Land Use Impacts on Miombo Woodland Species in Wenimbi Resettlement Area of Macheke, Zimbabwe.

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Abstract

The miombo woodlands are used in a diversity of ways that influence biodiversity and ecosystem stability most of which threaten woodland and agro-ecosystem sustainability. The study assessed the influence of three farming activities, namely tobacco, maize and horticulture production on *Brachystegia spiciformis* and *Julbernadia globiflora* tree species, which are dominant and are used in most household, construction and energy purposes. The fate of the timber harvested from the woodlands is important as it gives a clue on the most destructive farming activities and the size of trees required. Indicators to determine levels of deforestation, and capacity to regenerate were tree and stump populations per ha. For tree size preference, root collar diameter, stump and tree heights, and the ability of the remaining stumps to coppice were assessed.

Residual tree density was lowest ($P < 0.001$) on the tobacco sites compared to the other two sites that also differed significantly. Stump population was highest in woodlands where maize is actively grown in comparison to horticultural and tobacco sites. However stump survival and coppicing capacity were significantly higher ($P=0.000$) in woodlands of maize and horticulture active growing farms. Overall, there is selective and preferential utilization of woody biomass by size depending on the fate of the biomass though this does not reflect itself by species. It is concluded that the agricultural activities influence the cover of the two tree species and this could have detrimental effects on the *miombo* ecosystem and on the sustainability and viability of the farming activities especially tobacco production that has impacted mostly on bigger diameter trees whilst horticulture production is affecting the smaller diameter trees leaving the older trees.

Key words: *Brachystegia spiciformis*, *Julbernadia globiflora*, Forest sustainability, Criteria and indicators.

Introduction

Forest sustainability involves maintaining and enhancing the contribution of forests to human well-being, both of present and future generations, without compromising their ecosystem integrity, i.e., their resilience, function and biological diversity (Sayer et.al, 1997). Similarly, the concept of sustainable agriculture is a relatively recent response to the decline in the quality of the natural resource base associated with modern agriculture (McIsaac and Edwards, 1994). The concept, although controversial and diffuse due to existing definitions and interpretations of its meaning, it is useful because it captures a set of concerns about agriculture which is conceived as the result of the co-evolution of socio-economic and natural systems (Reijntjes et al, 1992).

The effects of land use and forest cover change influence global and regional climate processes, which may subsequently alter the patterns of productivity, resource availability and biodiversity (Frost and Desanker, 1998). The range of forests exposed to human disturbance has increased, with particular pressure now on the tree species occurring in the rich tropical forest ecosystems. Between 1980 and 1990, 8.4 % of the closed forest on the African continent underwent some form of land use conversion (Food and Agricultural Organisation, 1993). Clearing of tropical forests has created a highly modified landscape where remnant patches of native flora are set in a matrix of agricultural lands and urban-residential development (Holl, 1999). Loss of biodiversity in the tropics is directly related to forest clearing, which decreases total habitat area (Dale, O'neal; Southworth and Pedlowski, 1994). In tropical forests, fragmentation has been shown to affect genetic diversity and some forest tree species.

A wider understanding of the agricultural context requires the study between agriculture, the global environment and social systems given that agricultural development results from the complex interaction of a multitude of factors (Altieri, M.A 2004). Both economic and social factors affect the degree of forest sustainability. The important objective of this investigation is to disaggregate the impact of key farming activities that can be measured either quantitatively or qualitatively on the ground basing on the dominant *Brachystegia spiciformis* and *Julbernadia globiflora* species.

Methods and Materials

Study area

The Wenimbi Resettlement area lies 18^{o} 30' south and between the 31^{o} 30' and 32^{o} east. The resettlement farms, established in 1985, from commercial farms comprise of 49204 hectares of which 48 % was arable. It lies in Natural Farming Region 2, which is described as an intensive farming region based on crop production. The mean annual rainfall ranges from 800 to 1000 mm mainly falling between December and April. The temperature ranges from 5 to 25 ^{0}C with frost incidences frequent between May and July. The soils are predominantly paraferralitic soils, which are moderately deep, coarse-grained sands over pale loamy sands formed from granite.

The topography ranges from gently undulating with wide ridges and large vleis broken by granitic kopjes to narrow ridges and deeply incised streams with occasional hills and mountains. The altitude ranges between 1300 m and 1400 m above sea level (Lightfoot 1972; Agritex 1984). The vegetation is predominantly *Brachystegia spiciformis* (*musasa*) and *Julbernadia globiflora* (*munhondo*) woodland with mixed tree vegetation in the kopjes and hills. The grasslands are dominated by *Hyparrhenia* species with associated grass species being *Aristida*, *Digitaria, Stereochlaena* and *Loudetia*. This *Musasa-Munhondo* woodland covers most of the plateau country of Zimbabwe where it is commonly known as the *Miombo* vegetation in Central African countries (Lightfoot 1972; Agritex, 1984).

Sampling plots

Sampling for deforestation and impacts of the farming activities were carried out for *Brachystegia spiciformis* and *Julbernadia globiflora* species. The design used was circular plots with a radius of 17.85 m, resulting in a sample area of 1000 m^2. The sample plots were laid in woodlands of three land-use sites namely, areas active in tobacco production, maize growing and horticulture biased towards tomato production.

Measurements

The parameters measured were, tree density, root collar diameters and heights of stumps and residual trees. The stump density was measured in order to determine the number and sizes of trees that have been cut (an indicator of deforestation) together with the number of live and coppicing stumps and number of shoots on each stump, as indicators of regeneration. Determination of coppices was also done to investigate coppicing vigour by species, land-use site and stump size. Stump heights were determined using height rods to the nearest centimeter. Root collar diameter was preferred for breast height diameter for ease of reference of actual tree size to stumps since some of the stumps were below Diameter at Breast Height (DBH) level. Measurement of root collar diameters was done using diameter tapes to the nearest centimeter. Standing tree heights were measured using a Suunto hypsometer (Helsinki, Finland) to the nearest centimeter only for trees above 2 m in height.

Statistical analysis

The data was analysed using Statistical Package for Social Sciences (SPSS Version 6.1, 1994). The model for data analysis was as follows:

$$Y_{ijk} = \mu + S_i + F_j + (S \times F)_{ij} + e_{ijk}$$

Where: Y_{ij} is the dependent variable (e.g. stump density, root collar diameter), μ is the overall mean, S_i is the tree species effect, F_j is the farming activity effect, $(S \times F)_{ij}$ is the interaction between tree species and farming activity, and e_{ijk} is the residual error. The difference between means was separated by the Least Significance Difference (SPSS, 1994).

Results

The density of the residual trees for the two species was significantly (P = 0.000) different among the three sites. The maize-growing sites had the densest woodlands (123trees/ha) while the horticultural sites had 77 and the tobacco-growing sites had woodlands with a population of 7 trees/ha. However, the two species did not differ significantly (P > 0.05) in density within the sites with 68 trees/ha for each of them. The results of residual tree characteristics on the woodlands are shown in table 1.

Table 1: Residual standing trees as indicators of deforestation.

Woodland site category	**Species**	**Residual Tree density** (stems/ha)	**Mean height (m)**	**Root collar diameter (cm)**
Maize lands	*B. spiciformis*	141.100±3.146	7.010±0.120	13.020±0.232
	J. globiflora	99±3.58	6.4±0.134	15.788±0.260
Horticultural	*B. spiciformis*	65.2±1.406	6.520±0.74	21.293±0.362
	J. globiflora	90.077±1.511	10.627±0.80	26.154±0.388
Tobacco	*B. spiciformis*	4.125±0.539	2.723±0.113	4.387±0.2.7
	J. globiflora	7.000±0.508	2.773±.0107	6.000±0.195
Significance	Site	***	***	**
	Species	n.s	n.s	n.s
	Site x Species	n.s	*	n.s

* = P < 0.05, ** = P < 0.01, *** = P < 0.001, ns = not significant

The mean height of the residual trees was significantly different (P = 0.000) among the three sites. The maize and horticultural sites had higher mean heights of 6.8 and 8.5 m, respectively, compared to the tobacco site with 2.7 m. There was a significant (P = 0.00) site and species interaction for the mean heights of standing trees. The mean height of B. *spiciformis* and *J. globiflora* at the maize and tobacco sites were not different (P > 0.05). However, at the horticultural site, the mean height of *J. globiflora* was greater (P = 0.001) than that of *B.*

spiciformis and this contributed to the observed significant difference in the interaction. There was a significant tree height difference between the species with *B. spiciformis* having 5.17m and *J.globiflora* with 6.84m.

The root collar diameters of remaining trees for the two species did not differ significantly (P > 0.05) within sites but however were significant (P < 0.01) across the three sites. Trees within the woodlands on horticulture sites had the greatest mean root collar diameter of 24.2cm followed by trees in the maize site, 14.4cm, and the tobacco sites with 5.2cm. The stump density/ha, mean stump height and stump root collar diameter of the two tree species within the three sites is shown in Table 2.

Table 2: Stump population and characteristics as indicators of deforestation.

Woodland site category	**Species**	**Stump density** (Stumps/ha)	**Stump height** (m)	**Root collar diameter** (cm)	**Surviving stumps** (Number of coppicing stumps/ Total number of stumps) per ha (%)	**Shoots /stump**
Maize	*B. spiciformis*	381.2±4.308	0.579±0.40	20.00±1.953	99.900±4.217	9.8±1.983
	J. globiflora	201.25±4.816	0.646±.45	21.125±2.163	73.5±4.714	6.375±2.218
Horticultural	*B. spiciformis*	366.6±2.209	0.385±.043	6.067±0.738	99.667±2.811	6.667±0.935
	J. globiflora	101.538±2.373	0.416±0.046	7.846±0.793	98.846±3.019	6.15±1.004
Tobacco	*B .spiciformis*	56.250±3.669	0.723±0.111	32.00±5.421	33.875±1.423	3.125±1.479
	J. globiflora	98.00±3.459	0.810±0.104	44.899±5.111	22.000±1.341	1.222±1.394
Significance	Site	***	***	***	***	***
	Species	***	*	n.s	n.s	n.s
	Site x Species	***	n.s	n.s	n.s	n.s

* = P < 0.05,   *** = P < 0.001, ns = not significant

Stump density was greatest for the woodlands on maize growing sites (292 stumps/ha) followed by the horticultural sites, with 237 and lowest on the tobacco site, 83 stumps/ha. Significant differences were P=0.008 between woodlands in the maize and horticulture sites, P=0.000

between the maize and tobacco growing sites and finally between woodlands in the horticultural sites and tobacco growing sites P=0.000. Stump population was also significant (P=0.001) by species. A higher order interaction of species and site was as well significant (P = 0.001) on stump density.

The stump height was significantly higher (P = 0.001) at the woodlands in tobacco sites with a mean of 0.77m, whilst the maize sites had 0.61m, though significantly higher (P = 0.01) than the horticultural sites of 0.40m.

There was a significant (P = 0.000) difference across the three sites on stump root collar diameters. The mean stump root collar diameter for the tobacco site was greater, 38.7cm, than that of the maize sites of 20.8cm and for the horticultural sites of 7.1cm. The stumps of the two species showed a significant difference (P=0.047) against root collar diameters of 19.9 and 24.47 for *B. spiciformis* and *J. globiflora* respectively across the sites.

Regeneration results of the two tree species on the three sites as shown in Table 2 indicate that percentage survival of the stumps was mainly influenced by site effect while species had no effect. Horticultural sites had a higher (P = 0.001) stump survival of 99.25% than the maize and tobacco sites with 86.7 and 27.94 respectively.

The number of shoots per stump was significantly lower (P < 0.001) for the tobacco site with a mean of 2 shoots/stump compared to that of the maize, with 8 and horticultural sites with 6 between which there was no significant difference (P > 0.05).

Discussion

Numerous studies have evaluated sustainable farming systems (Lockeretz, 1988; Roberts and Lighthall, 1992). Farmers use *miombo* landscapes in a fine-grained manner, exploiting localized patches of higher fertility for cropping and avoiding areas of particularly poor soils (Carter and Murwira, 1995). The poorer sites are mostly left out as woodlands and the vlei areas are used for growing cereals and root crops during the wet season, and for vegetables and grazing livestock during the dry season (Bell, 1982). Land use in miombo reflects a range of adaptations by farmers to intrinsic constraints and opportunities of climate, landscapes, soils, vegetation, pests and disease thus ending up with specific production sites.

However the *miombo* ecosystem, once exposed to adverse conditions tends to degrade very rapidly hence the need to exercise sustainable farming. Regardless of perceived benefits, transition problems often limit the adoption of sustainable farming practices (Auburn, 1994, Taylor and Dobbs, 1990). The findings of the current study show that the two species on the remaining non-arable for the three woodland categories are affected equally. The dominant species are used as indicators of sustainability since their population per unit area is easier to determine. The three woodland site categories are affected differently by farming activities in the resettlement area due to variations in demands for woody resources. Variation in stump population and tree density indicates the rate of deforestation by farming activity and may be used to indicate wood biomass deficit for agricultural and household needs as a result of selective and preferential utilization of the *miombo* woody resource. Woodlands in tobacco growing farms have the lowest tree density (6 trees/ha) and mean stump population, 77/ha, indicating a very high rate of deforestation by number of residual trees/ha though stump density is far lower compared to the other two sites. This is explained by historical deforestation around this site for tobacco curing and the older stumps have been uprooted or rotted, leaving very small trees in the woodlands. This is supported by stump sizes with mean root collar diameters of 38.45cm and tree root collar diameters of 5.19cm. The preference of trees with bigger diameters is biased towards heavy biomass loads for tobacco curing, which burn longer. Tree density in woods where there is active maize production have a tree density of 125/hectare against stump density of 291 stumps/ha showing a much more reduced demand for the heaviest biomass though there is a higher stump population compared to residual standing trees. Woodlands in horticultural sites with a density of 78 standing trees compared with 234 stumps shows that deforestation is taking place but with preference for small diameter trees for use as banana and tomato props and fencing poles as indicated by stump mean root collar diameters of 6.2cm whereas the standing trees have mean root collar diameters of 23.7cm. The remaining trees have not yet started to experience intensive felling for fuel-wood compared to maize-land woodlands though this may follow shortly after trees in tobacco growing sites are depleted.

Such a trend can also be indicated by mean stump height where timber cut for fuel wood leaves higher stumps 0.61m in woodlands in maize growing areas and 0.76m in woodlands on tobacco farms since the trees cut are much bigger and have to be felled when one is in an ergonomically comfortable position by means of an axe, whereas the desire to fully utilize a pole and the ease with which one can cut a smaller tree results in shorter stumps (0.40m) left in the horticulture site woodlands. Surviving stumps per hectare by site indicated significant variation among the sites since the woods in horticulture site, with medium sized trees, had the highest survival, (99.26 %) as a result of the youthfulness of the trees at felling followed by maize-land site woods with a survival percentage of 86.7 and finally the tobacco-land site woods with 27.9%. Woodlands on tobacco production farms indicated very significant stump mortality compared to the other two sites as shown by stump population. This also applies to coppicing vigour where the younger stumps in maize and horticulture site woods have 8 and 7 shoots/stump compared to tobacco woodland sites with only 2 as a result of loss of coppicing vigour with age with the younger trees coppicing better compared to the older ones.

Impacts on *miombo* woodlands have been reported in different Southern African regions and more than 80 percent of people living in miombo landscapes depend on fuel wood and charcoal for cooking, heat and light (Misana et al, 1996). Distribution of these impacts varies with the economic activity of the site. Woodlands in maize farms lose an average of 34 trees/year and it is projected that it only requires 7 years before the trees are cleared. Woodlands in horticultural sites are getting deforested at a rate of 27 trees/year and will, without considering selective cutting take 6 years before the land becomes bare. The worst scenario is in tobacco-farm woodlands where the rate is at 9 trees/year and all the remaining standing trees will be cut within a year.

In Zambia cutting of woody vegetation for the production of charcoal, especially close to major roads and large urban centers is having a marked impact on the miombo vegetation. It is estimated that between 1937 and 1983, 51% of the Copperbelt region had been deforested for both industrial and household wood fuel (Chidumayo, 1987) and in Tanzania, increased clearing of land for agriculture and grazing is a growing problem (MacKinnon and MacKinnon, 1986). Like the Wenimbi resettlement farms, deforestation has resulted in heavy deterioration of the miombo woodlands. Tobacco site categories are the hardest hit. Growing tobacco for export has lead to large losses of woodland for both land and fuel wood (Moyo et al, 1993). The curing of tobacco is presently carried out using charcoal or fresh green wood, compounding environmental problems (Misana et al, 1996).

From a management perspective, agro-ecological principles must be applied to provide a balanced environment, sustained yields, biologically mediated soil fertility and natural pest regulation through the design of diversified agro-ecosystems and the use of low input technologies (Gleissman, 1998). Preferential and selective utilization of trees by size and species threatens the sustainability of woody resources, which are very essential in rural livelihoods. Individually or interactively, it affects the patterns of land use and productivity. The changes in land cover and ecological functioning have long term socio-economic impacts, as well as a range of environmental impacts and thus affecting ecological functioning, carbon storage, trace gas emissions, hydrology and regional climate (Justice et al, 1994). In addition, *miombo* woodlands are a habitat for different organisms and the modifications through the widespread removal or simplification of indigenous vegetation quickly changes the composition of arthropod and vertebrate communities above ground, whilst changes to the soil fauna may occur more slowly (Hunter, 1994).

Changes in land use and land cover in *miombo* potentially affect a wide range of socio-economic and environmental processes. Reductions in the area of uncultivated woodlands reduces the availability of fuel wood, construction material and non timber forest products; diminish the area of communal grazing land; and adversely affect the ecological services provided by trees. Reductions in tree canopy cover can adversely affect local, and possibly regional, climates through effects on albedo, air temperatures and relative humidity (Frost and Desanker, 1998), while the reduced leaf area means lower evapotranspiration rates, greater recharge of groundwater and changes in hydrological functioning downstream (McFarlane and Whitlow, 1990) therefore agro-ecosystems that mimic nature must be practised (Pretty 1994) and to be successful sustainable farming must be adapted to the conditions of each site (Lockeretz and Anderson, 1993). Emphasis must be placed on developing farming practices that fit the specific biophysical and socio-economic environments of each farm (Drost et al, 1996).

Conclusion

The rate at which deforestation has taken place in the resettlement area over the eighteen years is unsustainable. The environmental role played by the *miombo* woodlands as a cover of the non-arable land is ignored and the application of sustainable agriculture needs more emphasis without which a multitude of environmental problems ranging from soil erosion, loss of wildlife habitat, reduction of soil fertility, complete transformation of the landscape and finally unavailability of the woody resource for sustenance are anticipated.

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