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Using Natural Fertilizers in Miombo Woodlands

By Emmanuel Chidumayo

Introduction

Miombo woodlands grow on the ancient central African plateau and its escarpments. They form a swathe across the continent from Angola to Mozambique, and extend from Tanzania and southern Congo in the north, to Zimbabwe in the south. Scientists distinguish miombo from other savanna woodland and forest formations by the presence of legume trees belonging to the genera *Brachystegia, Julbernardia,* and *Isoberlinia.* The climate in the miombo zone is subhumid, characterized by a short seasonal rainfall ranging from 650 mm to 1,400 mm, occurring from November to March, and a long dry season (April to October/November). Miombo is divided with the wetter type (with > 1,000 mm of rainfall) occurring in the north, and drier type (with < 1,000 mm) (White 1983) occurring in the south of the miombo zone.

Miombo occurs on geologically old and acidic (pH 4–6) soils with low fertility. A characteristic association between miombo tree species and ectomycorrhizal fungi significantly increases mineral uptake from the soil. There is higher species diversity in miombo woodlands and associated wetlands or dambos than, for example, acacia woodlands. Miombo is of outstanding international importance for the conservation of plants and birds, many of which are endemic to the region. It provides seasonal habitat for two large, spectacular antelope in Africa, the roan and sable. Miombo trees are typically highly resilient to the annual fires that sweep across the region, and resprout rapidly after anthropogenic disturbance; however, woodland regeneration can be stalled or prevented if trees are uprooted and the connection with ectomycorrhiza is disturbed.

In spite of the inherently low soil fertility, miombo vegetation offers a range of products, including food, medicines, timber, and fuel (Clark, Cavendish and Coote, 1996). A large number of people depend on these products: Campbell, Cavendish and Coote (1996) estimate that in 1990, 40 million rural people inhabited the miombo zone, with an additional 15 million urban dwellers relying on miombo resources.

Various traditional forms of shifting agriculture have developed in response to the low soil fertility. However, under increasing human pressures, shifting cultivation systems tend to break down and are succeeded by more intensive systems that incorporate some form of soil fertility management. All of the traditional farming systems that replace shifting cultivation depend to varying degrees on natural fertilizers stored in the vegetation to improve crop production and are therefore well suited for use in regions with limited resources. This paper features three farming methods that depend on the miombo system's natural plant resources and nutrient recycling. The people who practice these traditional methods probably comprise the majority of rural inhabitants in the miombo zone, which is why these farming systems are important to human welfare.

Fertilizer Stocks in Miombo

Wetter miombo, although richer in tree species (70 species per hectare) (Malaisse 1984) than drier miombo (40 per hectare) (Chidumayo 1997), has low nutrient stocks in topsoil (0–10 cm deep). Stromgaard (1984) estimated that macronutrient content in a wetter miombo topsoil is 2.3 metric tonnes per hectare, about half that in drier miombo (4.8 metric tonnes/ha, Chidumayo 1993). The low fertility in the topsoil of wetter miombo is partly caused by excessive leaching of nutrients to the subsoil by the high rainfall. The prevalent tree species, however, with their deep roots, are well adapted to capturing leached nutrients in the subsoil. Consequently, the nutrient stock in trees is greater than that in the topsoil in wetter miombo. Compared to drier miombo, the higher concentration of nutrients in the vegetation of wetter miombo also results from the larger biomass of trees in the latter (70–150 metric tonnes per hectare compared to 30–70 metric tonnes per hectare in drier miombo) (Frost 1996). Table 1 shows average nutrient content in vegetation in a mature miombo woodland.

It is therefore no accident that agricultural development in the miombo zone has historically been confined to drier miombo areas, where topsoil fertility is higher. For example, although both types of miombo occur in Zambia, agricultural development until the 1960s was concentrated on the plateaus of Central, Eastern and Southern provinces, which are covered with drier miombo. Wetter miombo soils have, until recently, been subject to traditional forms of shifting cultivation that capitalize on the natural fertilizers stored in the vegetation. Further crop cultivation in the miombo zone will be influenced by:

Table 1. Average nutrient stocks in miombo woodland vegetation

Vegetation component	*Biomass ($t\ ha^{-1}$)*	*Nutrients ($t\ ha^{-1}$)*
Woody vegetation:		
Above-ground wood	84.0	3.48
Below-ground wood	29.0	0.86
Leaves	4.0	0.19
Herbs:		
Above-ground (grass)	1.7	0.08
Below-ground (grass)	3.4	0.08
Above-ground (other herbs)	0.4	0.03
Below-ground (other herbs)	1.8	0.07

Source: Chidumayo (unpublished).

- distribution of nutrients in the vegetation and soil
- degree of depletion of the nutrient stocks in the ecosystem
- capacity of farmers to access modern farming inputs, especially artificial fertilizers
- response of miombo soils to artificial fertilizers.

Here these factors are considered in relation to three traditional farming systems in the miombo zone that rely on natural fertilizers for crop production: (1) chitemene (Zambia), (2) fundikila (Zambia), and (3) communal area farming (Zimbabwe) (Table 2). A common feature among them is that they are all practiced by predominantly resource-poor farmers with limited access to artificial fertilizers.

Chitemene Cultivation in Zambia

The Chitemene (meaning "to cut") denotes a shifting cultivation system practiced by the Bemba in wetter miombo along the Congo–Zambezi watershed of northern Zambia. The best known of the three methods, this shifting cultivation system is unique in growing crops in an ash garden (infield) made from burning a pile of branches. These are obtained by lopping and chopping trees from an area (outfield) ten times larger than the ash garden. The pile of wood is burned just before the onset of the rainy season to ash-fertilize the garden and millet is sown in the ash without tilling the soil. The ash consists predominantly of potash (83 percent) and nitrogen (16 percent) (Stromgaard 1984). In addition to fertilization, the potash reduces soil

Table 2. Characteristics of chitemene, fundikila, and communal area farming systems in the miombo zone of southern Africa.*

Characteristic	*Chitemene (Zambia)*	*Fundikila (Zambia)*	*Communal Area (Zimbabwe)*
Ecosystem	Wetter miombo	Wetter miombo	Drier miombo
State of miombo woodland	Deforested where carrying capacity has been exceeded	Extensively deforested	Extensively degraded
Area (sq. km)	126,200	6,200	164,000
Population density (per sq. km)	5.7 (1990)	12.6 (1990)	25.5 (1982)
Average size of cultivated plot per household (ha)	1.5	0.5	2.8
Fallow as percent of total cropland	90	60	0
Natural source of fertilizer	Wood	Grass	Tree leaves and manure
Fertilizer incorporation method	Burning	Burying	Spreading and ploughing

* Based on data from various sources.

acidity by up to 50 percent, improving nutrient uptake by the millet crop that is sown during the first year (Araki 1992, Chidumayo 1987). In the second year, cassava, which matures over a 2–3 year period, succeeds millet before the ash garden is abandoned. During this period, soil acidity increases to the preburn level, and apparently triggers abandonment of the ash garden (Lungu and Chinene 1993).

Although other vegetation types occur in the chitemene zone, local people prefer setting up their gardens in miombo (Stromgaard 1984). It is unclear whether this preference is based on differences in nutrient content available from the trees or differential soil responses to burning in the different vegetation types. Woodland regeneration on ash gardens is extremely slow because stumps and roots, which are the main sources of woodland regrowth, are completely destroyed during the burns. Regeneration of miombo from seed is also extremely slow (Chidumayo 1997). Thus, the infield is severely affected by chitemene. By comparison, woodland recovery in the outfield is rapid; it is estimated that, after 25 years, the regrowth can be reused for cultivation (Chidumayo 1997). The landscape in the chitemene system is therefore made up of scattered spots of old ash gardens, devoid of trees, interspersed with regrowths of miombo of varying ages. The latter are important sources of bush meat, edible fruits, mushrooms, medicines, wild vegetables, honey, edible insects, and firewood (Stromgaard 1985).

The estimated carrying capacity of chitemene is three to four persons per square kilometer, but reductions in fallow periods and dependence on other forest products have allowed higher densities of up to 12 persons per square kilometer in some areas (Stromgaard 1985). Where carrying capacity has been exceeded, fallow periods have often become so short that woodland recovery is impaired and permanent deforestation has become apparent. This is especially the case within 50 km of major roads (Chidumayo 1987). In an attempt to reduce deforestation and promote permanent cultivation, the Zambian government initiated an agricultural development program in northern Zambia in the 1970s, based on hybrid maize monocropping and subsidized cheap artificial fertilizers (NORAGRIC and IUCN 1989). However, continuous use of nitrogen fertilizer (without lime) only increased soil acidity. After four to five years, low maize yields forced farmers to shift to new areas. In areas where land clearing was done by machines, removal of topsoil, coupled with acidification of the subsoil, has impaired miombo woodland regeneration after land was abandoned (personal observations). Thus, a new form of shifting cultivation resulting in soil acidification has replaced the traditional one that never acidified the soil. However, Structural Adjustment Policies in the late 1980s led to the reduction and eventual removal in the 1990s of fertilizer subsidies. This caused the farmers to revert to chitemene cultivation because they could no longer afford the artificial fertilizers (Holden 1996). This renewed dependence on the nutrients stored naturally in the miombo vegetation highlights the importance of maintaining the biodiversity and function of the ecoregion. Current approaches are focusing on agroforestry technologies that involve enrichment planting in fallows, but adoption by farmers has so far been limited (Holden 1991).

Fundikila Cultivation in Zambia

The fundikila (meaning "to mound") system, as practiced by the Mambwe tribe of northeast Zambia, is a compost-based farming system adapted to the secondary grassland that succeeds miombo woodland after repeated clearing for cultivation. Fundikila depends on the release of nutrients by decaying grass buried in mounds.

The cultivation cycle starts with the clearing at the end of the rainy season of grassland that is dominated by certain species of thatching grass (*Hyparrhenia*). During clearing, the grass turfs are buried in mounds to decay while excess grass is stacked, usually around remaining tree stumps, if any, to be burned later in the dry season. Determining the amount of grass that is incorporated in the mound is dictated by the experience and indigenous knowledge of the farmers. A legume crop, such as beans or groundnuts, is sown on the mounds. In the following season, the mounds are broken up and the soil is spread out to form a flat bed on which millet and other cereals are grown. This legume–cereal crop rotation is carried out for four to six years without significant change in soil fertility (Stromgaard 1990). Within the fundikila gardens, small ash spots are made by burning piles of excess grass on which other crops, such as pumpkins, are planted. Unlike chitemene, soil fertility in fundikila systems is actively managed, initially through compost-mounding and later through sequential cropping on mounds and flats made by spreading the mounds in alternate years. Apparently, abandonment of the cultivated plot is triggered by the invasion of weed grasses, which become increasingly difficult to control as the cultivation period progresses. Indigenous knowledge, guided by the reappearance of certain species of thatching grass, determines when a fallow site has recovered and is ready for recultivation.

The fundikila system appears to have evolved as a consequence of miombo woodland depletion (Stromgaard 1989) and is maintained by the use of grass fallows. However, by burning piles of excess grass around stumps during the initial clearing, the fundikila system gradually eliminates the possibility of woodland regeneration and perpetuates a secondary grassland vegetation. In such an environment, scarcity of forest products has become widespread and, in the long term, can be reduced only by tree planting. Nevertheless, the use of grass-composting and the growing of nitrogen-fixing legumes on mounds sustain soil fertility over a longer period relying on a single initial input of ash-fertilizer. Thus, the fundikila system can support more people than chitemene (Table 2).

Communal Area Farming System of Zimbabwe

The communal area farming system (CAFS) of Zimbabwe is a low-input agropastoral farming system in which croplands coexist in close proximity to areas of degraded miombo savanna used for livestock grazing. This system is often used because many farmers rely on cattle manure as fertilizer to maintain maize production. In the first year after the miombo is cleared, maize production is an estimated 2 metric tonnes per hectare (Grant 1967); however, production rapidly falls without further fertilization. Cattle are grazed in the communal miombo grazing lands and kept in pens overnight. The manure is dug out from the pens and spread on the fields before ploughing at the end of the dry season. However, maize is a poor user of soil nutrients (Swift et al. 1989) and the manure has low levels of nitrogen (Mugwira and Mukumbira 1984; Tanner and Mugwira 1984), which is the deficient nutrient in these soils for maize production. Therefore, a large amount of manure must be transferred from grazing lands to support each hectare of arable land (Swift et al. 1989). It has been estimated that between 14 and 42 hectares of grazing land are required to produce enough manure to supply the nitrogen needed to produce 2 metric tonnes of maize per hectare (Swift et al., 1989). Although hardly any fallowing occurs in the CAFS (Table 2), a field is usually manured once every four to five years, and more than half of the farmers supplement this with the direct transfer of leaf litter from miombo savanna to croplands (Campbell et al. 1991b). With such a soil fertility management regime, the CAFS has been able to support up to 26 persons per square kilometer (Whitlow 1988).

The area's high population density, coupled with cattle rearing, creates high pressure for grazing lands. Consequently, the miombo woodlands in the grazing areas are maintained in a degraded state. Cattle fodder in grazing lands consists of herbs, especially grass, and browse of many trees and shrubs. It is estimated that browse supplies form a large proportion of the protein intake of stock during the critical late dry season when there is little grass. The importance of browse is recognized by CAFS farmers who, when possible, plant indigenous browse species, such as *Julbernardia globiflora*, in grazing areas to increase stock feed (Campbell et al. 1991a).

Despite their degraded state, the miombo woodlands continue to supply products such as wild vegetables, mushrooms, insects, honey, firewood, and construction wood. These woodlands have the highest diversity of edible fruits in Zimbabwe, and, in the CAFS, indigenous fruit trees are selectively retained in fields cleared for cultivation (Campbell et al. 1991b). The CAFS illustrates how the sustainability of livestock, maize production, and human welfare depend not solely on isolated plant resources in the miombo woodland, but on the overall biodiversity of the ecosystem. The active management of the landscape to maintain indigenous fruits and enrichment planting in grazing areas with indigenous browse species indicate not only the local farmers' awareness of the variety and value of the miombo resources, but also their concern for the conservation of these resources.

The future

This paper has demonstrated how indigenous knowledge is being applied to manage soil fertility. Three traditional farming systems in miombo woodland depend on natural plant resources and nutrient cycling in the ecosystem. In all three systems, fertilizers stored in plants are used for crop production, although the methods used to transfer them to croplands vary. The systems cannot be replaced easily by modern farming technologies, as government intervention in chitemene in Zambia has demonstrated.

In addition to crop production, rural populations are dependent on miombo for many biodiversity resources for their livelihoods. It is therefore important to consider strategies that enhance conservation of these resources at the same time as promoting sustainable agriculture. However, pressure on miombo woodlands is increasing due to ever growing population pressure. Greater understanding of the biology and land-use practices in this ecosystem are needed through studies such as this one, in order to develop innovative and sustainable approaches that will respond to the needs of the human populations without destroying the resource base and character of the miombo ecoregion.

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Featured Author

Emmanuel N. Chidumayo, a senior lecturer in Biology at the University of Zambia, researches tropical ecology. Over the last 14 years, his research has focused on the ecology and utilization of regional woodlands, as well as methods for propagating and regenerating woodland species. Specific research topics have included assessing 1) regeneration of indigenous woody plants from seed, 2) productivity of *Leucaena leucocephala* as an agroforestry species, and 3) responses of miombo woodland to clearing for charcoal production. He has participated in the preparation of six national and international policy papers for Zambia. He also served on the senior advisory committee for BSP's Biodiversity Analysis for Africa Project and was a contributor to the final report, *African Biodiversity: Foundation for the Future*.

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