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Species composition and spatial heterogeneity of the seed bank and vegetation in protected and disturbed *Miombo* Woodland at Christon bank, Zimbabwe

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Abstract

The regeneration potential of *Miombo* woodland was evaluated by comparing above ground vegetation and seed banks in a protected area (Mazowe Botanical Reserve) and an adjacent disturbed farming area (Thetford Estates). Sampling was conducted in April and May 2012. In each area 30 sampling plots measuring 10x10 m were randomly selected and the species composition and abundance of all the above ground flora was determined. Soils were collected from each plot and the seedling emergence method was used to determine the species composition of seed bank. The results show that more species were recorded in the protected (264 above ground and 118 in seed bank) than in the disturbed area (119 above ground and 89 in seed bank), showing that disturbance factors were impacting on species composition. The results also show the absence of key *Miombo* woody species and the dominance of grasses and forbs in the seed banks. We interpreted this to mean that the seed banks cannot sustain the recovery of the *Miombo* woodland after disturbance. We recommend the use of more improved methods for estimating the size of the seed bank as the seedling emergence method used in this case is known to underestimate the seed bank.

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Introduction

Soil seed banks play an important role in maintaining the ecological and genetic diversity of populations and communities and in assuring community regeneration following disturbance (Tekle and Bekele, 2000). They constitute a source of propagules for recruitment after disturbance and provide a mechanism for populations to persist through adverse conditions (Williams *et al.*, 2005). Soil seed bank structures are dynamic, and fluctuate seasonally or annually due to variations resulting from seed production, seed fall, seed mortality, release of seeds from dormancy and seed germination (Thompson & Grime 1979). Anthropogenic determinants of vegetation structure in African savannas like fire, grazing and land clearance impact jointly or separately on any of these processes (Zida *et al.*, 2007).

The relationship between seed banks and standing vegetation has been investigated in varied studies concerned with effects of restoration and reforestation, disturbances, succession, and invasive species and for management purposes (Hopfensperger, 2007). Numerous studies have documented similarities in species composition between soil seed banks and aboveground vegetation but others have shown a poor correlation (Tessema *et al.*, 2012). Hopfensperger (2007) reported wider occurrence of woody species and perennial grasses in the above ground vegetation and of annual forbs in the seed bank and attributed the differences to variations in seed dormancy patterns and germination rates. The soil seed bank should mirror the composition of the existing above ground vegetation, provided that seeds arrive only from plants growing in the immediate area. Chaideftou *et al.* (2009), however, reported that not all species in a community may be represented in the seed bank. This may be due a number of factors like disturbances and fragmentation, for example, which may influence species richness and abundance in the soil seed bank (Salazar, 2010). Seed predation, pathogen infection and loss in viability following dispersal can also influence seed bank densities (Dalling, 2004). Correlations between soil seed banks and above ground vegetation vary depending on the types of vegetation and environments and the variability of the human impacts like deforestation, grazing, fire and also natural factors like drought (Telke and Bekele, 2000).

Most research on soil seed bank were focused on temperate habitats with fewer studies conducted in the *Miombo* ecoregion (Anderson *et al.*, 2011). Moreover, the studies in the *Miombo* have been inconclusive especifically on how seed banks change across environmental gradients. *Miombo* woodland is the most extensive tropical woodland in Africa (Dewees *et al.,* 2011) and presently is being severely altered due to a number of anthropogenic factors caused by high population growth rates (Campbell *et al.*, 2006). Studies in the *Miombo* ecoregion have focused on woodland distribution, ecology, use and disturbance (Campbell *et al.*, 2006; Dewees *et al.,* 2011) and largely exclude the importance of seed banks in the ecosystem (Diaz-Villa, 2003). Studies on the soil seed bank and extant vegetation are considered important in understanding community dynamics, restoration and succession and correspondingly provide valuable implications for conservation (Li *et al*, 2011).

This study aims at examining the relationships between soil seed bank structure and above ground vegetation to assess the potential for vegetation recovery of disturbed habitats in *Miombo* woodlands. The Christon bank area is ideal for such a study as it includes both protected areas at the Mazowe botanical reserve and many adjacent disturbed areas including Thetford farm estates.

Material and methods

Study sites

The study was conducted at Mazowe Botanic Reserve and the adjacent Thetford Estates (Figure 1). The study sites are located between latitudes 17° 39´ and 17° 36´ South and the longitudes 31° 31´ and 31° 01´

East, 30 km north of the city of Harare. Precipitation is variable from year to year averaging around 900 mm per year, with mean monthly temperatures ranging from 12.9°C in July to 21.6°C in November (Tsvuura and Nyamhanga, 2002). Soils are predominantly kaolinitic and belong to the paraferrallitic group (Nyamapfene, 1991). These vegetation types shared the same soil and topographic characteristics but differed in disturbance history.

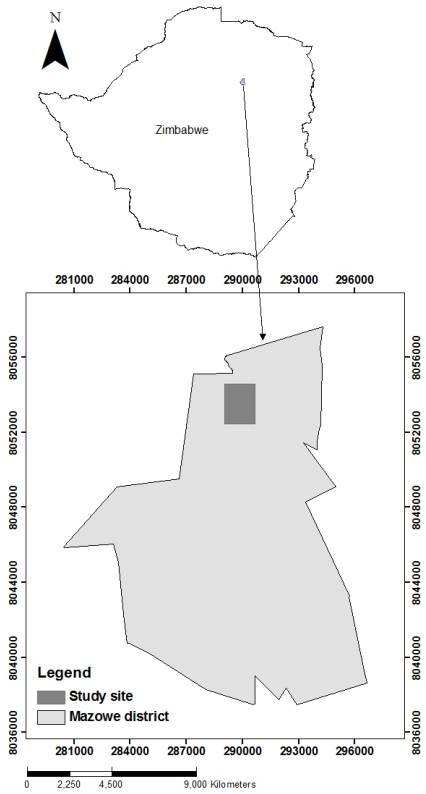

Fig. 1. Location of the study site in Mazowe District.

The vegetation is typically *Miombo*, with *Brachystegia spiciformis* Benth. and *Julbernardia globiflora* (Benth.) Troupin being the main elements. The study sites are adjacent to each other but differ in land tenure, management practices and disturbance regimes. The Botanic Reserve is relatively pristine *Miombo* woodland that is protected under the National Parks and Wildlife Act (1975) and managed by the National Botanic Garden. In contrast, Thetford is a privately owned farming area subjected to various forms of disturbance including crop cultivation, grazing and many other human impacts.

Sampling procedure

Sampling was carried out in May and April 2012. A modified Whittaker plot design (Stohlgren *et al.*, 1995) was used to collect vegetation data and soil samples from the study area. A total of 30 plots (10 m x 10 m) in each of the two study sites were randomly selected out of 150, identified in aerial photographs. In each sample plot, all plant species were identified and the numbers of each species counted. Specimens which could not be readily identified in the field were collected and later identified at the National Herbarium. The percentage cover of each species was estimated visually in the sub-plots using a 1 m² graduated quadrat and averaged.

Soil sampling was done by collecting five soil cores per plot following the method of Sutherland (2006). A 20 cm x 7cm auger was used to collect the soil samples. Soil samples were taken at the plot centre and at each of the four corners of the subplot. Woody material (twigs, branches) and leaf litter were removed before sampling. The soil auger was meticulously cleaned between two samples to avoid contamination. The soil samples were immediately bagged labelled and transported to the laboratory where they were air-dried.

Seedling emergence method

The seedling emergence method (Roberts 1981) was used to determine species composition of the soil seed bank. The soil samples from each subplot were thoroughly mixed, sieved through a 10 mm mesh to separate large pebbles and organic plant debris and stored in plastic bags. The experiments were carried out in glasshouses at the National herbarium in plastic trays measuring 22 x 16.5 x 5 cm. The trays were filled with soil samples and spread homogeneously to a thickness of 4 cm. Four replicates and one control were used for each microhabitat. Controls of pre-washed and sterilized sand soil were randomly interspersed among the soil samples to ensure all seeds in the substrate bed were killed during sterilization and to account for potential contamination of samples by exogenous seeds.The trays were watered twice a week and monitored for

four months for seedling emergence. All emerging seedlings were identified and counted.

Data analysis

The degree of floristic similarity between vegetation and seed bank communities was analyzed using the Morisita-Horn (Wolda, 1981) and Sørensen (Hopfensperger, 2007) similarity indices computed using EstimateS statistical software: version 8 (Colwell, 2006). Species rank abundance curves (Oldeland *et al.,* 2010), were used for visual and numerical comparisons of community patterns in the vegetation and soil seed bank per study site. The Shannon - Weiner's Diversity Index was calculated and compared for each site using the Estimates S software. Species evenness between the soil seed bank and above ground vegetation was calculated using Species evenness E = H'/lnS, where H is Shannon's diversity index and lnS is the natural logarithm of the species richness.

Results and discussion

Species composition of the above ground vegetation and soil seed bank

A total of 264 plant species belonging to 58 families were recorded in the above ground vegetation (ABV) (protected) as compared to 199 species belonging to 49 families in the AGV (disturbed). In the soil seed bank there were more species (118 species from 24 families) recorded from the protected area than the disturbed area (89 species from 20 families) (Appendix A). Seed banks sites had less species than aboveground sites.

The occurrence of less plant species and families in the disturbed sites indicates that disturbance has had an impact on the vegetation dynamics of the study area. This is also reflected in the growth forms where more growth forms are represented in the protected above ground vegetation than in the disturbed (table 1). Similar results have been reported in Ethiopia (Tessema *et al*, 2012) and in South Africa (Dreber *et al*, 2011). The disturbance factors in the Thetford area that include veld fires, grazing, wood cutting and clearing land for agriculture are among the key anthropogenic impacts on savanna woodlands (Luoga, 2000).

Woody species dominate the aboveground vegetation in both disturbed and protected areas whereas the soil seed bank is dominated by grasses and herbaceous species (Table 1).

The woody species dominant on the above ground vegetation include *Julbernardia globiflora* and *Combretum molle* on the protected site and *Brachystegia spiciformis, J.globiflora, C.molle, Dichrostachys cinerea* and *Burkea africana* on the disturbed site (Table 2). The dominant grass species on the soil seed bank from the protected area include *Themeda triandra* and *Andropogon gayanus,* and the dominant herbaceous flora includes *Ocimum obovatum* and *Aspilia mossambicensis*. The disturbed soil seed bank yielded the grass species *Hyperrhenia filipendula* and *Tristachya nodiflorum* and the herbaceous plant *Ocimum obovatum*.

Lyaruu and& Backéus (1999), reported similar observations in Tanzania. Some recent soil seed bank studies, in agreement with the present findings, have shown that the seeds of woody species are rare in seed banks compared with herbaceous and grass species in various tropical ecosystems (Tekle and Bekele, 2000; Figueroa *et al*., 2004; Solomon *et al*., 2006, Esmailzadeh *et al*., 2011). Of note in this study is the absence in the seed bank of key *Miombo* woodland species like *Brachystegia spiciformis, Julbernadia globiflora, Combretum spp., Pterocarpus spp, Burkea africana, Uapaca spp., Pseudolachnostylis maprounefolia* and *Lannea spp.* This may either mean the absence of such seeds in the soil, or possibly conditions for breaking their dormancy were not met during the experiment, or they could have lost their viability (Lyaruu and Backéus, 1999). The absence of these key species, coupled with the general limited dispersal of *Miombo* species (Chidumayo and Frost, 1996) might suggest the failure of the seed bank to sustain the recovery of the woodlands. However,

Miombo species are known to regenerate largely through coppice regrowth and root suckers rather than through seeds (Luoga *et al.*, 2004).

The percentage of annual to perennial species is higher in the soil seed bank (10.8% in SSBP, 10.7% in SSBD) than in the above ground vegetation (5.5 % in AGVD, 6.9 % in AGVP). The main annual species observed include *Bidens pilosa, Melinis repens, Tagetes minuta* and *Triumfetta annua,* all known to be ephemeral weeds dispersed by wind. Soil seed banks usually contain more annuals than perennials and more weeds when highly disturbed (Tessema *et al*, 2012). Colonization of annual species on grazed sites indicates that grazing is having an impact on the performance and seed production of the perennials, thereby reducing their seed contribution to the soil seed banks (Solomon *et al.* 2006). Annuals therefore become abundant owing to their high reproductive output (Scott *et al.*, 2010) and because perennials often propagate vegetatively (Tessema *et al*, 2012).

A number of ephemeral weeds were recorded only in the soil seed banks and not in the above ground vegetation. These include *Ageratum conyzoides* subsp. *conyzoides, Euphorbia hirta, Hypoestes forskalei, Kohautia caespitosa* subsp.*brachyloba, Murdannia simplex* and *Plectranthus gracillimus in the* SSBP *and Crassocephalum rubens, Phyllanthus reticulatus, Richardia scabra, Sphaeranthus randii* and the grass *Oplismenus hirtellus in the* SSBD. Presence of these new species in the seed bank could be an indication of an active seed rain in the study area or possibly these species are successful weeds capable of producing numerous, long lived seeds as part of their opportunistic survival strategy (Dreber *et al.*, 2011).

Species richness, evenness and diversity

Species rank abundance distributions for species assemblages in the soil seed bank and above ground vegetation are presented in figure 2. The shapes of the distributions are similar and independent of site with a steep initial slope due to a few species over-represented in both soil seed bank and above ground vegetation. Species richness is higher in the AGV (protected) than the AVG (disturbed) and in the SSB (protected) than the SSB (disturbed). The shapes of the curves also show that the majority of the species on all the sites have more or less similar abundances showing high evenness in species composition. Such patterns in species abundance distributions reflect a common pattern in community structure at a local scale and it can therefore be concluded in agreement with Olano *et al*, (2005) that the seed bank in semiarid environments may be a good predictor of community composition.

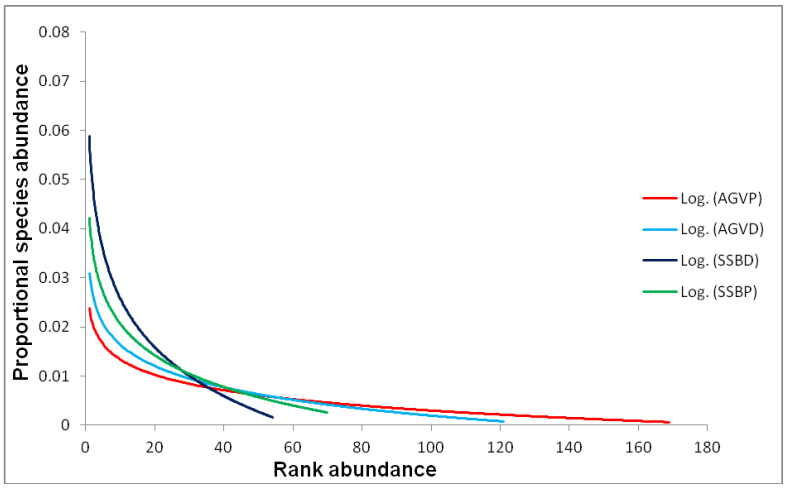

Fig. 2. Rank abundance curves for the above ground and seed bank species composition in the two study areas (ranked from most abundant to least abundant).

.The high species evenness in the study area is supported by calculated evenness values shown on table 3. Differences in evenness between aboveground and seed banks could be a result of an underestimation of the seed bank due to the sampling method used which assumes equal distribution of seeds in the seed bank ignoring other factors like the seed shadow, seed type and dispersal mode which are known to be species specific (Lyaruu and& Backéus,1999). The Shannon-Wiener diversity indices were high for all the study sites ranging from 4.05 in the SSB (disturbed) to 5.13 in the AGV (protected) (Table 3). This paralleled the species richness of the sites. Species diversity in the study area is high, but diversity indices here are not reliable in assessment of disturbance impacts since they only account for species richness and evenness and not changes in composition. The clearing of woody species leads to species composition changes as mainly annual grasses and forbs invade the open spaces.

Similarity between the soil seed bank and above ground vegetation

The soil seed banks and aboveground vegetation shared a number of common species as shown on table 4. The above ground vegetation in the protected and disturbed communities shows the highest similarity with similarity indices of 79 % (Morisita-Horn index) and 65 % (Sorensen index). This shows that the human impacts like woodcutting and land clearing at Thetford farm have not impacted much on species composition. Of concern, however, are the very low similarity values shown by both indices (52 % Morisita-Horn and 40% Sorenson) between the protected above ground vegetation and the disturbed soil seed bank. This is a significant result suggesting that the recovery of the *Miombo* woodland would not be possible from the seed bank after disturbance. Poor correspondence between the seed bank and above-ground vegetation has been reported for many ecosystems (Hopfensperger, 2007).

Table 1. Species growth frequencies in the studied area (AGVP-Aboveground vegetation protected, AGVD-Aboveground vegetation disturbed, SSBP-Soil seed bank protected, SSBD-Soil seed bank disturbed).

Habitat	Species growth form frequencies (%)						
	Climber	Fern	Grass	Herb	Orchid	Sedge	Woody
AGVP	0.2	2.4	19.3	35.7	0.1	3.2	39.1
AGVD	0	1.3	24.5	26.4	0	4.0	43.7
SSBP	0	3.1	36.2	42.2	0	7.8	10.7
SSBD	0	2.3	53.6	29.7	0	9.7	5.6

Table 2. The ten most abundant species in each vegetation community in decreasing order of abundance.

Above ground vegetation (protected)	Above ground vegetation (disturbed)	Soil seed bank (protected)	Soil seed bank (disturbed)
Themeda triandra	Brachystegia spiciformis	Themeda triandra	Hyperrhenia filipendula
Andropogon gayanus	Hyperrhenia filipendula	Ocimum obovatum	Tristachya nodiglumis
Julbernadia globiflora	Julbernadia globiflora	Indigofera setiflora	Bulbostylis macra
Combretum molle	Tristachya nodiglumis	Digitaria.gazensis	Ocimum obovatum
Tristachya nodiglumis	Combretum molle	Aspilia mossambicensis	Digitaria eriantha
Ocimum obovatum	Dichrostachys cinerea	Acalypha allenii	Heteropogon contortus
Indigofera setiflora	Burkea africanum	Andropogon gayanus	Melinis repens
Shizostephium artemisiiflorum	L.annea discolor	Cyperus angolensis	Panicum maximum
Aspilia mossambicensis	Monotes glaber	Heteropogon contortus	Andropogon gayanus
Poulzozia mixta	Bulbostylis macra	Hyperrhenia filipendula	Bidens pilosa

Table 3. Species evenness for the above ground vegetation and soil seed bank.

Area	Evenness	Shannon-Weiner
AGV protected	0.92	5.13
AGV disturbed	0.92	4.85
SSB protected	0.92	4.37
SSB disturbed	0.90	4.05

Table 4. Shared species and similarity statistics for the four sites in the study area

Vegetation types		Shared Species	Similarity indices	
First sample	Second sample	Observed	Morisita-Horn	Sorensen
AGVP	AGVD	151	0.789	0.653
AGVP	SSBP	114	0.763	0.596
AGVP	SSBD	71	0.516	0.403
AGVD	SSBP	82	0.600	0.518
AGVD	SSBD	83	0.649	0.580
SSBP	SSBD	65	0.736	0.631

Conclusion

The results show that anthropogenic disturbance had effects on the vegetation dynamics of the study area. Declines in species composition and richness, although not severe, are evident in the disturbed area. The absence of key *Miombo* woodland species in the seed banks is evidence these seed banks cannot support the natural regeneration of the woodlands after disturbance. Our results, however most likely underestimated the size of the seed bank as sampling was only done during one season. Seed bank sizes are known to vary with the season. Additionally, more accurate methods of seed bank estimation like the seed floatation and seed extraction method should be attempted.

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References

Anderson TM, Schütz M, Risch AC. 2012. Seed germination cues and the importance of the soil seed bank across an environmental gradient in the Serengeti. Oikos 121, 306–312.

Campbell BM, Frost P, Byron N. 2006. Miombo Woodlands and their use: overview and key issues. In: Campbell, B. (ed.) The Miombo in Transition: Woodlands and Welfare in Africa. pp. 1-10. Centre for International Forestry Research, Bogor, Indonesia

Chaideftou E, Thanos CA, Bergmeier E, Kallimanis A, Dimopoulos P. 2009. Seed bank composition and above-ground vegetation in response to grazing in sub-Mediterranean oak forests (NW Greece). Plant Ecology 201,255–265.

Chidumayo E, Frost P. 1996. Population Biology for Miombo Trees. In Campbell, B. (ed.). The Miombo in Transition: Woodlands and Welfare in Africa. Center for International Forestry Research (CIFOR), Bogor, Indonesia.

Colwell RK. 2006. Estimates S, Version 9.1. http://viceroy.eeb.uconn.edu/estimates

Dalling JW. 2004. The fate of seed banks: Factors influencing seed survival for light demanding species in moist tropical forests. In Forget, Pierre-Michel [eds.] Seed Fate: Predation, Dispersal and Seedling Establishment pp. 31-44. CAB International, Wallingford

Dewees PA, Campbell BM, Katerere Y, Sitoe A, Cunningham AB, Angelsen A, Wunder S. 2011. Managing the Miombo woodlands of southern Africa. Policies, Incentives, and Options for the Rural Poor. Program on Forests (PROFOR).

Diaz-Villa MD, Marannon T, Arroyo J, Garrido B. 2003. Soil Seed Bank and Floristic Diversity in a Forest-grassland Mosaic in Southern Spain. Journal of Vegetation Science 14, 701- 709.

Dreber N, Oldeland J, van Rooyen GMW. 2011. Species, functional groups and community structure in seed banks of the arid Nama Karoo: Grazing impacts and implications for rangeland restoration. Agriculture, Ecosystems and Environment 141 (3/4), 399-409.

Esmailzadeh O, Hosseini SM, Tabari M. 2011. Relationship Between Soil Seed Bank and Above-ground Vegetation of a Mixed- deciduous Temperate Forest in Northern Iran. Journal of Agricultural Science and Technology 13, 411-424.

Figueroa J A, Teillier S, Jaksic FM. 2004. Composition, size and dynamics of the seed bank in a Mediterranean shrubland of Chile. Austral Ecology 29,574–584.

Hopfensperger K. 2007. A review of similarity between seed bank and standing vegetation across ecosystems. Oikos 116, 1438-1448.

Lyaruu HVM, Backéus I. 1999. Soil seed bank and regeneration potential on eroded hill slopes in the Kondoa Irangi Hills, central Tanzania. Applied Vegetation Science 2, 209-214.

Li Q, Fang H, Cai Q. 2011. Persistent soil seed banks along altitudinal gradients in the Qilian Mountains in China and their significance for conservation management. African Journal of Agricultural Research 6 (10), 2329-2340.

Luoga EJ. 2000. The effect of human disturbances on diversity and dynamics of eastern Tanzania Miombo arborescent species. Unpublished Dphil thesis, University of the Witwatersrand, South Africa.

Luoga EJ, Witkowski ETF, Balkwill K. 2004. Regeneration by coppicing (resprouting) of Miombo (African savanna) trees in relation to land use. Forest Ecology and Management 189(1/3), 23-36.

Nyamapfene K.1991. Soils of Zimbabwe. Nehanda Publishers, Harare. pp 28-39.

Olano JM, Caballero I, Loidi J, Escudero A. 2005. Prediction of plant cover from seed bank analysis in a semi-arid plant community on gypsum. J. Veg. Sci. 16, 215–222.

Oldeland J, Dreber N, Wesuls D. 2010. Diversity measures in comparative range- land studies: application and advantages of species abundance distributions and diversity profiles. Dinteria 31, 50–66.

Roberts HA. 1981. Seed banks in soils. Adv. Appl. Biol. 6, 1-55.

Salazar A. 2010. Seed Dynamics and Seedling Establishment of Woody Species in the Tropical Savannas of Central Brazil (Cerrado). Unpublished Dphil thesis, Paper 371. University of Miami, USA.

Scott K, Setterfield S, Douglas M, Anderson A. 2010. Seed banks confer resilience to savanna grass- layer plants during seasonal disturbance. Acta Oecol. 36, 202–210.

Solomon TB, Snyman HA, Smit GN. 2006. Soil seed bank characteristics in relation to land use systems and distance from water in a semi-arid rangeland of southern Ethiopia. S. Afr. J. Bot. 72, 263–271.

Stohlgren TJ, Falkner MB, Schell LD. 1995. A Modified-Whittaker nested vegetation sampling method. Vegetation Science 117,113-121.

Tekle K, Bekele T. 2000. The Role of Soil Seed Banks in the Rehabilitation of Degraded Hillslopes in Southern Wello, Ethiopia'. Biotropica 32(1), 23-32.

Tessema ZK, de Boer WF, Baars RMT, Prins HHT. 2012. Influence of Grazing on Soil Seed Banks Determines the Restoration Potential of Aboveground Vegetation in a Semi- arid Savanna of Ethiopia. Biotropica 44(2), 211–219.

Thompson K, Grime J. 1979. Seasonal variation in seed banks of herbaceous species in ten contrasting habitats. Journal of Ecology 67, 893–921.

Tsvuura Z, Nyamhanga E. 2002. A preliminary checklist of plants from the Mazowe Botanic Reserve, Zimbabwe. Kirkia 18 (1), 49-62.

Williams PR, Congdon RA, Grice AC, Clarke PJ. 2005. Germinable soil seed banks in a tropical savanna: seasonal dynamics and effects of fire. Austral Ecology 30, 79–90.

Wolda H. 1981. Similarity indices, sample size and diversity. Oecologia 50, 296–30.

Zida D, Sawadogo L, Tigabu M, Tiveau D, Odén PC. 2007. Dynamics of sapling population in savanna woodlands of Burkina Faso subjected to grazing, early fire and selective tree cutting for a decade. Forest Ecology and Management 243(1), 102-116.

Appendix 1. List of species identified from the above ground vegetation and soil seed bank

Species	AGVP	AGVD	SSBP	SSBD
Acacia amythethophylla A.Rich.	1		1	
Acacia karroo Hayne	3	2		1
Acacia polyacantha Willd.	1	2		
Acacia schweifurthii Brenan	1			
Acalypha allenii Hutch.	14	8	12	6
Acalypha villicaulis Hochst.	7	3	5	2
Achyranthes aspera L.	6	1	4	1
Adenia gummifera (Harv.) Harms	1	1		
Aeschynomene mimosifolia Vatke	3	2		
Ageratum conyzoides L. subsp. conyzoides		2	1	1
Albizia antunesiana Harms	5	5		
Albizia versicolor Oliv.	1			
Ampelocissus africana (Lour.) Merr. var. africana	7	1	1	
Andropogon fastigiatus Sw.	1			
Andropogon gayanus Kunth	22	10	12	9
Annona senegalensis Pers.		1		
Aristida adscensionis L.	1	2	1	2
Aristida leucophaea Henrard	5	6	5	6
Asparagus africanus Lam.	2	6		
Aspilia mossambicensis (Oliv.) Wild	15	7	13	3
Barleria crassa C.B.Clarke	5		1	
Basananthe apetala (Baker f.) W.J.de Wilde				
Berkheya zeyheri (Sond. & Harv.) Oliv. & Hiern subsp. zeyheri	5			
Bewsia biflora (Hack.) Gooss.	1	2		2
Bidens biternata (Lour.) Merr. & Sherff	1		1	
Bidens pilosa L.	11	8	9	9
Biophytum petersianum Klotzsch		1		1
Blumea crispata (Vahl) Merxm.	5	3		
Boophone disticha (L.f.) Herb.		1		
Boscia salicifolia Oliv.	1			
Brachylaena discolor DC.	3			
Brachystegia boehmii Taub.	6	10	4	
Brachystegia glaucescens Burtt Davy & Hutch.	12	4	5	2
Brachystegia spiciformis Benth.	11	22		1
Bridelia carthatica G.Bertol.	1	2		
Bulbostylis macra (Ridl.) C.B.Clarke	11	12	10	12
Burkea africana Hook.	4	13		
Cassia abbreviata Oliv.	1	1	1	
Catunaregum swinnertonii (S.Moore) Bridson	2	1		

Celtis africana Burm.f.	1	1	1	1
Chamaecrista fenarolii (Mendonca & Torre) Lock	1			
Chamaecrista mimosoides (L.) Greene	2	5	1	3
Cheilanthes multifida (Sw.) Sw.	18	5	10	3
Chloris pychnothrix Trin.	1			
Chlorophytum polystachyum Baker	6	2		
Cissus cornifolia (Baker) Planch.		1		
Clematopsis villosa (DC.) Hutch. subsp. kirkii (Oliv.) J.Raynal & Brummitt		2		1
Clerodendrum ternatum Schinz	1			
Combretum apiculatum Sond.	1			
Combretum erythrophyllum (Burch.) Sond.		1		
Combretum hereroense Schinz subsp. hereroense		1		
Combretum molle G.Don	19	17		
Combretum zeyheri Sond.	3	1		
Commelina africana L.	12	10	6	2
Commelina benguelensis L.	2			
Commelina erecta L.	1			
Commelina forskaolii Vahl	2			
Commelina welwitcshii C.B.Clarke	2		1	
Commiphora mollis (Oliv.) Engl.	2	1		
Commiphora mossambicensis (Oliver.) Engl.	2			
Corchorus kirkii N.E.Br.	2			
Crabbea hirsuta Harv.	8	2	7	1
Craspedorhachis africana Benth.	2		1	
Crassocephalum rubens (Jacq.) S.Moore				1
Crotalaria natalitia Meisn. var. natalitia		1		1
Cryptolepis oblongiflora (Meisn.) Schltr.	1			
Cussonia arborea A.Rich.	2			
Cyanotis lanata Benth.	2			
Cymbopogon nardus (L.) Rendle	14	2	8	2
Cyperus angolensis Boeck.	11	8	12	8
Cyperus esculentus L.	5	3	5	
Cyperus rotundus L. subsp. rotundus	5	6	7	8
Cyphostemma buchananii (Planch.) Wild & R.B.Drumm.		2		
Cyphostemma junceum (Webb) Wild & R.B.Drumm.	1		1	
Cyphostemma rhodesiae (Gilg & Brandt) Wild & R.B.Drumm.	3			
Cyphostemma viscosum (Gilg & R.E.Fr.) Wild & R.B.Drumm.		1		
Cyrtorchis praetermissa Summerh. subsp. praetermissa	1			
Dalbergia nitidula Baker	9	1	1	
Danthoniopsis pruinosa C.E.Hubb.	6	1	6	1
Desmodium barbatum (L.) Benth. var. dimorphum (Baker)	9	2	3	

B.G.Schub.				
Desmodium repandum (Vahl) DC.	1		1	
Desmodium salicifolium (Poir.) DC. var. salicifolium		2		
Desmodium tortuosum (Sw.) DC.	1			
Desmodium uncinatum (Jacq.) DC.	4	3	1	3
Dichrostachys cinerea (L.) Wight & Arn.	13	14	3	3
Dicoma anomala Sond.	1	5	5	3
Dicoma gerrardii F.C.Wilson	6	1		
Digitaria brazzae (Franch.) Stapf	1		1	
Digitaria eriantha Steud.	5	10	4	10
Digitaria gazensis Rendle	14	6	13	5
Digitaria milanjiana (Rendle) Stapf	7	5	7	4
Digitaria velutina (Forssk.) P.Beauv.	1			
Diheteropogon amplectens (Nees) Clayton var. katangensis (Chiov.) Clayton	7	10	4	8
Dioscorea dumetorum (Kunth) Pax	1			
Dioscorea silvatica (Kunth) Eckl. var. brevipes (Burtt Davy) Burkill		1		
Diospyros kirkii Hiern		3		
Diospyros lycioides Desf.	1	1		
Diospyros natalensis (Harv.) Brenan	1	1		
Diplolophium zambesianum Hiern	1		1	
Diplorhynchus condylocarpon (Mull.Arg.) Pichon	3	2		
Dolichos kilimandscharicus Taub. subsp. kilimandscharicus	2	2		
Dombeya rotundifolia (Hochst.) Planch. var. rotundifolia	3	1		
Dovyalis zeyheri (Sond.) Warb.	2	1		
Duosperma crenatum (Lindau) P.G.Mey.	3		1	
Dyschoriste alba S.Moore	13	4	7	1
Elephantorhiza goetzei (Harms) Harms	7	2	2	
Emilia discifolia (Oliv.) C.Jeffrey		1		
Englerophytum magalismontanum (Sond.) T.D.Penn.		1		
Eragrostis cylindriflora Hochst.	1		1	
Eragrostis patens Oliv.		1		1
Eragrostis racemosa (Thunb.) Steud.	6	2	3	2
Eragrostis sclerantha Nees	5	5	3	4
Eriosema englerianum Harms	1			
Eriospermum abyssinicum Baker	9	4		
Erythrina livingstoniana Baker		1		
Euclea divinorum Hiern	3	3		
Euclea natalensis A.DC. subsp. acutifolia F.White	4	3		
Euphorbia griseola Pax	1			
Euphorbia hirta L.			1	

Fadogia ancylantha Hiern	4	2		
Fadogia stenophylla Hiern subsp. odorata (K. Krause) Verdc.	4	1	1	
Faurea rochetiana (A.Rich.) Pic.Serm.	3			
Faurea saligna Harv.	8	4	1	1
Ficus abutilifolia (Miq.) Miq.		1		
Ficus burkei (Miq.) Miq.		1		
Ficus glumosa Delile	1	1		
Ficus natalensis Hochst. subsp. graniticola J.E.Burrows	1	1		
Ficus sur Forssk.	1	1		
Fimbristylis dichotoma (L.) Vahl	1		1	
Flacourtia indica (Burm.f.) Merr.	8	8		
Flueggea virosa (Willd.) Voigt subsp. virosa	2			
Friesodelsia obovata (Benth.) Verdc.	3			
Garcinia huillensis Oliv.	3	1		
Gerbera viridifolia DC. Sch.Bip. subsp. viridifolia			1	
Gloriosa superba L.	1			
Grewia flavescens Juss.	3	1		
Grewia herbacea Hiern.	1			
Grewia monticola Sond.		3		
Gymnosporia maranguensis (Loes.) Loes.	1	1		
Gymnosporia senegalensis (Lam.) Loes.	1	4		
Helichrysum nudifolium (L.) Less.		1		
Helinus mystacinus (Aiton) Steud.	1			
Hermannia depressa N.E.Br.	1		1	
Heteromorpha arborescens (Thunb.) Cham. & Schltdl.	2			
Heteropogon contortus (L.) Roem. & Schult.	12	11	12	10
Hexalobus monopetalus (A.Rich.) Engl. & Diels	4	1		
Hibiscus ovalifolius (Forssk.) Vahl	4	2	1	
Hymenodictyon floribundum (Hochst. & Steud.) B.L.Rob.	4			
Hyparrhenia filipendula (Hochst.) Stapf	13	21	12	21
Hyparrhenia newtonii (Hack.) Stapf	3	2	3	1
Hyparrhenia schimperi (A.Rich.) Stapf	5	2	4	1
Hyparrhenia variabilis Stapf		1		1
Hyperthelia dissoluta (Steud.) Clayton		4		4
Hypoestes forskaolii (Vahl) Roem. & Schult.			1	
Indigofera antunesiana Harms	1			
Indigofera arrecta A.Rich.	1	1		
Indigofera astragalina DC.		1		1
Indigofera emarginella A.Rich. var. emarginella	10		7	
Indigofera hilaris Eckl. & Zeyh.	1			
Indigofera hirsuta L. var. hirsuta		1		

Indigofera lupatana Baker f.	1			
Indigofera rhynchocarpa Baker var. rhynchocarpa	13	4	8	
Indigofera setifera Baker	18	8	14	3
Indigofera viscoides Jaub. & Spach var. rogersii (R.E.Fr.) J.B.Gillett	1		1	
Indigofera wildiana J.B.Gillett	1			
Inula glomerata Oliv. & Hiern	2			
Ipomoea obscura (L.) Ker Gawl.var. obscura	6		2	
Ipomoea verbascoidea Choisy	1			
Julbernardia globiflora (Benth.) Troupin	21	19	1	
Justicia protracta (Nees) T.Anderson	5		2	
Justicia striata (Klotzsch) Bullock subsp. striata	7	1	4	1
Kalanchoe lanceolata (Forssk.) Pers.	3		2	
Kirkia acuminata Oliv.	2			
Kohautia caespitosa Schnizl. subsp. brachyloba (Sond.) D.Mantell			2	
Lannea discolor (Sond.) Engl.	13	13		
Lannea edulis (Sond.) Engl.		3		
Lantana rugosa Thunb.	2			
Ledebouria zambesiaca (Baker) S.Venter	5			
Leptactina benguelensis (Hook. F.) R.D.Good	3			
Leptochloa fusca (L.) Kunth	1		1	
Leucus tettensis Vatke	4		1	
Lippia javanica (Burm. F.) Spreng.	1		1	
Loudetia simplex (Nees) C.E.Hubb.	3		3	
Macrotyloma densiflorum (Baker) Verdc.	1	1		
Maerua juncea Pax	1			
Margaritaria discoidea (Baill.) G.L.Webster	11	1	3	
Mariscus deciduous (Boeck.) C.B.Clarke	1		1	
Markhamia obtusifolia (Baker) Sprague	1			
Melhania forbesii Mast.	1			
Melinis kallimorpha (Clayton) Zizka	2	1	2	1
Melinis longiseta (A.Rich.) Zizka	5	7	4	6
Melinis repens (Willd.) Zizka	2	11	1	10
Melinis subglabra Mez	2	1	2	
Microchloa caffra Nees		2		2
Millettia stuhlmannii Taub.	1			
Monotes engleri Gilg	3	1		
Monotes glaber Sprague	14	13		1
Murdannia simplex (Vahl) Brenan	1			
Mystroxylon aethiopicum (Thunb.) Loes.	1			
Mystroxylon aethiopicum (Thunb.) Loes.	1			
Neonotonia wightii (Arn.) J.A.Lackey	1		1	

Ochna pulchra Hook.	7	7		
Ochna schweinfurthiana F.Hoffm.		1		
Ocimum americanum L.		2		
Ocimum obovatum Benth. var. obovatum	17	11	14	11
Olea europaea L. subsp. cuspidata (G.Don.) Cif.		1		
Opilia amentacea Roxb.		1		
Oplismenus hirtellus (L.) P.Beauv.		1		1
Oxalis obliquifolia A.Rich.	1	1	1	2
Ozoroa reticulata (Baker f.) R.Fern. & A.Fern.	1			
Panicum deustum Thunb.	1			
Panicum maximum Jacq.	10	10	9	10
Panicum sabiense Reinvoize	1		1	
Parinari curatellifolia Benth.	6	2		
Passiflora edulis Sims	2			
Pavetta schumanniana K.Schum.	1	1		
Pellea calomelanos (Sw.) Link var. calomelanos	4	4	4	4
Peltophorum africanum Sond.	1	2		1
Pentas angustifolia (DC.) Verdc.	4	1	4	2
Pericopsis angolensis (Baker) Meeuwen	3			
Perotis patens Gand.	2	1	2	1
Philenoptera violacea (Klotze) Schrire	1			
Phyllanthus maderasparensis L.	2		2	
Phyllanthus pentandrus Schumach. & Thonn.	1		1	
Phyllanthus reticulatus Poir.				1
Pittosporum viridiflorum Sims	1	2		
Plectranthus gracillimus (T.C.E.Fr.) Hutch. & Dandy	2	1	2	
Pleurostylia africana Loes.	4	2		
Pogonarthria squarrosa (Roem.) & Schult.) Pilg.	1	2		2
Poulzolzia mixta Solms	15	8	9	3
Protea angolensis Welw.	4	1		
Protea gaguedi J.F.Gmel.	3	1		
Protea welwitschii Engl.	4	3		
Pseudarthria hookeri Wight & Arn.	6	3	3	1
Pseudolachnostylis maprouneifolia Pax	6	10		
Psorospermum febrifugum Spach	5	7		
Psydrax livida (Hiern) Bridson	3	1	1	
Pterocarpus angolensis DC.	4	2		
Pterocarpus rotundifolius (Sond.) Druce	3	7		
Pterolobium stellatum (Forssk.) Brenan	2			
Rhoicissus revoilii Planch.		1		
Rhoicissus tridentata (L.f.) Wild & R.B.Drumm.	3	1		

Rhus chirindensis Baker f.	2			
Rhus dentata Thunb.	1			
Rhus leptodictya Diels	3	5	2	2
Rhus longipes Engl.	2			
Rhus tenuinervis Engl. var. tenuinervis	2	3		
Rhynchosia minima (L.) DC.		2		
Rhynchosia resinosa (A.Rich.) Baker	5		1	
Richardia scabra L.				2
Rotheca myricoides (Hochst.) D.A.Steane & Mabb.	4	1	1	
Rottboellia cochinchinensis (Lour.) Clayton	1			
Schistostephium artemisiifolium Baker	16	4	11	2
Schizachirium jeffreysii (Hack.) Stapf	1			
Schizachyrium sanguineum (Retz.) Alston	1			
Senna singueana (Delile) Lock	4	3		
Setaria homonyma (Steud.) Chiov.	2			
Setaria longiseta P.Beauv.	2	2	4	3
Setaria pumila (Poir.) Roem. & Schult.	1			
Solanecio angulatus (L.) C.Jeffrey	1			
Solanum delagoense Dammer	1			
Spermacoce senensis (Klotzsch) Hiern		2		2
Sphaeranthus peduncularis DC.		3		
Sphaeranthus randii S.Moore	2		1	1
Sphenostylis erecta (Baker f.) Baker	1	2		
Sporobolus festivus A.Rich.	1		1	
Sporobolus ioclados (Trin.) Nees	3	2	3	2
Sporobolus molleri Hack.	1		1	
Sporobolus panicoides A.Rich.	1			
Sporobolus pyramidalis P.Beauv.	3	2	2	2
Sporobolus sanguineus Rendle	1	1		
Steganotaenia araliacea Hochst.	1			
Sterculia quinqueloba (Garcke) K.Schum.		1		
Stereochlaena cameronii (Stapf) Pilg.	1	4		2
Striga angustifolia (Don) C.J.Saldanha		1		
Strychnos madagascariensis Poir.	3	3		
Strychnos spinosa Lam.	2	2		
Swartzia madagascariensis Desv.		1		
Syzygium guineense (Willd.) DC.	1			
Tagetes minuta L.	3	1	3	1
Tapiphyllum velutinum (Hiern) Robyns		1		
Tephrosia acaciaefolia Baker	2	1	2	1
Tephrosia decora Baker	6	9	3	6

Tephrosia elata Deflers	5	3	5	2
Tephrosia linearis (Willd.) Pers.	4	2	1	1
Tephrosia micrantha J.B.Gillett	1	1	1	1
Tephrosia purpurea (L.) Pers.	3	4	2	4
Terminalia brachystemma Hiern		1		
Terminalia sericea DC.		1		
Terminalia stenostachya Engl. & Diels	3	4		
Tetradenia riparia (Hochst.) Codd	7	1	5	
Thelipteris confluens (Thunb.) C.V.Morton	2			
Themeda triandra Forssk.	23	8	15	8
Thesium goetzeanum Engl.	2			
Thunbergia crispa Burkill		1		
Thunbergia lancifolia T.Anderson	1			
Tinnea rhodesiana S.Moore	2		1	
Tithonia rotundifolia (Mill.) S.F.Blake	4		3	
Tricalysia niamniamensis Hiern subsp. nodosa (Robbr.) Bridson	1			
Tristachya nodiglumis K.Schum.	19	18	10	18
Triumfetta angolensis Sprangue & Hutch.		2		1
Triumfetta annua L.	3	2	2	
Triumfetta rhomboidea Jacq.	1	2	1	1
Tulbaghia alliaceae (L.f.) Thunb.	1			
Turbina oblongata (Choisy) A.Meeuse	1			
Tarries nilotica Kotschy & Peyr.	5	3		
Uapaca kirkiana Mull.Arg.	4	3		
Uapaca nitida Mull.Arg.	3			
Vangueria infausta Burch. subsp. infausta	11	9		
Vangueriopsis lanciflora (Hiern) Robyns	1			
Vernonia colorata (Willd.) Drake	2			
Vernonia glabra (Steetz) Vatke		1		
Vigna pygmaea R.E.Fr.	2			
Vitex payos (Lour.) Merr.	1	2		
Waltheria indica L.		4		1
Xerophyta equisetoides Baker	5	7		
Ximenia americana L.	2	1		
Ziziphus abbysinica A.Rich.	1			
Ziziphus mucronata Willd.	2	2	1	1
Zornia glochidiata DC.		1		1