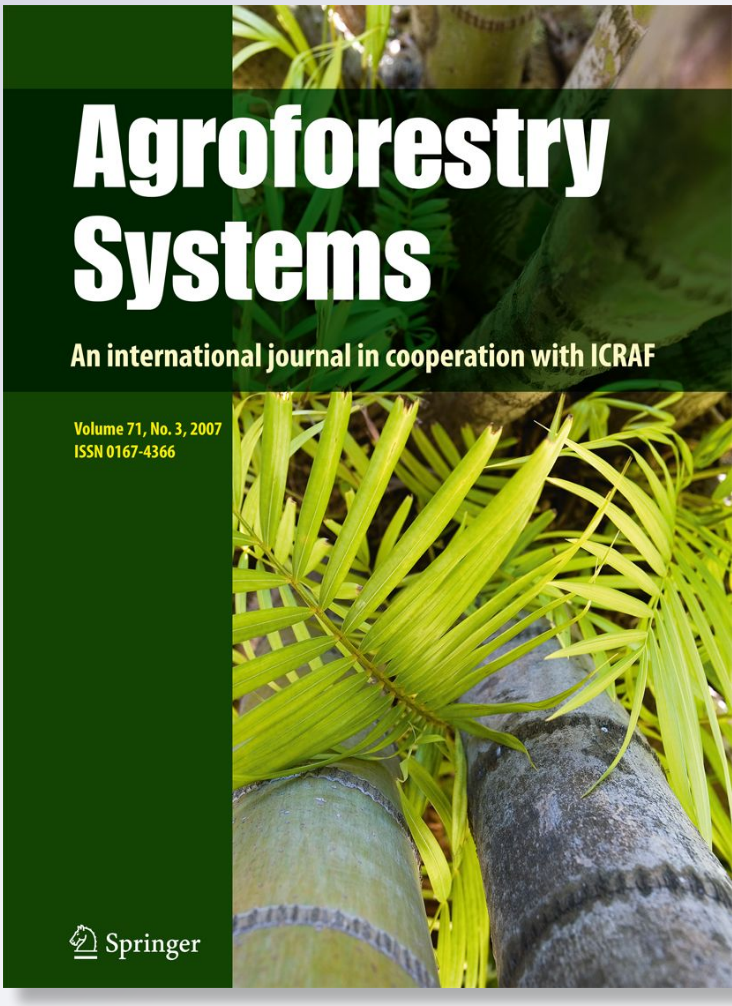
Farming does not necessarily conflict with tree diversity in the mid-Zambezi valley, Zimbabwe

Edwin Tambara, Amon Murwira, Shakie Kativu & Emmanuel Torquebiau

Agroforestry Systems
An International Journal incorporating
Agroforestry Forum

ISSN 0167-4366

Agroforest Syst
DOI 10.1007/s10457-011-9467-3



Springer

Agroforest Syst
DOI 10.1007/s10457-011-9467-3

Farming does not necessarily conflict with tree diversity in the mid-Zambezi valley, Zimbabwe

Edwin Tambara · Amon Murwira · Shakie Kativu · Emmanuel Torquebiau

Received: 14 May 2011 / Accepted: 16 December 2011

Abstract We tested whether cultivation and fallowing have any significant effect on tree species diversity and dominance in semi-arid Zimbabwe. To this end, we quantified tree species diversity and physiognomy on two soil types (*mutapo* and *bandati*) stratified into three land-use categories, i.e., cultivated land, fallow land and woodland. Results showed that tree species diversity was significantly different on the two soil types. Tree species diversity was high on *bandati* soil and low on *mutapo* soil. Results also showed that there was significant difference in tree species diversity among the three land-use categories on *mutapo* soil but no differences on *bandati* soil. Pairwise comparisons revealed significant differences in species diversity between paired categories on *mutapo* soil but no significant differences on *bandati* soil. Tree physiognomy was significantly different among all three land use categories. *Colophospermum mopane* and *Diospyros kirkii* were the dominant species within woodlands, while *Acacia tortilis* subsp. *spirocarpa* replaced them as the dominant species within the fallow land category. These results indicate that woodland conversion for cultivation purposes has no immediate significant effect on tree species diversity on *bandati* soil, while it has a pronounced effect on *mutapo* soil, at least in the short term.

E. Tambara (✉)
Biological Sciences, University of Zimbabwe,
P.O. Box MP 167, Mount Pleasant, Harare, Zimbabwe
e-mail: edytambara@gmail.com

A. Murwira
Geography and Environmental Sciences,
University of Zimbabwe, P. O. Box MP 167,
Mount Pleasant, Harare, Zimbabwe

S. Kativu
Tropical Resource Ecology Program (TREP),
University of Zimbabwe, P.O. Box MP 167,
Mount Pleasant, Harare, Zimbabwe

E. Torquebiau
Centre for International Research and Development
(CIRAD)/Centre for Environmental Studies,
University of Pretoria, Geography building 2.1.1,
Pretoria 0002, South Africa

Keywords Cultivation · Fallowing · Physiognomy · Species dominance · Woodland

Introduction

Agriculture is often perceived to be a major threat to biodiversity in forest and woodland ecosystems (Balmford et al. 2005; Kadoya and Washitani 2011). Today, the common landscape pattern within many tropical areas is woodland patches embedded in an agricultural mosaic matrix (Teodoro et al. 2011). In this regard, conventional scientific wisdom has prescribed the separation of woodlands ("locking away resources") and agricultural activities as the preeminent way to conserve biodiversity in tropical biodiversity hotspots (King 1979). Tilman et al. (2001) has

Published online: 06 January 2012

noted that for the next 50 years (50% larger global population) the major driver of global environmental change will be food production. Therefore, today's major challenge for conservation practitioners and land-use managers is the achievement of a balanced compromise between the ever-growing demand for agricultural products and biodiversity conservation (Harvey et al. 2008; Gardner et al. 2009).

"Land sparing" and "wildlife-friendly" farming are currently the two conflicting strategies that have been proposed in trying to balance conservation and agricultural production (Fischer et al. 2008). Land sparing involves intensification of existing farmland and separation of reserves aimed at biodiversity conservation. In contrast, wildlife-friendly farming integrates conservation and farming within landscapes. For each of these strategies to be effective, there is need to consider both social and biophysical factors within a particular area. There has been increasing advocacy for agricultural intensification as the most viable strategy for sparing land for nature (Balmford et al. 2005; Green et al. 2005; Mattison and Norris 2005; Matson and Vitousek 2006; Ewers et al. 2009; Rudel et al. 2009). In reality, however, agricultural intensification requires costly inputs of fertilizers, high yielding crop varieties, water, energy and pesticides, thus consequently has a negative impact on "spared" land. Currently, therefore, there is strong advocacy for integrated landscapes and conservation efforts within and outside parks and reserves, in the matrix of surrounding human habitats (Scherr and McNeely 2008; Brussaard et al. 2010; Guillen and Perfect 2010).

Most poor farmers in tropical countries cannot afford the inputs necessary for agricultural intensification (King 1979) as they traditionally rely on natural soil fertility. These farmers, thus, view extensification (spatial intensification) as a cheaper strategy to increased agricultural production. This strategy is demonstrated in the mid-Zambezi valley of Zimbabwe. Many farmers in this area no longer use synthetic fertilizers (organic or inorganic) to maintain or improve fertility of fields due to declining economic circumstances (Baudron et al. 2009). Any perceived decrease in productivity of a field results in its abandonment as fallow, and a new field is opened instead. This practice has led to agricultural extensification into, lowly populated areas, with large undisturbed natural forests. Rather than trying to conserve biodiversity through management of protected areas separated from agricultural areas, it is therefore reasonable that complementarities between trees and farming be identified (Augusseau et al. 2006). In this way, conservation and production units within agricultural landscapes can be managed jointly for long term sustainability through existing practices (Harvey et al. 2008).

Agricultural extensification results in rapid woodland conversion. This conversion follows two alternative patterns: floristic or physiognomic. Floristic conversion involves qualitative and quantitative changes in vegetation composition. Through this type of conversion, some plant species are lost and others increase in relative abundance. The most common pattern is the physiognomic one, which involves changes in vegetation structure (Crawley 1997). Through physiognomic conversion, forests and woodlands give way to cultivated fields, grassland, shrub grassland, bushland and wooded grassland. Scientific studies have noted the effect of agriculture on woodlands which mainly result in negative changes in the floristic composition of forests and woodlands (Bierregaard et al. 1992; Oba et al. 2002; Ogunleye et al. 2004; Augusseau et al. 2006). Such change is not confined to floristic composition, neither is it always negative.

The present study investigated the effects of agriculture on woody species in a landscape of global importance for conservation: the mid-Zambezi valley of Zimbabwe in Southern Africa. Specifically, we tested whether cultivation and fallowing have any significant effect on woody species diversity or, alternatively, tree species physiognomy. In addition, we tested whether there was change in species dominance due to cultivation and fallowing.

Materials and methods

Study area

The study was conducted in Mushumbi, Dande Communal Area in Mbire Rural District of the mid-Zambezi valley of Zimbabwe. The mid-Zambezi valley, approximating some 40 km wide, and at an average altitude of 400 m, lies between 30° and 31° longitudes, and 15° 30′ and 16° 20′ latitudes. The area is characterized by deciduous dry savanna vegetation

(Timberlake et al. 1988), and has a dry, tropical climate, with an annual mean temperature of 25°C, and minimum and maximum temperature of 10 and 40°C, respectively. Annual rainfall is low and variable (350–650 mm), with dry spells occurring during the rainy season. The mid-Zambezi valley is a marginal area that still host rich biodiversity (Baudron et al. 2009; Biodiversity Project 2002). A total of 729 plant species have been identified in the area, reflecting a wide range of habitats (Biodiversity Project 2002). The area also has an important diversity of mammals, several of which are emblems of big African game animals (lion, leopard, buffalo and elephant).

The human population of the mid-Zambezi valley expanded rapidly after the Tsetse fly (*Glossina* sp.) eradication and associated provision of roads and infrastructure (Chizarura 2003). Population figures in Dande area increased from 36.074 (18.5 inhabitants/km^2) in 1992 to 71.096 (36.6 inhabitants/km^2) in 2002 (Baudron et al. 2009). In the early 80s, the government of Zimbabwe embarked on a resettlement project that was earmarked to resettle 3,000 families. Each family received a 0.4 ha residential plot and a 4.8 ha plot for farming (Derman 1996). Intensive agriculture development is less than 50 years old. New settlers and new extension advice brought in cotton as a major crop, which did quite well in the deep virgin soils which were fertile, and thus suited this crop very well. Today other crops grown include maize, millet, sorghum and groundnuts (Baudron et al. 2011).

Tree species data collection and analysis

An interpreted soil map that was produced as part of a previous study in the mid-Zambezi valley (Biodiversity Project 2002) was used in the present study to stratify the delineated area into two zones based on the two dominant soil types, *mutapo* and *bandati*. These two spatial zones were demarcated as: (1) Site 1, where *mutapo* soil (grey-white clays), are present. *Mutapo* soils are eutrophic soils associated with sodic/saline areas. The soils are heavy, with high moisture holding capacity, and a depth reaching up to 3 meters; and (2) Site 2, where *bandati* soils (sandy clay soil) are present. *Bandati* soils are moderately heavy soil that makes huge dust clods when ploughed, and have high moisture retention capacity. Fertility rate in the latter is high, and gives a good yield of cotton, maize, millet and sorghum.

At each study site, a 1 km radius study area was demarcated after traversing and identifying areas at relatively the similar elevation using a handheld Global Positioning System (Garmin eTrex H Handheld GPS Navigator) receiver. To evaluate the effect of cultivation and fallowing on woody species, the two study sites were stratified into different land-use categories: (1) an area where natural vegetation has been cleared for agricultural purposes, with the crops grown including cotton, sorghum, maize and millet, denoted as cultivated area; (2) previously cleared or cultivated areas of different ages with recovering vegetation, denoted as fallow areas; and (3) natural woodland. All fields and fallows within the two sites were located and their area determined with the help of a hand held GPS. Data on each field in the study area were adopted from Baudron et al. (unpublished, 2008) and included name of farmer, current crop, field age and fallow age. Sampling plots to evaluate tree diversity and physiognomy were established within fields, fallows and natural vegetation. Each sampling plot measured 30 m width and 100 m length. Fields and fallows to establish these sampling plots were randomly selected at each site. This was achieved by entering information on all plots into a spread sheet and arranging all cultivated fields and fallows by age, ranging from 1 to 30 years for cultivated fields, and 1 to 6 years for fallows. Fields or fallows within each particular age were allocated numbers and for each particular age, random selection of sampling plots was achieved by generating random numbers from a calculator. Selection of sampling plots in the natural woodland was simultaneously carried out with that of cultivated fields. Random selection of these plots was achieved by moving a distance of 300 m into the adjacent natural woodland from a randomly selected field. Sampling involved dividing each plot along its length into strips of 5 m width and 100 m length. This part of the study was done between March and July 2009.

In this study, trees were defined as woody plants in the form of stumps, seedlings, saplings, shrubs and adult trees. On each sampling plot, all woody species (from seedling, sapling, shrubs and adult tree) encountered were identified in situ by their botanical and local names and recorded. Nomenclature of species followed Drummond and Coates-Palgrave (1973), Van Wyk and Van Wyk (1997), Palgrave (2002) and Biodiversity Project (2002). Vernacular names were adopted from the local community. Dominant species of the study area were selected for detailed analysis of physiognomic status in each of the three land-use categories. Within each sampling plot, individuals of the dominant species were grouped by height into four classes (1) seedlings and immature saplings, woody plants with a height less than 0.5 m (<0.5 m); (2) stumps and saplings, woody plants with a height between 0.51 and 1 m (0.51–1 m) (3) shrubs, woody plants with a height between 1.1 and 2 m (1.1–2 m) and (4) mature trees, woody plants with a height more than 2 m (>2 m). The physiognomic status of the dominant species in each land-use category was assessed on the basis of frequency of individuals within each size class.

Species diversity was quantified using Simpson's and Shannon-Wiener indices as recommended by (Magurran 1988). To test the two hypotheses that (1) increasing field age results in a decrease in tree diversity and (2) increasing fallow age results in an increase in tree species diversity parameters, simple regression analysis was used with age as the single explanatory variable. But as a preamble to regression analysis normality tests using a Kolmogorov–Smirnov test were conducted to find out whether our data did not significantly deviate from a normal distribution. Since our data did not significantly deviate from a normal distribution we therefore carried out the regression analysis. A standard analysis of variance (ANOVA) was used to compare recordings from the three land-use categories described above. Multiple comparisons (Tukey's) tests were made between specific land-use categories. In all cases, a level of $P < 0.05$ was adopted as the minimum significance.

Results

Tree diversity

A total of 82 woody species from 32 families were recorded across the study area. More species were present on mutapo soil (53 species, 63%) than on *bandati* soil (43 species, 52.4%). Tree diversity (Simpson's and Shannon-Weiner diversity indices) was generally higher on bandati soil than on *mutapo* soil in all three land-use categories.

On *mutapo* soil, the highest number of species was recorded on fallow land (45 species) followed by cultivated land (36 species) and natural woodland (27 species). As expected, tree density was considerably higher within the woodland category (1,819 trees/ha) than the other two categories. Tree diversity, however, was highest (Simpson's and Shannon-Weiner diversity indices 11.83 and 2.47, respectively) in the fallow land category, and lowest in the woodland category (8.54 and 1.45, respectively, see Table 1). On *bandati* soil, only 34 tree species were recorded within cultivated land compared to 45 species within fallow land and 42 species within woodland. Tree density was also lower within cultivated areas (673 trees/ha) than within fallow land (1,653 tree/ha) and woodland (1,242 tree/ha). Highest tree diversity (Simpson's, 23.96 and Shannon-Weiner diversity, 2.07) was again recorded within fallow land. Cultivated land recorded the lowest tree diversity (Table 2).

Species richness showed significant differences among land-use categories on *mutapo* soil ($F = 2.67_{3,48}$, $P = 0.02$) but diversity indices (Simpson's

Table 1 Tree diversity parameters within three different land-use categories on *mutapo* soil, mid-Zambezi valley, northern Zimbabwe

	Cultivated	Fallow	Woodland
Diversity measures			
Total no. of spps.	36	45	27
Individuals/ha	1051.5	1147.26	1819.26
Species/ha	21.71	41.66	17.40
Simpson's index (1/D)	10.88*	11.83*	8.54
Shannon–Weiner index (H')	2.07*	2.47*	1.45

Values with asterisks (*) in a row do not differ significantly at $P < 0.05$ (Tukey's post hoc test)

Table 2 Tree diversity parameters within three different land-use categories on *bandati* soil, mid-Zambezi valley, northern Zimbabwe

	Cultivated	Fallow	Woodland
Diversity measures			
Total no. of spps.	34	46*	42*
Individuals/ha	673.30	1653.32	1242.41
Species/ha	27.83	38.26	28.20
Simpson's index (1/D)	19.12*	23.96*	20.68*
Shannon–Weiner index (H')	1.66*	2.07*	1.78*

Values with asterisks (*) in a row do not differ significantly at $P < 0.05$ (Tukey's post hoc test) and Shannon-Weiner indices) revealed no significant differences in woody species diversity among the three land-use categories (Simpson's: $F = 3.67_{3,48}$, $P = 0.186$; Shannon-Weiner: $F = 3.42_{3,48}$, $P = 0.165$). Tukey's pairwise comparison test on the two diversity indices revealed that the woodland category significantly differ from the other two categories. Land-use categories on *bandati* soil, showed no significant differences in woody species richness and diversity (Species richness, $F = 2.43_{3,46}$, $P = 0.231$; Simpson's, $F = 1.95_{3,46}$, $P = 0.155$; Shannon-Weiner, $F = 2.05_{3,46}$, $P = 0.108$). Tukey's pairwise comparison tests revealed that the cultivated category significantly differ from the other two categories only in terms of species richness.

Tree diversity parameters as a function of field and fallow age

We observed that tree diversity decreased with age of the field, on both *mutapo* and *bandati* soils (Fig. 1). Within young fields, tree diversity parameters were high, then gradually decreased to a relatively constant level as fields become older. Non-linear regression analysis, showed significant ($P < 0.05$) relationships between field age and all tree diversity parameters except species richness which showed a sturdy variance for each particular field age overtime. All diversity parameters showed an exponential decrease with an increase in field age on both soils. On the other hand, high values in tree diversity parameters were recorded within young fallows. We observed that there is a gradual decrease in tree diversity as age of fallow increased (Fig. 2). Regression analysis on fallow data showed a significant ($P < 0.05$) exponential decrease in tree diversity with increasing fallow age. In fact we observe that high R^2 values of 0.79 and 0.85 are obtained when fallow age is used to predict tree diversity (Simpson's and Shannon-Weiner index respectively). For fallows both number of species and tree density showed a linear decrease with increase in fallow age. However, the linear trend was not significant, $P > 0.05$ in both cases and very low R^2 values of 0.15 (number of species) and 0.05 (tree density).

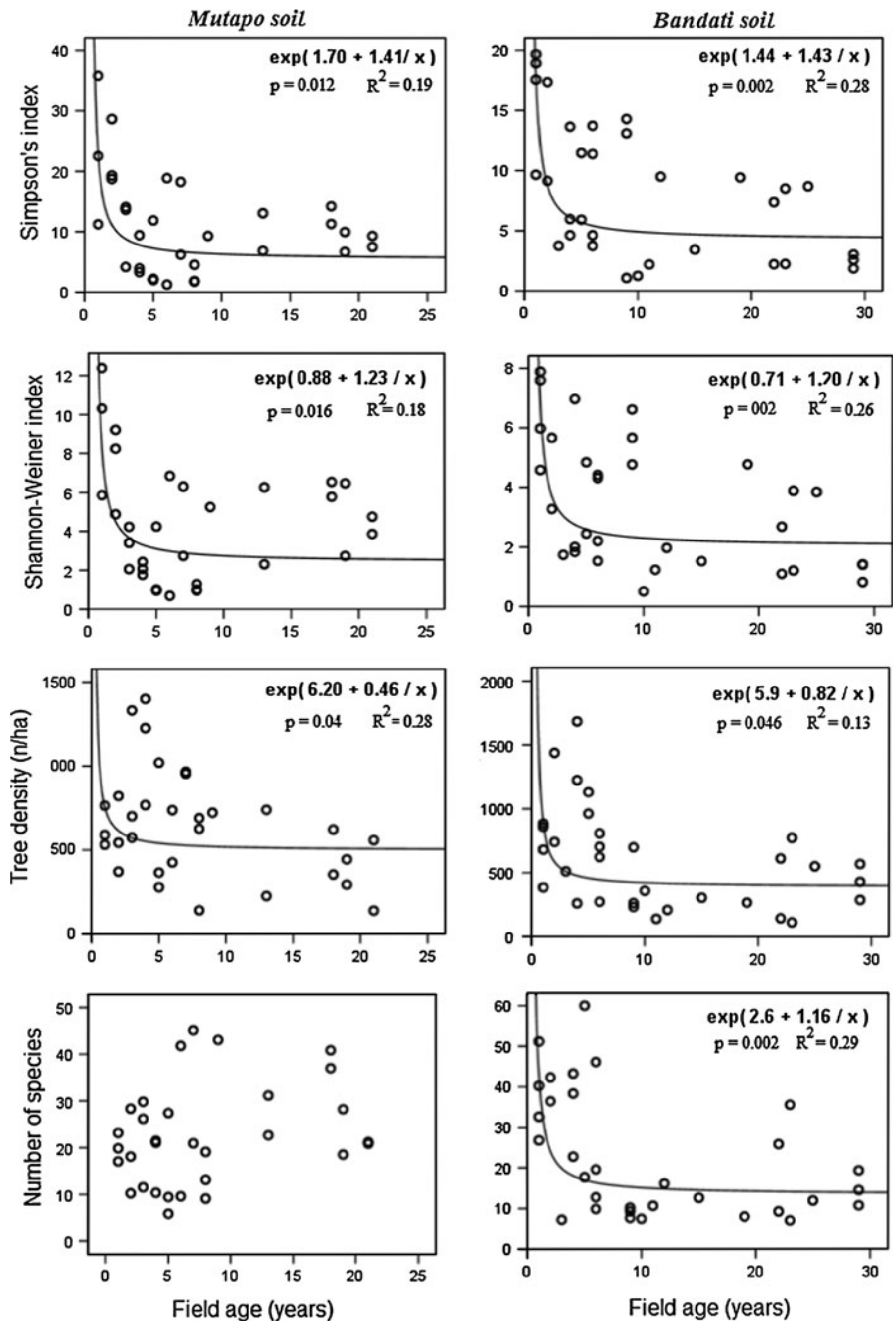
Tree physiognomy

The lowest height class (<0.50 m) recorded the highest frequency in the cultivated land category for each of the 10 dominant species, and frequency decreased with increasing size class (Fig. 3). Farmer's practices confirm the above trend as field opening includes clearing of all vegetation, and fields subsequently burnt before planting each season. In the fallow land, maximum frequency was recorded in the >2 m height class, followed by the <0.50 m class. The least frequency was recorded in the 1.1–2 m size class. Of major interest is the observed increase in frequency within the upper size class from the cultivated category to the fallow category. In the woodland category, a very high frequency was recorded for the >2 m height class and very low frequencies were recorded for each of the remaining size classes (Figs. 3, 4). For size classes <0.50 m, 0.51–1 m and >2 m, there were significant differences ($P < 0.05$ for all classes) in frequency among the land use categories. In contrast, size class 1.1–2 m ($P = 0.09$) showed no significant differences in frequency among land use categories.

Tree dominance

Tree dominance varied from one soil type to another and from one land–use category to another. Sixteen woody species occurred in very high abundances and these dominated the vegetation in the study area. Generally, in the cultivated category at all sites mature trees most frequently occurred within field edges. Only a limited number of species, such as *Adansonia digitata* L., *Azanza garkeana* (Hoffm) Excell & Hillc, *Diospyros kirkii* Hiern, *Kigelia africana* (Lam.) Benth, *Lonchocarpus cappassa*, *Tamarindus indica* L. and *Z. mauritiana* Rolfe were present within fields as mature trees. The natural vegetation on *mutapo* soil was characterized by the omnipresence of *Colophospermum mopane* Benth forming tall 'cathedral mopane' woodlands. Other woody trees occurred only as small trees and shrubs. Among these was *C. elaeagnoides*, *D. quiloensis* and *D. cinerea*. Some parts of the woodland were exclusively dominated by *C. mopane* which formed pure mopane stands with very little or no herbaceous cover. A complete change in the dominance pattern was observed in fallow areas were *A. tortilis* subsp. *spirocarpa* was the most abundant woody species with *C. elaeagnoides*, *D. cinerea* and *Z. mauritiana* also present in high abundance. Cultivated areas on *mutapo* were characterized by high abundances and dominance of *D. cinerea* and *C. elaeagnoides*.

Fig. 1 Tree diversity parameters as a function of field age, mid-Zambezi valley, northern Zimbabwe



The natural vegetation on *bandati* soil was diverse open woodland characterized by dominance of *D. kirkii* with *A. tortilis* subsp. *spirocarpa*, *D. cinerea* and *Z. mauritiana* also occurring in high frequency. The natural woodland at this site was also characterized by a well pronounced herbaceous stratum of tall, well-developed grass layer. *A. tortilis* subsp. *spirocarpa* was by far the dominant species within fallow areas with *D. cinerea* and *C. elaeagnoides* also present in high abundances. Similarly, *A. tortilis* subsp. *spirocarpa* dominated the regenerating vegetation within cultivated areas.

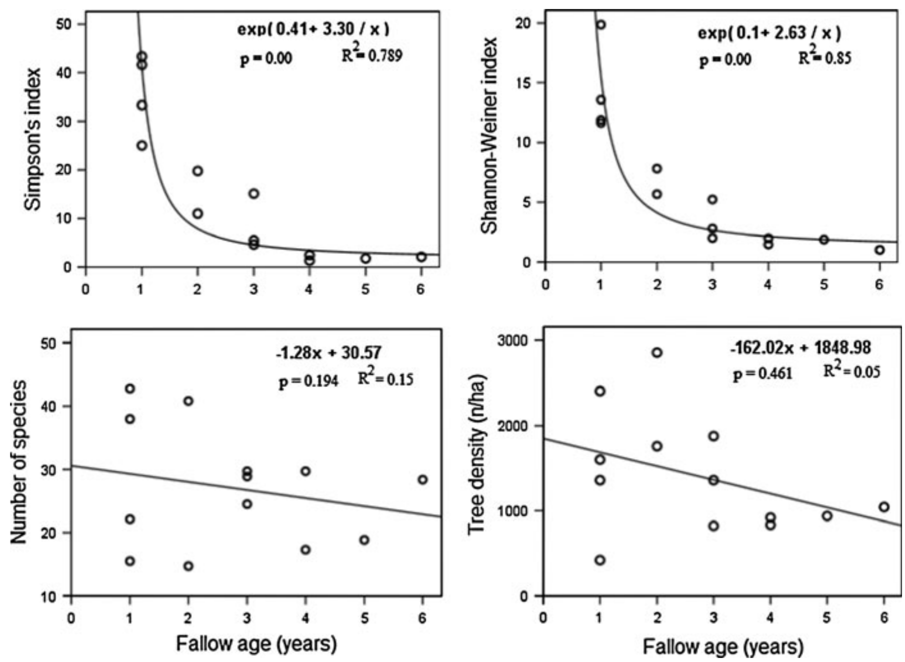


Fig. 2 Tree diversity parameters as a function of fallow age, mid-Zambezi valley, northern Zimbabwe

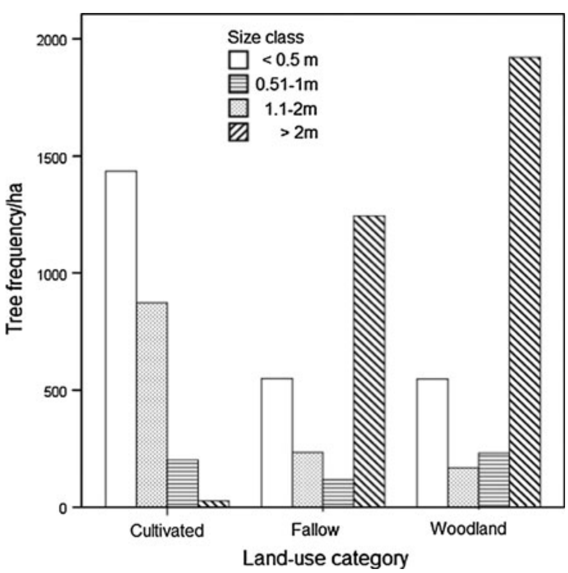


Fig. 3 Frequency of tree size classes by land category on *mutapo* soil, mid-Zambezi valley, northern Zimbabwe

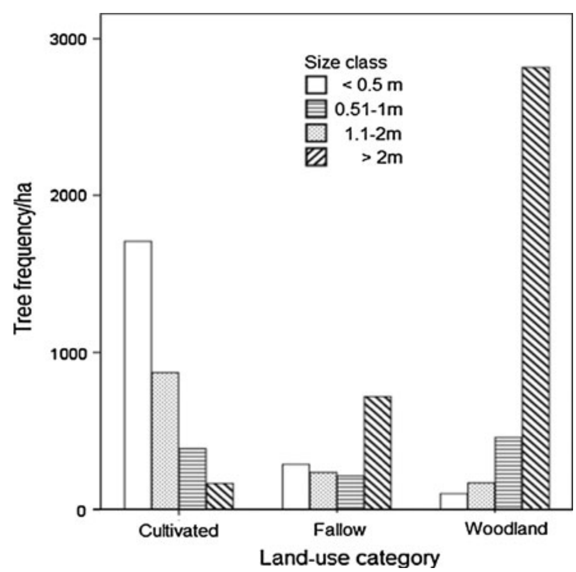


Fig. 4 Frequency of tree size classes by land category on *bandati* soil, mid-Zambezi valley, northern Zimbabwe

Discussion

Our results indicate that soil type significantly explain differences in tree species diversity in the landscape. This was shown by greater dissimilarities in woody species composition between the two soil types. The two dominant soils in the study area (*mutapo* and *bandati*) are known to have different chemical and physical properties. *Mutapo* soils are eutrophic, grey-white clays which are associated with sodic/saline conditions. Fertility rating in these interfluvial soils is very low. On the other hand, *bandati* soils are moderately heavy sandy clay soils. Compared to the clayey interfluvial soils these alluvial soils have a high moisture retention capacity (Mvuriye et al. 2001). Therefore, each soil type is associated with a set of tree species that have managed to adapt to the chemical and physical properties of the soil. Our observations are in line with observations from studies by Timberlake et al. (1993), Biodiversity Project (2002); Fritz et al. (2003) in the same area. These studies highlighted that vegetation composition and structure in the mid-Zambezi valley vary with type of soils.

It was not surprising that results show high tree species diversity on *bandati* soil than on *mutapo* soil. Keeping in mind the description of the two soils highlighted above, *mutapo* soil supports a floristically distinct vegetation type that is predominantly composed of *C. mopane* which form mopane woodlands (Mapaure 1994). The unique characteristic of mopane woodlands is their low number of associated species, low alpha diversity (Timberlake et al. 1993; Poilecot and Gaidet 2011). Alluvial soils, showed high diversity of woody species, chemical and physical conditions in these soils are not restrictive to tree growth therefore many tree species grow well in these soils. Thus, we make a claim that soil type is an important aspect in determining tree diversity in an area.

Results on the response of woody species diversity to the effect of agricultural activities indicate that in the short term agricultural activities do not necessarily conflict with tree diversity. However, woody species response is different between the two soil types. Contrary to the commonly held assertion that woodland conversion for agricultural purposes results in loss of tree species diversity through habitat destruction and fragmentation (Bierregaard et al. 1992; Oba et al. 2002; Ogunleye et al. 2004; Augusseau et al. 2006), on *mutapo* soil woody species diversity increased after natural woodland conversion to agricultural farmland. Thus clearing of mopane woodlands allows other species to establish on the cleared areas thereby increasing species diversity. The characteristic tree species to establish on the newly opened fields and fallows include *A. tortilis* subsp. *spirocarpa*, *C. elaeagnoides*, *M. zanzibarica*, *D. qualoensis*, *D. cinerea*, *C. mossambicense*, *G. monticola* and *A. versicola*. However, it is interesting to note that most of these species are early succession species with strong invasive qualities and *A. tortilis* subsp. *spirocarpa* and *D. cinerea*, being the most abundant species. On *bandati* soil they are no immediate changes in woody species diversity within agricultural landscapes.

Similar to what has been observed elsewhere (e.g. Turkwel River, northwestern Kenya: Oba et al. 2002; Olokemeji Forest Reserve, Nigeria: Ogunleye et al. 2004; Torokoro, Burkina Faso: Augusseau et al. 2006) our results indicate that in the long term agricultural activities adversely affect woody species diversity. Trends observed in the present study show high tree diversity within young fields coupled with a decrease in diversity parameters as fields become older. High values within young fields may be explained by the fact that newly opened fields are characterized by active regeneration of trees during the dry season and high invasion from new species that were previously absent. In essence, older fields have repeatedly been subjected to clearing and ploughing before each planting season. Overtime, all potential sources for tree regeneration that include stumps, soil seed banks and live root stalks are destroyed. In addition, tree selection by farmers each year leads to removal of most species and subsequent dominance of fewer species (fruit trees and other species of cultural importance). However, it is important to note that there is strong variability in tree species diversity from young to older fields. Thus, changes observed should only be considered as trends. This variability in tree diversity parameters could be a result of land-use cycles (clearance–cultivation–abandonment–recovery–clearance cycle) employed by some farmers in the area.

Our results indicate that early stages of the fallowing phase are characterized by a recovery in tree diversity. However, this high tree species diversity is gradually lost under a progressive increase in the fallowing period. The high species diversity within young fallows can largely be attributed to the reinvasion of the abandoned fields by new species. As fallow age increases, there is a notable decrease in species richness and abundances of most species except *A. tortilis* subsp. *spirocarpa*. Fallowing practice, as observed in the present study, promotes vigorous recruitment and growth of *A. tortilis* subsp. *spirocarpa* at the expense of all other species. In essence, the decreased diversity within fallow areas is accompanied by a progressive dominance of a single species (*A. tortilis* subsp. *spirocarpa*). Dominance of *A. tortilis* subsp. *spirocarpa* and loss of other species could be attributed to such factors as inter-specific interactions with surrounding vegetation, environmental modification, seedling bank, availability of resources and dispersal limitation (Tripathi et al. 2009). However it is important to note that, due to high immigration that has resulted in high demand for cultivatable land, the length of the fallow period has progressively shortened over recent years (Baudron et al. 2009). This implies that vegetation recovery within fallow areas is limited.

Although our observations indicate that the fallow phase is characterized by a decrease in tree diversity, results also show that it is the fallow phase that allows recovery in tree physiognomy. Land clearing has created patches of natural vegetation within an agricultural matrix dominated by shrubby vegetation. In a way, cultivation is turning woodland areas into agricultural field matrices characterized by trees in the form of saplings, regenerating stumps and mature trees on field edges and small patches (islands) of undisturbed natural vegetation. The only tree species left within fields are tolerated by farmers (i.e. protected and left within fields during vegetation clearing). Tolerated species include woody plants that provide edible fruits (e.g. *Azanza garckeana* (Hoffm) Excell & Hillc, *Z. mauritiana*, *Sclerocarya birrea*, *A. digitata*, *Tamarindus indica* L. and *D. kirkii*), medicinal plants (e.g. *Cassia abreviata* Oliv. and *Kigelia africana* (Lam.) Benth.) and other traditionally important trees species (e.g. *L. cappassa*). According to Leakey et al. (2004) tolerated trees have undergone a long traditional selection process and usually have a social value to the community. Augusseau et al. (2006) highlights that these tolerated tree species have the potential to contribute to the development of "agroforestry parklands" within agricultural landscapes.

It has emerged from our findings that woodland clearing for cultivation purposes is effecting removal and replacement of tree species previously dominant in the natural woodland areas. Within recovering fallow land, *A. tortilis* subsp. *spirocarpa* is replacing *C. mopane* and *D. kirkii* as the dominant species in the landscape. This observation suggests that clearing of woodlands for cultivation purposes is changing the pattern of species composition. In essence, cultivation is simultaneously effecting selective removal of dominant species (*C. mopane* and *D. kirkii*), thus facilitating growth and dominance of *A. tortilis* subsp. *spirocarpa*. This subsequent increase in relative abundance of *A. tortilis* subsp. *spirocarpa* in the disturbed sites is not surprising. The species is highly invasive (Palgrave 2002), as *A. tortilis* subsp. *spirocarpa* is easily raised from seed, and although rather slow growing, is very hardy and drought resistant. This observation raises the need for intensive studies on the ecology of *A. tortilis* subsp. *spirocarpa* within the context of the mid-Zambezi valley in order to assess the role of this species within recovering fallow areas.

A survey through recent literature (Maitima et al. 2009; Asase et al. 2010; Norris et al. 2010; Tabor et al. 2010; Kayhko et al. 2011) has shown there has been wide research on land-use change from natural woodlands and forests to human managed landscapes. No study in particular has focused on the response of tree diversity to these land-use changes. This study focused on how tree diversity responds to land-use change. Overall, findings from this study indicate that farming practices in the mid-Zambezi valley are not necessarily leading to tree species loss in the short term. This suggests some potential to harmonize agricultural activities and biodiversity conservation in this area. In this regard, practices such as improved tree fallowing and agroforestry could be highly suitable for this area.

International Council for Research into Agroforestry (ICRAF 2001) defines agroforestry as a dynamic, ecologically-based, natural resource management system that, through integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased economic, environmental and social benefits. Although it is not possible to conserve all biodiversity, in a situation where agroforestry is practiced, more can be conserved than lost (Augusseau et al. 2006). In arguing for the role of agroforestry in agriculture and biodiversity conservation, Augusseau et al. (2006) highlights that in order to influence tree diversity conservation in a way which could be compatible with farmers objectives, efforts should be directed towards land-use units which traditionally harbor tree diversity. These land-use units include fallows and natural woodland patches within agricultural landscapes. In the mid-Zambezi valley, the only challenge lies in instilling willingness within farmers to conserve the broader suite of species making up the natural biodiversity.

Conclusions

In this study, we found evidence that woodland conversion into agricultural landscapes has no negative effect on species diversity in the mid-Zambezi, at least in the short term. This also implies the potential of agroforestry practices in promoting conservation and tree diversity. However, the effects of cultivation on woody species are detrimental after long periods cultivation. The fallow phase allows for tree recovery in terms of physiognomy. It, however, also facilitates dominance of invasive species, resulting in a complete replacement of the original vegetation type. Thus, land-use changes alternately reduce vegetation stature (clearing and cultivation) and allow recovery (fallow). Based on these findings, we recommend maintenance of a mosaic of different land-use units, each in a different phase of clearance-cultivation-abandonment-recovery-clearance cycle. Such a landscape will allow co-existence between conservation and providing farmers with wood for cooking and heating and food production which is the dominant need in the area.

Acknowledgements This study would not have been possible without efforts from colleagues from the Department of Biological Sciences, Tropical Resource Ecology Program, and the Department of Geography and Environmental Science University of Zimbabwe. We thank the Ministère Français des Affaires Etrangères et Européennes for supporting (Edwin Tambara) through the French Embassy in Zimbabwe (Research Platform-Production and Conservation in Partnership, RP-PCP grant/CC#4). Mbire Rural District Council allowed the work to be carried out in the area.

References

Asase A, Frimpong KO, Ekpe PK (2010) Impact of cocoa farming on vegetation in an agricultural landscape in Ghana. Afr J Ecol 48:338–346

Augusseau X, Nikiema P, Torquebiau E (2006) Tree biodiversity, land dynamics and famers' strategies on the agricultural frontier of southwestern Burkina Faso. Biodivers Conserv 15:613–630

Balmford A, Green RE, Scharlemann JPW (2005) Sparing land for nature: exploring the potential impact of changes in agricultural yield on the area needed for crop production. Glob Chan Bio 11:1–12

Baudron F, Corbels M, Monicat F, Giller KE (2009) Cotton expansion and biodiversity loss in African savannahs, opportunities and challenges for conservation agriculture: a review paper based on two case studies. Biodivers Conserv 18:2625–2644. doi:10.1007/s10531-009-9663-x

Baudron F, Corbels M, Andersson JA, Sibanda M, Giller KE (2011) Delineating the drivers of waning wildlife habitat: The predominance of cotton farming on the fringe of protected areas in the Mid-Zambezi Valley, Zimbabwe. Biol Conserv 144:1481–1493. doi:10.1016/j.biocon.2011.01.017

Bierregaard ROJ, Lovejoy TE, Kapos V, Santos AA, Hutchings RW (1992) The biological dynamics of tropical rainforest fragments. BioScience 42:859–866

Biodiversity Project (2002) The Mankind and the animal in the mid-Zambezi valley, Zimbabwe. CIRAD-Emvt. Harare. p 75

Brussaard L, Caron P, Campbell B, Lipper L, Mainka S, Rabbinge R, Babin D, Pulleman M (2010) Reconciling biodiversity conservation and food security: scientific challenges for a new agriculture. Terres Syst 2:34–42

Chizarura L (2003) Impact of globalisation on rural livelihoods; In the mid-Zambezi valley, Harare, SEATINI

Crawley MJ (1997) Plant ecology. Oxford, Blackwell Publishing

Derman B (1996) Changing land-use in the Eastern Zambezi valley: socio-economic considerations. CASS/WWF, Harare

Drummond RB, Coates-Palgrave C (1973) Common trees of the highveld. Salisbury, Longman

Ewers MR, Scharlemann JPW, Balmford A, Green RG (2009) Do increase in agricultural yields spare land for nature? Glob Chan Bio 15:1716–1726

Fischer J, Brosi B, Gretchen CD, Ehrlich PR, Goldman R, Goldstein J, Lindenmayer DB, Manning AD, Mooney HA, Pejchar L, Ranganathan J, Tallis H (2008) Should agricultural policies encourage land sparing or wildlife friendly–farming? Front Ecol Environ 6:380–385

Fritz H, Said S, Renaud PC, Mutake S, Coid C, Monicat F (2003) The effects of agricultural fields and human settlements on the use of rivers by wildlife in the mid-Zambezi valley, Zimbabwe. Lan Ecol 18:293–302

Gardner TA, Barlow J, Chazdon R, Ewers RM, Harvey CA, Peres CA, Sodhi NS (2009) Prospects for tropical forest biodiversity in a human-modified world. Ecol Lett 12:561–582

Green RE, Cornell SJ, Scharlemann JPW, Balmford A (2005) Farming and the fate of wild nature. Science 307:550–555

Guillen KW, Perfect I (2010) Effects of agricultural intensification on the assemblage of leaf-nosed bats (Phyllostomidae) in a coffee landscape in Chiapas, Mexico. Biotropica 42:605–613

Harvey CA, Komar O, Chazdon R, Ferguson BG, Finegun B, Griffith DM, Martinez-Ramos M, Morales H, Nigh R, Soto-Pinto L, Breugel MV, Wishnie M (2008) Integrating agriculture landscapes with biodiversity conservation in the Mesoamerican hotspot. Conserv Biol 22:8–15

International Council for Research into Agroforestry (ICRAF 2001) www site: http://www.ciesin.org/IC/icraf/ICRAF.html

Kadoya T, Washitani I (2011) The Satoyama index: a biodiversity indicator for agricultural landscapes. Agric Ecosyst Environ 140:20–26

Kayhko N, Fagerholm N, Asseid BS, Mzee AJ (2011) Dynamic land use and land cover changes and their effect on forest resources in a coastal village of Matemwe, Zanzibar. Tanzania Land Use Policy 28:26–37

King KFS (1979) Agroforestry and the utilisation of fragile ecosystems. Forest Ecol Manage 2:161–168

Leakey RRB, Tchoundjeu Z, Smith RI, Munro RC, Fondoun JM, Kengue J, Anegbeh PO, Atangana AR, Waruhiu AN, Asaah E, Usoro C, Ukafor V (2004) Evidence that subsistence farmers have domesticated indigenous fruits (*Dacryodes edulis* and *Irvingia gabonensis*) in Cameroon and Nigeria. Agro Syst 60:101–111

Magurran AE (1988) Ecological diversity and its measurement. Princeton University Press, Princeton

Maitima JM, Mugatha SM, Reid RS, Gachimbi LN, Majule A, Lyaruu H, Pomery D, Mathai S, Mugisha S (2009) The linkages between land use change, land degradation and biodiversity across East Africa. Afr J Environ Sci Technol 3:310–325

Mapaure I (1994) The distribution of *Colophospermum mopane* (Leguminosac-Caesalphiniodeae) in Africa. Kirkia 15:1–5

Matson PA, Vitousek PM (2006) Agricultural intensification: will land spared from farming be land spared for nature? Conserv Biol 20:709–710

Mattison EHA, Norris K (2005) Bridging the gaps between agricultural policy, land-use and biodiversity. Tren Ecol Evol 20:610–616

Mvuriye D, Bel SL, Mutak S, Mukutirwa W, Mudavanhu MS, Mapuvire G (2001) Biodiversity in Dande. CIRAD, Harare

Norris K, Asaseb A, Collenc B, Gockowksid J, Masone J, Phalanf B, Wadea A (2010) Biodiversity in a forest-agriculture mosaic–The changing face of West African rainforests. Biol Conserv 143:2341–2350

Oba G, Stenseth NC, Weladji RB (2002) Impacts of shifting agriculture on floodplain woodland regeneration in dryland, Kenya. Agric Ecosyst Environ 90:211–216

Ogunleye AJ, Adeola AO, Ojo LO, Aduradola AM (2004) Impact of farming activities on vegetation in Olokemeji forest reserve, Nigeria. Glob Nest: Int J 6:131–140

Palgrave KC (2002) Trees of Southern Africa. Struik Publishers, Cape Town

Poilecot P, Gaidet N (2011) A quantitative study of the grass and woody layers of a Mopane (*Colophospermum mopane*) savannah in the mid-Zambezi Valley, Zimbabwe. Afr J Ecol 49:150–164

Rudel TK, Schneider L, Uriarte M, BL Turner II, DeFries R, Lawrence D, Geoghegan J, Hecht S, Ickwizt A, Lambin EF, Birkenholtz T, Batista S, Grau R (2009) Agricultural intensification and changes in cultivated areas. PNAS 106:20675–20680

Scherr SJ, McNeely JA (2008) Biodiversity conservation and agricultural sustainability: towards a new paradigm of 'ecoagriculture' landscapes. Phil Trans R Soc B 363: 477–494

Tabor K, Burgess ND, Mbilinyi BP, Kashaigili JJ, Steininger MK (2010) Forest and woodland cover and change in coastal Tanzania and Kenya, 1990 to 2000. J East Afr Nat His 99:19–45

Teodoro AV, Munoz A, Tscharntke T, Klein AM, Tylianakis JM (2011) Early succession arthropod community changes on experimental passion fruit plant patches along a land-use gradient in Ecuador. Agric Ecosyst Environ 140:14–19

Tilman D, Fargione J, Wolf B, Antonio CD, Dobson A, Howarth R, Schindler D, Schlesinger WH, Simberloff D, Swackhamer D (2001) Forecasting agriculturally driven global environmental change. Science 292:281–284

Timberlake JR, Drummond RB, Maroyi A (1988) Biodiversity assessment of the lower Guruve region. Zambezi Valley, Zimbabwe. Occasional Publications on Biodiversity 4

Timberlake JR, Nobanda N, Mapaure I (1993) Vegetation survey of the communal lands-North and West of Zimbabwe. Kirkia 14:171–204

Tripathi OP, Upadhaya K, Tripathi RS, Pandey HN (2009) Diversity, dominance and population structure of trees species along fragment-size gradient of a subtropical humid forest of northeast India. Res J Environ Earth Sci 2:97–105

Van Wyk BV, Van Wyk PV (1997) Field guide to trees of Southern Africa, Struik Publishers. Cape Town