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Temporal and Spatial Variation in Soil Seed Banks in Elain Natural Forest Reserve North Kordofan, Sudan

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Abstract
This study was conducted in Elain Natural Forest Reserve, 26 km Southeast of Elobeid town, capital of North Kordofan State, Sudan. It was carried out in May and December 2004 to estimate soil seed banks in four soil depths (5, 10, 15 and 20 cm) under two densities of trees (88.9 and 150.3 trees per ha). Vegetations (trees, shrubs and natural regenerations) were sampled and number of stems and species composition per sample plot were obtained. Visible seeds were estimated for each soil depth at each tree density. Collected soil samples were exposed to germination under nursery conditions and the germinated seeds were identified and counted. The obtained data were analysed using descriptive statistics and means comparison. Possible co-relations between tree seed density and number of stems per sample plot (0.1 ha) were worked out. Though seven tree species were reported and five naturally regenerated, in the study area, seeds of *Acacia mellifera* were the only detected seeds in the bank. Tree seeds density ranged from 828.6 to 1052.6 seeds m^{-2} representing 59.7 to 73.9% in the top 5 cm soil depth, whereas the highest germinated seeds (trees, shrubs and herbaceous) were 3540.5 seeds m^{-2} of which only 10.0% were tree seeds. The results of the study showed that tree seeds available up to 10 cm soil depth and decreasing with increasing in depth, while herbaceous seeds are vary and available up to 20 cm depth. These findings may be of great values for the upcoming studies in the context of soil seed banks and their impacts on plant biodiversity.

Keywords: *Acacia mellifera*, Elain Natural Forest Reserve, plant biodiversity, soil seed bank.

1. Introduction
There is an increasing demand for reliable information on seed banks, both for scientific purposes and as decision tool in habitat and landscape management (Hölzel and Otte 2004). The topic of soil seed banks is important because of the impact seed reserves in soil have on current and future vegetation (Greene and Waters 2001). Moreover, soil seed banks play an important role in restoration and rehabilitation projects and initiating natural regeneration after disturbance (Bakker *et al.* 1996). While seed banks are essential to maintain life and growth in forests it can also reflect evolutionary changes in plant communities as a consequence of changes in land use (Greene and Waters 2001) beside serving as safeguards for genetic variability (Baker 1989). However, the crucial and controversial question, whether soil seed banks play an important role in regeneration of tropical forests, has been difficult to resolve because regeneration from dominant seeds that have accumulated in the soil through time has seldom been distinguished from regeneration from seeds that have recently dispersed into a site (Garwood 1980). The temporal and spatial variations of soil seed banks may reflect the plants distribution and diversity on specific area.

As part of the Sahelian Region the vegetation cover in the North Kordofan State underwent drastic deterioration due to desertification and drought effects. However, trends of recovery were observed. Mohamed *et al.* (1996) mentioned that the resilience of the semi-desert areas of North Kordofan and its potential for recovery if good moisture conditions prevail. Hence it is possible to postulate here that the observed trends of recovery are the result of climatic factors. In this context it is worthwhile to investigate and assess seed banks in such sensitive ecosystems. The main objective of this study was to investigate the temporal and spatial changes of the soil seed bank in Elain Natural Forest Reserve, North Kordofan Sudan.

2. Materials and methods
This study was conducted in 2004 in Elain Natural Forest Reserve (12º 52´ -13º 04´ N and 30º 10´-30º 24´ E), 26 km south of Elobeid, Capital of North Kordofan State, Sudan. The forest falls under semi-desert and receives annual rainfall between 200-250 mm. The mean annual temperature is 27º C. Soil is non cracking clay, locally *gardud*, of hard surface, low water permeability and high run off. Ecologically the forest lies within the *Acacia*

Wooded Grassland Savannah and dominated by *Acacia mellifera*. Other woody vegetations are namely *Acacia nilotica, Terminalia brownie, Balanites aegyptiaca* and *Adansonia digitata*. *Acacia mellifer*a is a multi-stemmed shrub usually grown gregariously in nearly pure stands. It is a typical dry savanna. The shrub is an important source of quality fuel-wood and charcoal and building materials in many parts of Sudan. It is also commonly used as life fence. Although deciduous, the shrub is important for its forage value (El Amin 1990, Vogt 1995).

Three biodiversity components – species richness, floristic diversity and soil seed bank were studied. Two community patches, of one hectare each, were located in the forest. These patches were determined according to tree density i.e. 88.9 and 150.3 trees/ha later known as site A and B respectively. In each community patch, nine circular sample plots were fixed. Distant between samples 50x50m and sample area 0.1 hectare. Diversity and frequency of woody species were measured. To take into account the variation in soil seed bank overtime it is advisable to take samples on at least two occasions (Sutherland 1996). For this study seed bank samples were taken in two occasions, before and after rainy season, i.e. in May and December 2004 respectively. Soil samples and vegetation sampling were taken simultaneously. Soil samples were taken, using auger, at four depths (0-5, 5-10, 10-15 and 15-20 cm). The soil samples were then packed, labeled and number of visible seeds (tree seeds), in each soil sample (≈300 cm^3), was counted. Accordingly, average number of seeds m^{-2} in each soil depth for each community patch and season was calculated.

Soil samples were put in a container for seeds germination under nursery conditions. Germinated seeds were observed and counted daily up to six weeks to confirm no further seeds germination. Emerged seedlings were identified as trees/shrubs and grass to dicotyledonous and monocotyledonous. The seedlings were removed after counting and identification to facilitate further counting. Number of emerged seedlings was obtained in each depth for each site and season.

3. Results and discussion

The results of the trees/shrubs sampling showed that the average density of tree species ranged from 88.9 to 150.3 stems/ha having 85.5 and 43.3 stems/ha of natural regeneration. Seven tree species were reported of which only five naturally regenerate which, however, indicates that Elain forest is poor in species diversity. Nevertheless, *A. mellifera* is dominated the forest (81.1- 150.0 stems/ha) and constitutes more than 97% of the tree species in the forest. The study carried by Mohammed (2000) at the same study site also reported seven tree/shrub species of which, however, three species were naturally regenerated.

The maximum seed density (1052.6 seeds m $^{-2}$) was reported in site B after rainfall (Table 1). Most of seeds (59.7-73.9%) concentrated in the top 5 cm soil depth. Although seven tree species were reported in the study site, no tree seeds other than *A. mellifera* seeds were detected in the bank and constitute 6.8-20.8% of the plant community. This means the presence of plant species may not indicate the availability of its seeds in the soil bank. 5.4 to 18.2% of viable tree seeds were detected in the top 5 cm (Table 2). Freigoun (2001) recommended that when evaluating seed banks of *A. seyal*, seeds below 5 cm depth should not be included because seeds below 5 cm depth have no contribution to the natural regeneration (Freigoun 2001, Mustafa 1997). Seed densities vary greatly but generally decreasing with increasing in depth. This result confirms of that revealed by Gaiballa (1995), Sutherland (1996), Freigoun (2001) and Swaine (2001). The results of the study also showed that tree seeds are available up to 10 cm soil depth, while herbaceous seeds are vary and available up to 20 cm depth. This agrees with the results of Swaine (2001) who stated that seeds of persistent species may be found at considerable depth (>30 cm) but at low abundance. Seeds of grasses are abundant greatly compared to tree seeds and constitute between 79.2 to 93.3 % of the soil seed banks. The occurrence of tree seeds in 10 cm depth may attribute to the non cracking surface of *gardud* soil which does not allow large seeds to fall into the soil. Cracks may direct a portion of the falling seeds down into the soil, when those at the deep layers cannot readily contribute to the natural regeneration (Mustafa 1997).

Table 1. Seed bank m^{-2} (trees´ seeds) in Elain Natural Forests, North Kordofan Sudan

Soil depth (cm)	Community patch			
	Site A		Site B	
	Before rain	After rain	Before rain	After rain
0-5	614.0	583.8	494.7	777.9
5-10	244.8	337.4	333.9	274.7
10-15	0.0	0.0	0.0	0.0
15-20	0.0	0.0	0.0	0.0
Total	858.8	921.2	828.6	1052.6

Table 2. Viable seed bank m^{-2} in Elain Natural Forests, North Kordofan Sudan

Soil depth (cm)	Community patch			
	Before rain		After rain	
	Site A	Site B	Site A	Site B
0-5	188.3 (508.5)	301.3 (2777.5)	148.4 (1525.5)	389.0 (847.5)
5-10	37.7 (320.2)	52.8 (277.1)	33.4 (678)	55.0 (508.5)
10-15	0.0 (56.5)	0.0 (113.0)	0.0 (339)	0.0 (169.5)
15-20	0.0 (0.0)	0.0 (18.8)	0.0 (0.0)	0.0 (169.5)
Total	226.0 (885.2)	354.1 (3186.4)	181.8 (2542.5)	444.0 (1695.0)
Tree seeds (%)	20.3	10	6.8	20.8

Note: Between brackets are germinated seeds of grasses.

The relationship between soil seed density and tree density is seem to be weak, R^2= 0.05 and 0.13 for site A and B respectively (Figure 1). The study carried out by Luo and Wang (2006) found positive correlation between seed density and above ground vegetation density. The weak relationship could be attributed to two factors: 1) soil surface. The non cracking surface of *gardud* soil does not allow seeds penetrate into the soil; and 2) the high runoff washes the seeds away. Rain may wash small seeds into coarse –textured soil (Garwood, 1989). This was observed along streams where species diversity is higher than the rest of the forest area. In contrast, litter thick (Amiaud and Touzard 2004) or plant residuals also assist in the presence of seeds in the soil by intercepting the seeds to wash away. This mechanism leads to availability of seeds in the soil. Predators also destroy seeds after dispersal and/or after penetration. These results come together with Amiaud and Touzard (2004). The results of mean comparison (*t-test*) between seed density temporally and spatially is not significant (α= 0.05). These findings may be of great values for the upcoming studies in the context of soil seed banks and their impacts on plant biodiversity.

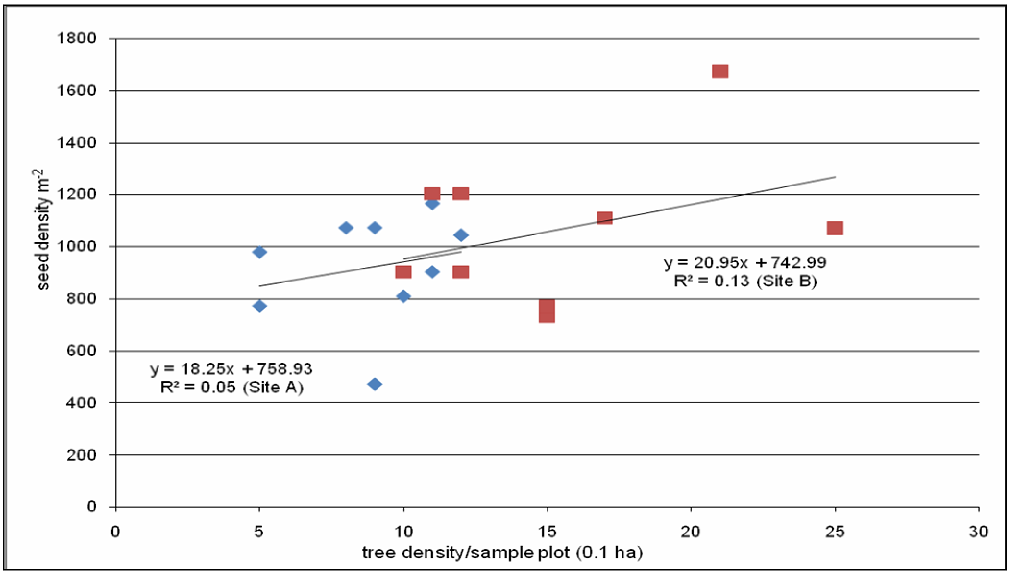

Fig. 1 The relationship between soil seed bank and tree density in Elain natural forest reserve, Sudan.

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