambia. CIFOR, Harare.

Mwabumba, L. & Situabi, L.A. 1995. Seed pre-treatment, growth and phenology of some indigenous fruit trees of the *miombo* ecozone at Maungu Forestry Reserve, Malawi. In: Maghembe, J.A., Ntupanyama, Y. & Chirwa, P.W. (eds). Improvement of indigenous fruit trees of the *miombo* woodlands of southern Africa. ICRAF, Nairobi. pp. 66- 75.

Mwambo, L.R. 2000. Species utilisation preferences and resource potential of *miombo* woodlands: a case of selected villages in Tabora, Tanzania. M.Sc thesis, University of Stellenbosch, Stellenbosch.

Mwase, W.F., Bjornstad, A., Bokosi, J.M., Kwapata, M.B. & Stedje, B. 2007. The role of land tenure in conservation of tree and shrub species diversity in *miombo* woodlands in southern Malawi. *New Forests*, 33: 297-307.

Nyathi, P. & Campbell, B.M. 1993. The acquisition and use of *miombo* litter by small-scale farmers in Masvingo, Zimbabwe. *Agroforestry Systems*, 22: 43-48.

Nyirenda, W. 1995 Effect of licensed grazing on seasonal variation in cattle weight. In: Lowore, J., Abbot, P.G., & Khofi, C.F. (Eds). Management of *miombo* by local communities. Proceedings of a workshop for technical forestry staff. Forest Research Institute of Malawi and University of Aberdeen.

O'Brien, E.M. 1988. Climatic correlates of species richness for woody edible plants across southern Africa. *Monographs in Systematic Botany of the Missouri Botanic Garden*, 25: 385-401.

Panayotou, T. & Ashton, P.S. 1992. Not by timber alone. Island Press, Washington D. C.

Peters, C.R. & O'Brien, E.M. 1981. The early hominid plant food niche: insights from an analysis of human, chimpanzee and baboon plant exploitation in eastern and southern Africa. *Current Anthropology*, 22: 127-140.

Pearce, G.D. 1993. Natural regeneration of indigenous trees: the key to their successful management. In: Pearce, G.D. and Gumbo, D.J. (eds.) *The Ecology and Management of Indigenous forests in Southern Africa*. Proceedings of an International Symposium, Victoria Falls, Zimbabwe, 27-29 July 1992.

Prins, E. & Kikula, I.S. 1996. Deforestation and regrowth phenology in *miombo* woodland assessed by Landsat Multispectral Scanner System data. *Forest Ecology & Management*, 84: 263-266.

Prins, H. & Maghmebe, J.A. 1994. Germination studies on seed of fruit trees indigenous to Malawi. *Forest Ecology & Management*, 64: 111-125.

Saka, J.D. & Msonthi, J.D. 1994. Nutritional value of edible fruits of indigenous trees in Malawi. *Forest Ecology & Management*, 64: 245-248.

Sayer, J. & Campbell, B.M. 2004. *The science of sustainable development: local livelihoods and the global environment*. Cambridge University Press, Cambridge. 268 pp.

Schippers, R.R. 2000. *African Indigenous Vegetables. An Overview of the Cultivated Species*. Natural Resources Institute/ACP-EU Technical Center for Agricultural and Rural Cooperation. Chatham, UK.

Scholes, R.J. & Biggs, R. 2004 (eds). *Ecosystem services in southern Africa: a regional assessment*. CSIR, Pretoria. 78 pp.

Schwartz, M.W. & Caro, T.M. 2003. Effect of selective logging on tree and understory regeneration in *miombo* woodland in western Tanzania. *African Journal of Ecology*, 41: 75-82.

Shackleton, C.M. 1998. Annual production of harvestable deadwood in semi-arid savannas, South Africa. *Forest Ecology & Management*, 112: 139-144.

- Shackleton, C.M. 2001. Managing regrowth of an indigenous savanna tree species (*Terminalia sericea*) for fuelwood: the influence of stump dimensions and post-harvest coppice pruning. *Biomass & Bioenergy*, 20: 261-270.
- Shackleton, C.M., Botha, J. & Emanuel, P.L. 2003. Productivity and abundance of *Sclerocarya birrea* subsp. *caffra* in and around rural settlements and protected areas of the Bushbuckridge Lowveld, South Africa. *Forests, Trees & Livelihoods*, 13: 217-232.
- Shackleton, C.M. & Shackleton, S.E. 2006. Household wealth status and natural resource use in the Kat River Valley, South Africa. *Ecological Economics*, 57: 306-317.
- Shiundu, K.M. 2002. Role of African leafy vegetables (ALVs) in alleviating food and nutrition insecurity in Africa. *African Journal of Food & Nutrition Science*, 2: 96-97.
- Smith, W., Meredith, T.C. & Johns, T. 1996. Use and conservation of woody vegetation by the Batemi of Ngorongoro district, Tanzania. *Economic Botany*, 50: 290-299.
- Strang, R.M. 1974. Some man-made changes in successional trends on the Rhodesian highveld. *Journal of Applied Ecology*, 11: 249-263.
- Sunderland, T. & Ndoye, O. 2004. Forest products, livelihoods and conservation: case studies of non-timber forest product systems 2: Africa. CIFOR, Bogor. 333 pp.
- Trapnell, C.G. 1959. Ecological results of woodland burning experiments in northern Rhodesia. *Journal of Ecology*, 47: 129-168.
- Trollope, W.S.W. 1984. Fire in savanna. In: Booysen, P. de V. & Tainton, N.M. (eds). *Ecological effects of fire in South African ecosystems*. Springer-Verlag, Heidelberg. pp. 149-176.
- Tuyahabwe, N., Geldenhuys, G.J., Watts, S. & Obua, J. 2007. Local organizations and decentralized forest management in Uganda: roles, challenges and policy implications. *International Forestry Review*, 9: 581-596.

Twine, W.C., Siphungu, V. & Moshe, D. 2003. Harvesting of communal resources by 'outsiders' in rural South Africa: a case of xenophobia or a real threat to sustainability. *International Journal of Sustainable Development & World Ecology*, 10: 263-274.

Twine, W. 2004. Medicinal bark harvesting and yields in woodlands. In: Lawes, M.C., Eeley, H.A., Shackleton, C.M. & Geach, B.S. (eds). *Indigenous forests and woodlands in South Africa: policy, people and practice*. University of KwaZulu-Natal Press, Pietermaritzburg. pp. 533-537.

Van Huis, A. Insects as food in sub-Saharan Africa. *Insect Science & its Application*, 23: 163-185.

Van Jaarsveld, A.S., Biggs, R., Scholes, R.J., Bohensky, E., Reyers, B. Lynam, T., Musvoto, C. & Fabricius, C. 2005. Measuring conditions and trends in ecosystem services at multiple scales: the southern African Millennium Ecosystem Assessment (SAfMA) experience. *Philosophical Transactions of the Royal Society B*, 360: 425-441.

Vedeld, P., Angelsen, A., Sjaastad, E. & Berg, G.K. 2004. Counting on the environment: forest incomes and the rural poor. *Environment Dept Paper no. 98*. World Bank, Washington. 95 pp.

Vermeulen, S.J. 1996. Cutting of trees by local residents in a communal area and an adjacent state forest in Zimbabwe. *Forest Ecology & Management*, 81: 1010-111.

Weinberger, K. & Swai, I. 2006. Consumption of traditional vegetables in central and north-eastern Tanzania. *Ecology of Food & Nutrition*, 45: 1-17.

Werren, M. 1995. A framework for *miombo* participatory management planning and implementation in Malawi. In: Lowore, J., Abbot, P.G., & Khofi, C.F. (eds) 1995. *Management of miombo by local communities*. Proceedings of a workshop for technical forestry staff. Forest Research Institute of Malawi and University of Aberdeen.

Williams, V.L. 2004. Trade and socio-economic value of forest and woodland resources within the medicinal plant market in Johannesburg. In: Lawes, M.C.,

Eeley, H.A., Shackleton, C.M. & Geach, B.S. (eds). Indigenous forests and woodlands in South Africa: policy, people and practice. University of KwaZulu-Natal Press, Pietermaritzburg. pp. 439-472.

Wilson, K.B. 1990. Ecological dynamics and human welfare: a case study of population, health and nutrition in Zimbabwe. PhD thesis, University Collage London, London. 664 pp.

Wong, T., Delang, C.O. & Schmidt-Vogt, D. 2007. What is a forest? Competing meanings and the politics of forest classification in Thung Yai Naresuan wildlife sanctuary, Thailand. *Geoforum*, 38: 643-654.

Zinyama, L.M., Matiza, T. & Campbell, D.J. 1990. The use of wild foods during periods of food shortage in rural Zimbabwe. *Ecology of Food & Nutrition*, 24: 251-265.