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Full Length Research Paper

Plant species diversity on marginal and degraded areas for *Jatropha curcas* L. cultivation in Malawi

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This study examined plant species diversity on marginal and degraded land earmarked for cultivation of *Jatropha curcas*. A rapid biodiversity assessment of plant species was conducted using visual encounter survey on patches of degraded fallow land and uncultivated marginal areas within commercial and subsistence agricultural landscapes. Measures of species diversity and richness were assessed using Shannon-Wiener Index (H´) and Simpson's (D´) indices to assess the effect of intensified cultivation on biodiversity. Results indicate that cultivation and intensified farming significantly influenced floristic composition within agricultural landscapes. Fallow areas were floristically rich in herbaceous plants that are adapted to frequently disturbed sites but poor in trees as opposed to uncultivated areas. Uncultivated areas recorded some endangered species including high value *Pterocarpus angolensis*. *J. curcas* cultivation should concentrate on degraded fallow areas as they contain species that are adapted to frequent disturbance while uncultivated areas within agricultural landscapes that have higher potential for conservation of indigenous woody species should be spared as village conservation sites.

Key words: *Jatropha curcas,* species diversity, village conservation areas.

INTRODUCTION

The decline of biodiversity in agricultural landscapes due to increasing demand for agricultural land and intensified farming is of increasing concern (Matson et al., 1997; Clough et al., 2007). Consequently, conservation of plant species within patches of marginal and degraded areas has been considered to be a step towards reversing this trend (Hutson, 1993). Furthermore, these areas are excellent reserves for conservation of agrobiodiversity which is vital for maintaining a stable agro-ecosystem (UNEP, 1999). Conservationists prioritise marginal and degraded areas as a mechanism to reduce competition with food production (Bai and Dent, 2006). Worldwide critical fuel shortages accompanied with high prices as well as the global issues of climate change due to global warming has prompted Governments and nongovernmental organizations to search for alternative sources of energy, which are renewable, safe and non-polluting. In this regard, renewable vegetable fuels such as Jatropha *curcas* are being promoted for cultivation in marginal and degraded land (Jimu et al., 2009).

Proponents of biofuels consider marginal areas as potential sites for growing bioenergy crops as a way of reducing competition with food crops (Del Greco and Rademakers, 2005). Because *Jatropha* belongs to the succulent Euphorbiaceae family it survives well in tropical low precipitation areas (<600 mm per annum) (Jongschaap et al., 2007) but seed production is likely to be minimal and therefore cultivation is economically not

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Abbreviations: Pt. ***angolensis*,** *Pterocarpus angolensis*; **P. *angolensis,*** *Pericopsis angolensis.*

viable. Higher water availability due to higher precipitation or irrigation does not automatically increase seed yield but is a prerequisite. Bio Energy Resources Limited (BERL) which in Malawi is promoting the growing of *Jatropha curcas* through mobilising small holder farmers into contracts on land they perceive as degraded and unproductive. However, studies by Leonard (1989), Fan and Hezell (1997) and World Bank (2005) showed that most poor people are shifted to marginal areas. Due to shortage of productive land farmers clear more areas including ecologically fragile ones without conservation concerns leading to land degradation. Degraded areas are left as fallow to naturally regain vegetation and provide several products and ecological services. *J. curcas* for biofuel production planted in these areas is said to be conservation oriented. However, no studies have been conducted to assess the current status of plant species diversity in marginal areas within agro-ecosystems. The purpose of our study was to determine the effect of cultivation and intensified farming on diversity of plant species within agricultural landscapes.

METHODOLOGY

Study areas

The study was conducted in two districts and three Extension Planning Areas (EPAs) in Kasungu (Kaluluma and Santhe EPA) and Mzimba (Mpherembe EPA) in the northern and central regions of Malawi (Figure 1). The sample frame for enumeration of plant species was marginal and degraded areas earmarked for *J. curcas* cultivation which was obtained from BioEnergy Resources Limited (BERL) in Mzimba and Kasungu district offices. Marginal and degraded areas are scattered, remote and patchy pieces of land with high variation at local scale. Therefore, the survey used a two-stage cluster sampling to draw sample units (Reed and Mroz, 1997).

First, in each of the two districts, villages were randomly selected from the list of participating villages. Secondly, patches of marginal and degraded areas within cultivated and uncultivated areas were randomly selected for the survey. In Kasungu both commercial and subsistence landscapes were sampled to assess the effect of intensified farming. A group of smaller homogeneous units in terms of degree of anthropogenic activities were taken together to make up the sampling unit. A fixed area sampling approach was used in which rectangular plots of 10 by 20 m plots were laid to capture habitat heterogeneity. The number of plots was determined proportional to patch size and a total of 39 plots were laid out based on 2% sampling intensity. Details of plots per site are presented in Table 1 below. Plots were laid at a distance of 250 m from one another and 50 m away from roads, gardens or homes. The starting point of plot was determined randomly and a 20 m base line was laid following true north campus direction. The plots were extended on either side of the base line by 5 m. Global Positioning System (GPS) was used to locate the plots and geographic coordinates were taken at the centre. The plots were overlaid on national map themes obtained from Malawi's National Spatial Data Centre (NSDC) using ArcView GIS (Applegate, 2002).

A rapid biodiversity assessment was conducted using visual encounter survey in March, 2009. Prior to the survey, a reconnaissance was conducted in November, 2008 through which a general idea of marginal and degraded areas for *J. curcas* cultivation was obtained. Patches of marginal and degraded areas were used as a basis for sampling. All plants including regenerants, saplings, shrubs, large trees and herbs in the plot were identified by their scientific name or local name, counted and recorded. Trained local people were involved in species identification using local names and the corresponding scientific names were checked in the Dictionary of Plant Names in Malawi (Binns, 1972). Samples of unidentified plants were collected using plant press and later identified by taxonomists from Forestry Research Institute of Malawi and the National Herbarium and Botanical Gardens where voucher specimen were deposited.

Data analysis

Data was processed and analysed using Microsoft Excel and BioDiversity Professional (McAleece, 1997). The data was analysed using descriptive statistics and diversity indices. Anthropogenic disturbances and/or spatial variations of environmental factors are assumed to lead to changes in plant communities by narrowing the number of species and change their abundance. The following indices were considered in the analysis of species richness, diversity and evenness.

Species richness S denoted the number of species present in a patch. Diversity was measured using Shannon-Weiner (H), and Simpson's indices (1949). Simpson's index measures concentration of species and yields values on a probability scale from 0.0 to 1.0 in ascending order with increased diversity and it was calculated as:

$$1/D = 1 \Bigg/ \frac{\sum_{i=1}^{s} n_i (n_i - 1)}{N (N - 1)}$$

Where S is the number of species, n_i number of individuals belonging to the ith species and N the total number of individuals in the sample.
Shannon-Wiener index (*H')* was calculated as:

$$H' = C \sum_{i=1}^{s} p_i \log p_i$$

Where C is a constant and p_i can be estimated by n_i/N.
Evenness was estimated using Pielou's evenness or equitability index expressed by Siccha Rojas and Lindegarth (2003) as:

$$J = \frac{H'}{H'_{\max}} = \frac{H'}{\log S}$$

Where,

H' is the Shannon-Wiener diversity measure, *S* is the average species richness. If there is perfect equitability then log(*S*) = *H'* and *J* = 1. J' will approach 1 if H' will approach the maximal possible value for the given set of species, meaning that all species in the sample will be equally abundant. Beta diversity which is defined as the extent to which the diversity of two or more spatial units differs is used as an indicator of spatial heterogeneity (Magurran, 2004). In this study, the extent to which two site categories contain common species was used to characterise spatial homogeneity as cultivation and intensified farming are hypothesised to promote homogeneity. Kulezynski's coefficient was used in assessing floristic similarity (Mathieson et al., 2008) and is expressed as follows:

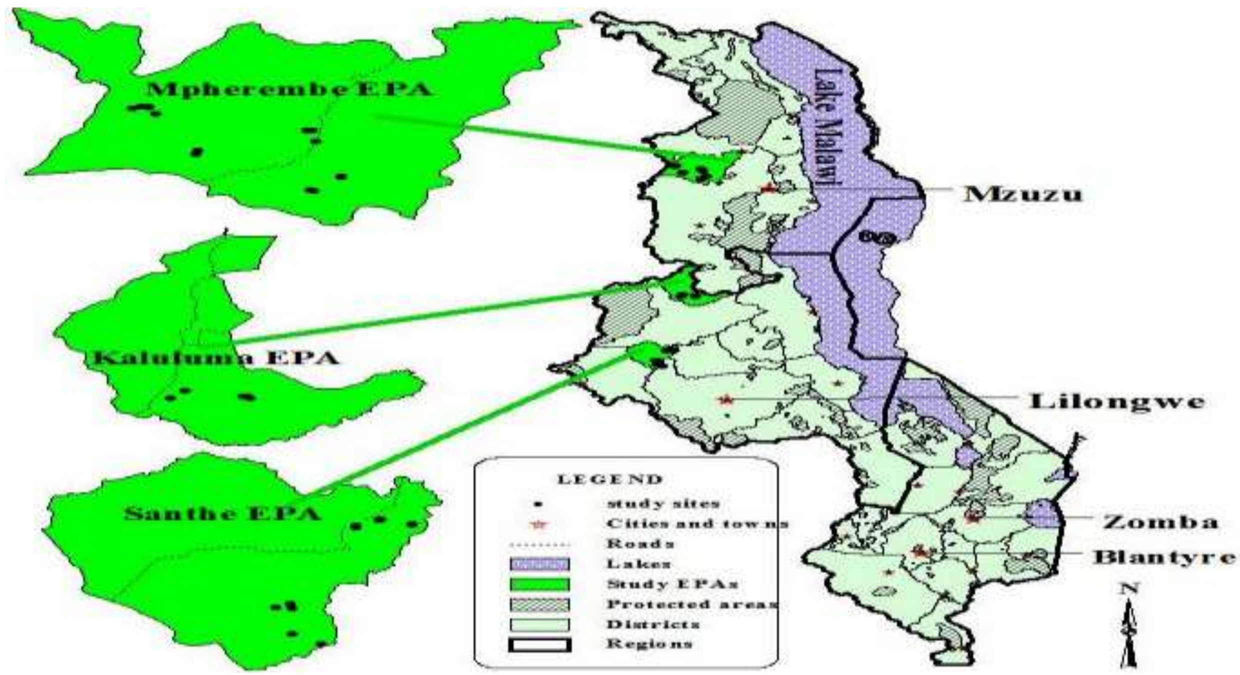

Figure 1. Map of Malawi showing study sites for plant species diversity assessment.

Table 1. Site classification using farming intensity and major land use.

Site code	Description	No. of plots
1MSC	Mzimba subsistence cultivated	11
2MSW	Mzimba subsistence uncultivated	7
3KSC	Kasungu subsistence cultivated	8
4KSW	Kasungu subsistence uncultivated	4
5KCC	Kasungu commercial cultivated	6
6KCW	Kasungu commercial uncultivated	3
Total		39

$$C_k = \frac{\left(\frac{j}{a} + \frac{j}{b}\right)}{2} * 100$$

Where, j is the number of species common to both site classes, a and b are respectively the total number of species in each site class.

RESULTS

Species richness

The study found that marginal and degraded areas under observation are floristically rich in taxa. The total number of species in the 39 plots of 0.02 ha each was 21 families, 39 genera and 54 species of trees; 41 families, 78 genera and 98 species of shrubs and regenerants/ saplings; and 27 families, 47 genera and 58 species of herbaceous plants (Table 2).

Table 2 shows that trees were more prevalent on uncultivated areas than on cultivated areas but also on subsistence landscapes than on commercial landscapes. No trees were recorded in commercial cultivated areas (5 KCC). Cultivated areas were richer in herbaceous plants compared to uncultivated areas. Comparatively, comer-cial landscapes were richer in herbs than subsistence landscapes.

Species abundance

Species abundance curves (Figure 2) shows that subsis-tence cultivated areas in Mzimba (1 MSC) had higher diversity while commercial uncultivated areas in Kasungu (6 KCW) had least diversity of tree and shrub species. In general, diversity was lower in commercial areas than subsistence sites. Cultivated areas had relatively higher diversity than in adjacent uncultivated areas. Figure 3

Table 2. Richness of trees, shrubs and herbaceous plants (per hectare) within different farm systems and cultivation status.

Class	Trees (dhb >5cm)			Shrubs/regenerants			Herbs		
	Family richness	Genus richness	Species richness	Family richness	Genus richness	Species richness	Family richness	Genus richness	Specie richness
1MSC	9	11	16	23	41	47	13	16	21
2MSW	10	21	24	20	32	37	6	9	12
3KSC	10	15	17	13	23	29	10	14	17
4KSW	12	19	20	19	26	31	3	5	8
5KCC	0	0	0	15	21	23	13	21	22
6KCW	11	17	19	9	11	12	4	6	9
Total	21	39	54	41	78	98	27	47	58

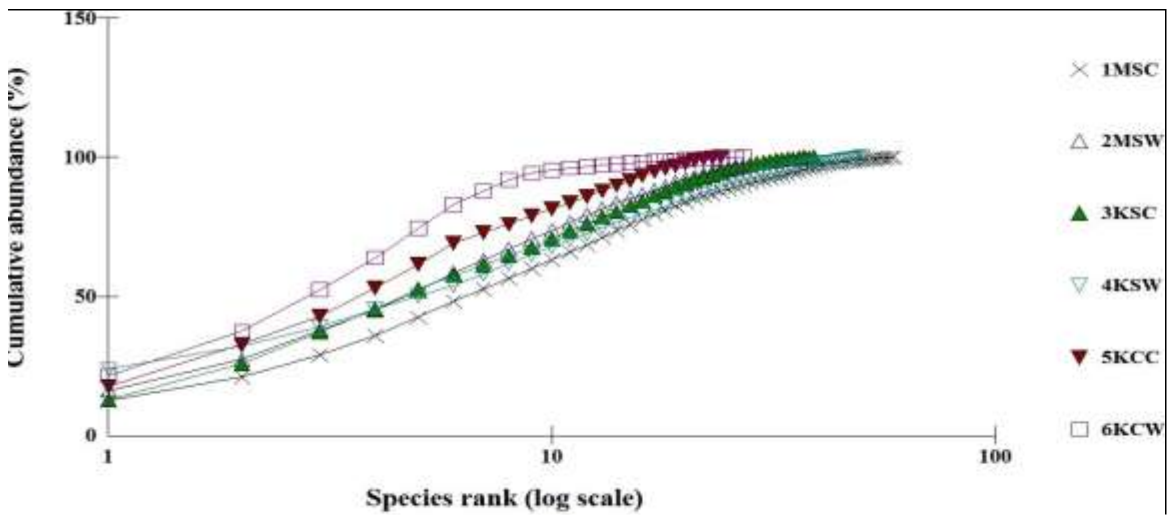

Figure 2. K-Dominance showing the diversity of woody plants within the six site classes (see meaning of codes in Table 1).

shows that there is no clear pattern in distribution of diversity of herbaceous plants across sites. However, more species with lower numbers were noted in cultivated areas (5 KCC and 3 KSC) as shown by the extended curves. The lower curves for 3 KSC, 1 MSC and 5 KCC indicate that cultivated areas contained species that were more abundant than uncultivated areas.

Species diversity of trees and shrubs and of herbaceous plants

Table 3 shows Simpson's (1/D) and Shannon-Weiner (H') diversity and Pielou's equitability (J') indices of tree and shrub species and of herbaceous plants. In Mzimba, cultivated areas were more diverse in tree and shrub species but with equal evenness compared to uncultivated areas. In terms of herbaceous plants, cultivated areas were more diverse and more even than uncultivated areas. In Kasungu, subsistence landscapes had higher diversity and more evenness of tree and shrub species than commercial landscapes. Cultivated areas were more diverse and more even in terms of both woody and herbaceous species than uncultivated areas in both subsistence and commercial agricultural landscapes.

Floristic similarity between study site classes

Kulezynski's coefficients of floristic similarity indicating the extent to which two site categories contain common species are presented in Table 4. Highest species similarity was observed in Mzimba with more than 60% tree and shrub species common to both cultivated (1 MSC) and uncultivated (2 MSW) areas. A few species (21.58%) were shared between subsistence uncultivated areas (4 KSW) and commercial cultivated areas (5 KCC) in Kasungu. Commercial cultivated areas shared relatively fewer species (<30%) with other landuse categories.

Overall, floristic similarity of herbaceous plants was lower than 40% and comparatively lower than that of woody plants. Higher spatial heterogeneity was observed between site categories 1 MSC and 4 KSW with only 8.88% of the species common to both categories. In

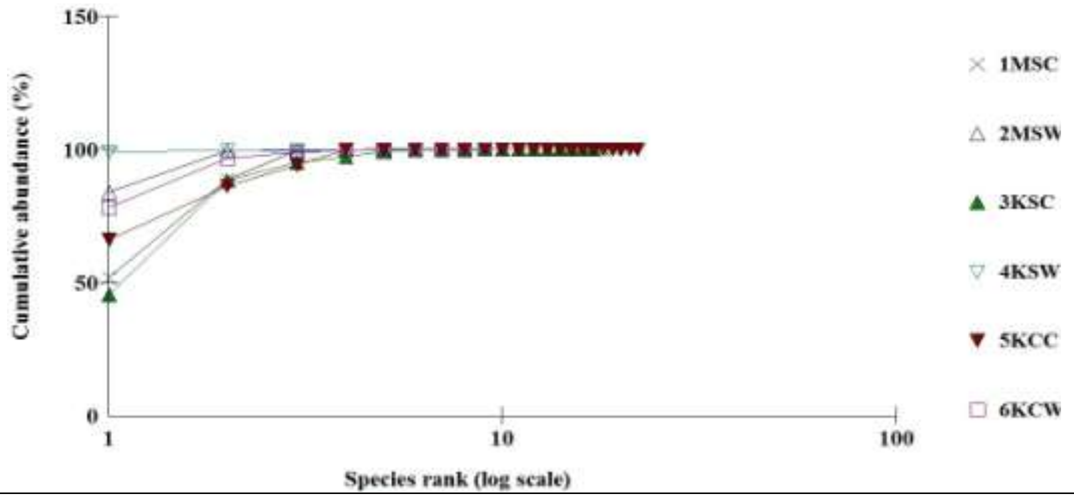

Figure 3. K-dominance plot showing the diversity of herbaceous plants (see meaning of codes in Table 1).

Table 3. Tree and shrub species diversity and evenness within different farming systems.

Landuse category	Trees and shrubs			Herbaceous plants		
	H' (nats ± SE)	1/D (nats ± SE)	J'	H' (nats ± SE)	1/D(nats ± SE)	J'
1MSC	3.3±0.06a	0.95±0.01	0.82	1.5±0.02	0.584±0.00	0.50
2MSW	3.0±0.09b	0.93±0.02	0.82	1.2±0.02	0.546±0.01	0.43
3KSC	3.0±0.07b	0.93±0.01	0.82	1.8±0.01	0.768±0.00	0.63
4KSW	3.1±0.12b	0.92±0.02	0.79	0.8±0.04	0.338±0.02	0.41
5KCC	2.7±0.10c	0.91±0.02	0.84	1.5±0.01	0.708±0.00	0.47
6KCW	2.3±0.06d	0.87±0.02	0.69	1.2±0.02	0.615±0.01	0.55

Table 4. Percent similarity of tree and shrub and of herbaceous species among the six site classes.

Landuse category	Trees and shrubs species						Herbaceous species					
	1MSC	2MSW	3KSC	4KSW	5KCC	6KCW	1MSC	2MSW	3KSC	4KSW	5KCC	6KCW
1MSC	*						*					
2MSW	61.6	*					23.9	*				
3KSC	46.9	34.2	*				27.9	37.7	*			
4KSW	42.5	35.3	47.9	*			8.88	38.3	36.8	*		
5KCC	26.4	27.5	43.8	21.6	*		19.6	16.8	31.3	25.6	*	
6KCW	32.4	28.8	43.9	45.6	31.5	*	16.4	17.8	34.0	35.4	31.3	*

Kasungu floristic similarity was higher between 3 and 4 (36.8%), followed by 4 and 6 (35.4%) then 3 and 6 (34%). The least floristic similarity of 31.3% was found between categories 3 and 5 but also between 5 and 6.

Threatened, protected and high value species

The study areas contain three endangered species namely *Pt. angolensis, Pericopsis angolensis* and *Vellozia splendens*. The areas also contain two lower risk species like *Ozoroa reticulatum* and protected species including A*fzelia quanzesis*, *Burkea africana*, *Terminalia sericea* and *Diplorhynchus condylocarpon*.

DISCUSSION

People in rural areas are highly dependent on the integrity of their local environment and maintenance of a heterogeneous local environment provides the widest possible range of ecosystem services reduces the exposure of local people to risk and lessens their dependence on the vagaries of global markets or on development assistance (Ash and Jenkins, 2007). When considered from the perspective of poor people it is this local level of biodiversity that is important.

In Malawi human induced disturbances such as clearance of natural vegetation for agricultural cultivation and the subsequent intensive use of the resource base has been the major threat in agro-ecosystems. Consequently, its management is the major focus in conservation of agrobiodiversity. This study examined the effects of cultivation and agricultural intensification on plant species diversity. The study suggests that cultivation and intensive farming has an influence on number and distribution of plants in marginal and degraded areas within agricultural landscapes. Cultivation has been found to affect the number and distribution of larger trees (dbh >5 cm). Woodlands adjacent to agricultural fields had relatively higher number of taxa of trees than previously cultivated fields. This could be attributed to complete or selective removal of trees to pave way for most productive agricultural practices. Wooded areas had low taxonomic richness of shrubs and regenerants compared to cultivated areas. This trend is in line with the mode of regeneration of most tree and shrub species in miombo region. Chidumayo (1997) noted that stumps and roots of almost all trees produce sucker shoots once the above ground parts have been removed. Sucker shoots arise from buds which develop on root and stem bases. In addition, some species remain dormant in the seed bank and the opening up of canopy coupled with tilling create conducive environment for colonisation. Chidumayo (1997) found that the sapling population in regrowth miombo may consist of up to one third seedlings recruited from the seed pool.

Subsistence landscapes had higher species richness of trees compared to commercial farms. Subsistence agricultural landscapes are complex and provide alternative habitats and sources for colonisation of fields hence tend to support higher species richness than simple commercial landscapes. A study by Weibul et al. (2003) provide insights into the relationship between species richness and farming system at field level though they found no effect of farming system on species richness at landscape level. Clough et al. (2007) studied plant species diversity within agro-ecosystems and found that organic farming enhanced species diversity compared to commercial farming where chemicals are intensively used. However studies in Tanzania by Wahl et al. (2009) report that *J. curcas* is being planted on land ranging from rather fertile to very fertile and none of the farmers interviewed planted *Jatropha* on marginal dry land not suitable for food crops. This suggests that even when the crop is being recommended for marginal lands small holder farmers may plant the crop on fertile arable land that is likely to change the floristic composition and dynamics of species of the landscapes.

Intensification of cultivation enhanced prevalence of herbaceous species and shrubs mostly regenerants. Diversity of herbaceous plants, most of which are weeds in annual crop fields, depends on the intensity of cultivation and the resulting receptive substrate for colonisation but also on the surrounding landscape. Weeds are highly dynamic and adapted to a frequently disturbed habitat, relying on seed bank as well as on immigration from surrounding habitats. Consequently, herbaceous species diversity in commercial fields benefited from landscape complexity as these areas are more frequently disturbed by complete and deep tillage and use of herbicides than subsistence fields. In addition vast areas within commercial landscapes are dominated by herbaceous plants which provide immigrant seed. The site categories shared between 21 to 62% of woody species and 16 to 37% of herbaceous species. Cultivated areas were dominated by different species as indicated by low number of species shared. In general, cultivated areas within commercial landscapes in Kasungu shared the least species with other areas. This implies that intensified cultivation modified the species composition and lead to larger spatial heterogeneity in diversity between the sites. The distribution of tree regeneration and shrubs of some selected species within and between site categories revealed that cultivation and the subsequent intensification may lead to a decline in number and subsequent loss of some previously abundant species. As argued by van Oarschot et al. (2008) human induced loss of biodiversity through conversion of natural systems to agricultural use is mainly characterised by the decrease of many original species and the increase in abundance of a few other pioneer species emerging as a result of human activities. The higher prevalence of common species in both cultivated and uncultivated areas within subsistence landscapes is symptomatic that regeneration is dominated by existing species. Most woody species in the study area are miombo (African savannah) which when cut above the ground level coppice well. In commercial landscapes, mechanical tillage leads to unintended uprooting of stumps and disturb most local species that shoot from stumps but favours a few species that regenerate through root shots.

The study found nine species with high conservation value namely *Pt.angolensis, P. angolensis, V. splendens, O. reticulatum, O. insignis*, A*. quanzesis*, *B. Africana*, *T. sericea* and *D. condylocarpon*. Msekandiana and Mlangeni (2002) point out that *Pt. angolensis* and *P. angolensis* are found in dry woodlands and threatened by forestry exploitation for high value timber. *V. splendens* is threatened by fires and is endemic while *Ozoroa* is a lower risk genus found in most areas. As indicated by Newton (2007) sites containing red list species are prime areas for conservation. To conserve these endangered species, there is need to integrate conservation strategies into economic development oriented projects. Although Mwase et al. (2007) concluded that woodlands on customary land had less potential for conservation; these results indicate that traditionally farmers have been conserving plant species within their fields. With the current high demand for land and high pressure on natural resources the previous hands off approach for conservation has been found to be ineffective. Involvement of communities in management of natural resources as is being promoted in most parts of Southern Africa might enhance biodiversity conservation and protect endangered species. Apart from economic development, these nutrient poor areas provide high potential for conservation that will have some impacts on socioeconomic development and livelihoods of most small holder farmers.

Conclusion

The study suggests that diversity of plant species in marginal and degraded areas is influenced by cultivation and to a greater extent by intensified farming. Species which were abundant and evenly distributed in uncultivated lands had low numbers in cultivated areas. Moreover, cultivated areas were dominated by a different set of species that do well in disturbed soils. Intensified cultivation further increased the dominance of species that strive under frequent cultivation. Red list species were prevalent especially in woody uncultivated areas indicating the potential for conservation of these species at local level. Sustainability of locally abundant species would therefore be achieved by setting aside patches of indigenous woodlands as village conservation areas. Village conservation areas should be set out especially in areas containing endangered species in order to protect them. In addition, adoption of low-impact management practices such as conservation farming should be encouraged in production systems where these can be shown to deliver significant on-site benefits.

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