Do Coastal forests of Tanzania have the potential to undergo natural vegetation restoration?

ABSTRACT

Aim: To determine soil seed bank as a basis for forest restoration through natural regeneration in the Zaraninge and Mbwebwe coastal forests in Bagamoyo District Tanzania.

Study design: Temporary concentric sample plots of size 0.07 ha established systematically along transect lines that run parallel to each other was used. The sampling intensity was 0.02%. The distance between plots was 100m and between transect lines was 200m.

Place and duration of the study: Soil samples were collected at Zaraninge and Mbwebwe coastal forests in Bagamoyo District Tanzania

Methodology: Eighteen sample plots of size 0.07 were established systematically along transect lines on each of the two forests to cover as much variations as possible. Soil samples were collected within each plot at 0-10 cm, 10-20 cm and 20-30 cm depths. Soil sample were analyzed for frequency of germination and seed density of different plant species at the different depths.

Results: The seed bank density for vascular plants was 2,782 seeds m-^{2} and 1,170 seeds m-^{2} for Zaraninge and Mbwebwe forest respectively. A total of 71 seedlings belonging to 17 species and 10 families emerged from all samples of the two forests, most of them being herbs and grasses. The number of germinants significantly decreased with increasing soil depth in both forests (*P*=0.05) as most seeds (37) germinating from the 0-10 cm soil depth and least (10) germinants in 20-30 cm stratum.

Conclusion: Forest restoration through natural soil seed bank may greatly depend on the seed bank at the surface soil horizons.

Keywords: Coastal forests, Soil seed bank and Restoration potential.

1. INTRODUCTION

Tanzanian coastal forests are recognized globally as major centers of both species diversity and endemism [1]. These forests harbour a unique diverse of flora and fauna which show endemism. Based on Burgess et al. [2] Tanzania coastal forests are rich in species that has national socio-economic values and are highly prioritized by the Forest Department through the Tanzania Forest Action Plan (TFAP, 1988) for conservation due to their values. However, despite their values, coastal forests are rapidly being destroyed. Some of the direct threats include charcoal production, logging, grazing and expansion of agricultural land [3]. Ecological restoration is used as a process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed [4, 5, 6]. It is an intentional activity that initiates or accelerates the recovery of an ecosystem with respects to its health, integrity and sustainability [7]. Forest restoration may be achieved through natural regeneration from coppicing, soil seed bank or artificial planting. Restoration though natural seed bank may be relatively cheap and reliable compared to the other methods [4]. Standing vegetation in mature forests has reproductive structure that remains in the soil for a period of time or germinates immediately after seed dispersal. Seed bank is a central topic for plant communities' restoration (Erfanzadeh *et al.,* 2014) [8]. According to Faist et al. [9] the term soil seed bank serve as reservoirs for future plant communities, and when diverse and abundant can buffer vegetation communities against environmental fluctuations.

The existence of dormant, soil seed banks can allow different vegetation communities to occupy the same space at different periods of time [10, 11, 12, 13]. Seed-banks are formed by seeds, either born and produced on site or carried to the site by dispersal agents [13, 14, 15]. All the viable seeds present in the soil or mixed with soil debris constitute the soil seed bank and it reflects the cumulative effects of many years of crop and soil management [16]. Seed bank studies help to increase the efficiency and efficacy of management decisions [17].

Seed bank may play an important role in the conservation of genetic diversity and natural restoration to ecosystem vegetation as well as specific plant species [18]. Seed dynamics play an important role in structuring and maintaining plant communities. Seeds sustain populations during temporarily unfavorable conditions, allow establishment in new areas, and can introduce novel genotypes to populations. Seed banks in particular are important in maintaining species and genetic diversity in communities and in allowing species to persist through disturbance or adverse conditions [19, 20]. The presence of seed banks in soil allowed a plant species to maximize its chance for survival and creating benefits for that population [21]. Seeds stored in the seed bank can withstand harsh conditions over many years allowing the plant species to be propagated many years after initial seed dispersal. Heavy human disturbance especially extensive timber logging, agricultural clearance, fire burning have been documented to occur at Zaraninge and Mbwebwe coastal forest [22]. Such disturbances have different impacts on different plant species including loss of some endemic, threatened and other species such as *Milicia excelsa*, *Afzelia quanzensis* and *Pterocarpus angolensis* which may sometimes need restoration. However, the relationship between plant species composition and soil seed banks is not well documented in Tanzania given the variety and variability of forest ecosystems. Therefore, this study was conducted to determine soil seed bank as basis of forest restoration through natural regeneration in Zaraninge and Mbwebwe forests. This assessment forms a baseline for restoration potentials of plant species through soil seed bank in Zaraninge and Mbwebwe coastal forests.

2. MATERIALS AND METHODS

Description of the study

The study was conducted at Zaraninge, located in Bagamoyo district coastal region which is approximately 50 km north of Bagamoyo town, 20 km south - west of Saadani Game reserve and 20 km north-west of Wami River [2]. Zaraninge forest is one among the 39 recognized coastal forests in Tanzania [23]. It occupies about 18 000 ha (6^{o} 04' S - 6^{o} 13' S, 38^{o} 35' E - 38^{o} 42' E; 100 m to 300 m a.s.l.) [22]. On the other hand, Mbwebwe forest was formally part of Zaraninge forest however currently it is a village forest after being annexed from Zaraninge forest. The forest is about 61 ha and is adjacent to Zaraninge forest.

Annual average rainfall ranges between 820 mm and 1050 mm per year. February and March are the warmest months and August the coldest with an average annual temperature between 20.8^{o}C and 26.5^{o}C. The area experiences four months of dry season (June to September) and two wet seasons (February to May and October to December). The forest grows on a plateau of limestone and calcareous stone (possibly Jurassic age). Sandstone is exposed at the margins of the plateau. A large part of the forest is occupied by fairly homogeneous sandy soils with a thin dark humus layer [24]. The forest has at least 40 mammal species including seven bats and eight rodent species. Seventeen forest dependent reptile species and ten amphibian species are also found in the forest 25]. Seventy-one (71) bird species have been recorded in the forest of which ten are classified as globally scarce rendering the site of international importance [25].

Soil seed bank sampling and data collection

The sampling was done in temporary concentric sample plots of size 0.07 ha established systematically along transect lines that run parallel to each other. The sampling intensity was 0.02%. The distance between plots was 100m and between transect lines was 200m. Systematic sampling design were employed to lie transects in such a way that they cover as much variations as possible in the forest including highly disturbed area, partially disturbed area and intact area. Soil samples were collected carefully from the 3 separate soil layers, each layer was 10 cm thick (0-10 cm, 10-20 cm and 20-30 cm), totally 30 cm deep as done by using standard soil digger and labelled metal rods. The soil samples were taken from three different points within a plot. Similar layers from these three points within a plot were mixed to form a soil composite in order to reduce variability within plots. The composite sample for each soil layer was again divided into five equal parts among which one was randomly selected for further study. Sampling was completed within two weeks to avoid differences between habitats, and thus any temporal bias in seed availability and composition following the method used by Toledo and Ramos [26]. The samples from each soil layer were used to determine variations of seed distribution at each depth of the soil layers. Soil samples from each layer were picked in to plastic bags and transported for the further study. Soil samples were first sieved with a mesh size of 2 mm and then using a mesh size of 0.5 mm to remove plant materials/gravel and left for seeds to germinate [27]. Each soil sample was spread in the plastic germination trays filled with sterilized sand. The well-labeled germination trays were randomly arranged in a germination room and watered once daily from the top using fine sprays of tap water to stimulate natural rainfall conditions. The germination trays were maintained in the germination room with an average day and night temperature fluctuating, relative humidity ranging from 60% to 80% and light for 12 hours per day. Control trays with only sterilized sand were set alongside the experiment to detect contamination by wind-dispersed seeds [28]. The emerging seedlings were counted, recorded and identified to species and family level. After identification, the seedlings were immediately uprooted and discarded so as to minimize overcrowding. Those, which could not be identified easily, were removed from germination trays and transplanted in polythene tubes where they were identified later. The experiment ended at three months after the seedlings had presumably stopped emerging.

Data analysis

The germinated seeds were segregated by species and density of viable seeds per m^2 computed for each species and by depth. Analysis of Variance (ANOVA) was used to compare the number of viable seeds between soil layers and among growth forms using the MS Excel software. Seed bank density was calculated using average depth method [29].

3. RESULTS AND DISCUSSION

Seed bank

The average density of seeds in the soil seed bank was 2782 seeds m^{-2} in Zaraninge Coastal forest and 1170 seeds m^{-2} in Mbwebwe forest (Table 1). For Zaraninge forest, more seeds were recorded in 0-10 cm and 10–20 cm soil depth. The frequency and seed density of forest and ancient forest species is often lower in the deeper soil layer 20–30 cm. In addition, plot 8, 13 and 18 in Zaraninge forest and plot 12, 13, 15, 17 and 18 in Mbwebwe village forest for all soil depths recorded no seeds implying that there will be no regeneration potentials for the aboveground vegetation at those plots unless dispersal agents to take their role. On the other hand, there might be animals eating seeds of the aboveground vegetation hence might be a source of some species to disappear with time. Dense seed banks have often been observed in intact forest compared to disturbed forest which may be an influence of differential disturbances, mechanisms of seed dispersal, seed predation and soil fauna in the two forests. Since Zaraninge forest is protected forest, most soil faunas could occur in this forest. Lema [30] observed that, seed density in intact forest is higher than in disturbed forest. Generally, the species richness and density of aboveground vegetation under nurse plants is higher than that in the open sites [31]. Therefore, we hypothesize that seed-trapping and higher recruitment success under the nurse plant could increase seed input to the soil and enhance the density and richness of seeds buried in the soil, thereby increasing the similarity between soil seed bank and aboveground vegetation. Forey et al. [32] reported that, soil fauna are known to play an important role in the predation seeds that are buried in the soil. Seeds may be eaten or damaged or moved by soil fauna. Species abundance in the soil and its nature is assumed to be a useful guideline for vegetation management and restoration [30].

Table 1: Number of seed recorded from soil seed bank, their average depth (cm) distribution, frequency and densities (seeds m^{-2}) in Zaraninge and Mbwebwe Coastal Forests

Forest type	Plot No	Depth			Frequency	Average Density	Density (seeds/m^{-2})
		0 -10cm	10-20cm	20-30cm			
	1	0	1	0	1	20.5	68.33
	2	2	0	0	2	10.5	70
	3	1	1	0	2	15.5	103.33
	4	1	0	0	1	10.5	35
	5	2	2	1	5	18.5	308.33

Zaraninge forest	6	6	5	4	15	19.17	958.33
	7	1	0	0	1	10.5	35
	8	0	0	0	0	0	0
	9	3	1	0	4	13	173.33
	10	1	1	1	3	20.5	205
	11	1	1	0	2	15.5	103.33
	12	3	2	0	5	14.5	241.67
	13	0	0	0	0	0	0
	14	0	2	0	2	20.5	136.67
	15	1	0	0	1	10.5	35
	16	2	1	0	3	13.83	138.33
	17	0	1	1	2	25.5	170
	18	0	0	0	0	0	0
Total							**2782**
Mbwebwe forest	1	0	0	1	1	30.5	101.67
	2	2	0	0	2	10.5	70
	3	2	1	1	4	18	240
	4	0	2	0	2	20.5	136.67
	5	1	0	0	1	10.5	35
	6	0	1	0	1	20.5	68.33
	7	1	0	0	1	10.5	35
	8	0	1	0	1	20.5	68.33
	9	2	0	0	2	10.5	70
	10	2	0	0	2	10.5	70
	11	1	0	0	1	10.5	35
	12	0	0	0	0	0	0
	13	0	0	0	0	0	0
	14	0	1	1	2	25.5	170
	15	0	0	0	0	0	0
	16	2	0	0	2	10.5	70
	17	0	0	0	0	0	0
	18	0	0	0	0	0	0
Total							**1170**

Seed germination from different soil stratum

A total of 71 seedlings representing 17 species and 10 families emerged from all samples of the two forests. The species were grouped into trees, shrubs, climbers, herbs and graminoids (i.e. grasses) (Table 2 and 3). In Zaraninge forest, three tree species, 14 herbs, seven shrubs, 10 climbers and 15 graminoids were germinated. On the other hand Mbwebwe forest had one tree species, three climbers, six herbs and 12 graminoids. Most herbs and graminoids were found in the upper soil strata whereas trees were found in deeper soil strata. Only five out of the 17 species were common to all forests. These are *Isoglosa sp, Monanthotaris trichocarpa, Panicum maximum, Panicum tricholabum* and *Uvaria tanzaniae.*

Table 2: Species in the seed bank germinated at different soil layers in the Zaraninge Coastal Forest of Bagamoyo District Tanzania

Species name	Family	Life form	Soil depth (cm)		
			0-10	**10-20**	**20-30**
Scorodophloeus fischeri	Caesalpinioideae	Tree	1	0	0
Baphia kirkii	Papilionaceae	Tree	1	1	0
Phyllanthus nummularifolins	Euphobiaceae	Shrub	3	2	2

Millettia impressa	Papilionaceae	Climber	3	0	0
Uvaria tanzaniae	Annonaceae	Climber	3	0	0
Monanthotaris trichocarpa	Annonaceae	Climber	1	1	0
Landolphia sp	Caesalpinioideae	Climber	0	1	1
Panicum maximum	Gramineae	Graminoid	8	3	0
Panicum tricholabum	Gramineae	Graminoid	2	2	0
Isoglosa sp	Acanthaceae	Herb	2	8	4

Table 3: Species in the seed bank germinated at different soil layers in the Mbwebwe Coastal Forest Bagamoyo district Tanzania

Species name	Family	Life form	Soil depth (cm)		
			0-10	10-20	20-30
Ficus sycomorus	Moraceae	Tree	1	0	0
Uvaria tanzaniae	Annonaceae	Climber	2	0	0
Monanthotaris trichocarpa	Annonaceae	Climber	0	1	0
Panicum maxima	Gramineae	Graminoid	2	3	2
Panicum tricholabum	Gramineae	Graminoid	2	0	0
Panicum heterotrichium	Gramineae	Graminoid	2	1	0
Isoglosa sp	Acanthaceae	Herb	4	1	1

Findings revealed that most of the germinated seedlings from these forests were climbers and graminoids (Table 2 and 3). Dominance of annual species in the soil seed bank has also been documented by Lyaruu [33]. The dominance of coastal forest with non-woody species characterized by transient seed bank is a sign of woody diaspores in the soil. Several factors have contributed to fewer numbers of woody species in the soil. Among them are seed predation, fungal decay, deep burial by ants and termites and rodents [33]. Many tropical tree seeds tend to lower viability within a short time and have irregular seed production [34]. Large number of annual herbs and graminoids reflect various characteristics of these species, including their efficient dispersal agents, large number of dormant seeds in the soil, rapid germination of these species and also copious seed production.

Although contribution of seed bank to regeneration is variable, a wide knowledge on the contribution of seed bank in ecological restoration especially in forests depends on persistent seed bank. Falahati-Anbaran [36] suggested that species capable of persistent seed bank have a better chance of recolonizing disturbed sites than with transient seed bank. Lyaruu and Backeus [37] reported that the property of seeds to remain dormant in the soil for a long time is important because such seeds form future vegetation in the process of secondary succession since they can survive long in the soil following disturbance. Most dominant species particularly canopy species of some vegetation communities do not accumulate persistent seed bank. The longevity of the seed bank is an important aspect in restoration ecology. The ability to build up a permanent seed bank is a means for plants to "disperse in time" and to survive unfavorable conditions. Germinable seeds in the soil are part of the population of a species even if it has already disappeared from the actual vegetation. Since species differ greatly in germination requirements, the greenhouse conditions are not always suitable for the germination of all species [38].

Depth Distribution of Seeds in the soil

The seed banks identified in this study exhibited variations in seed distribution in the soil. In both forests, seed abundance declined with soil depth with most seeds germinating from the 0-10cm-soil depth (Fig 1). Higher seedlings germination in the upper soil layer has also been reported by other researchers [39, 40]. This pattern can be attributed to historical changes in above-ground vegetation and seed bank regime [40], seed mass and shape, the vertical transport of seeds by earthworms as well as the accessibility of seed disperser to the forest area especially animals and birds.

There was a significant difference in seed distribution with depth in both forests (*P*=.05). The decline in the number of seeds in the soil with depth has very strong implication in the ecology of soil seed bank, for it is an indication that most seeds in the soil seed banks are confined to the superficial soil layers [41]. The density and distribution of buried seeds in the soil according to soil layer may be associated with frequency and intensity of disturbance, seed dispersion, predation and pathogens and micro site conditions affecting dormancy and germination [42]. According to Thompson et al. [35] deeply buried seeds are older than shallow ones, the results from this study therefore suggest that not all forest species form a transient seed bank and that at least some of them (e.g. *Baphia kirkii*) appear to form a long term persistent seed bank, as they were still recorded in the lower soil layers (Table 2). The vegetation history of the study area is related to seeds distribution in soil layers and to some extent prevalence of secondary dispersers such as earthworms and rodents [32].

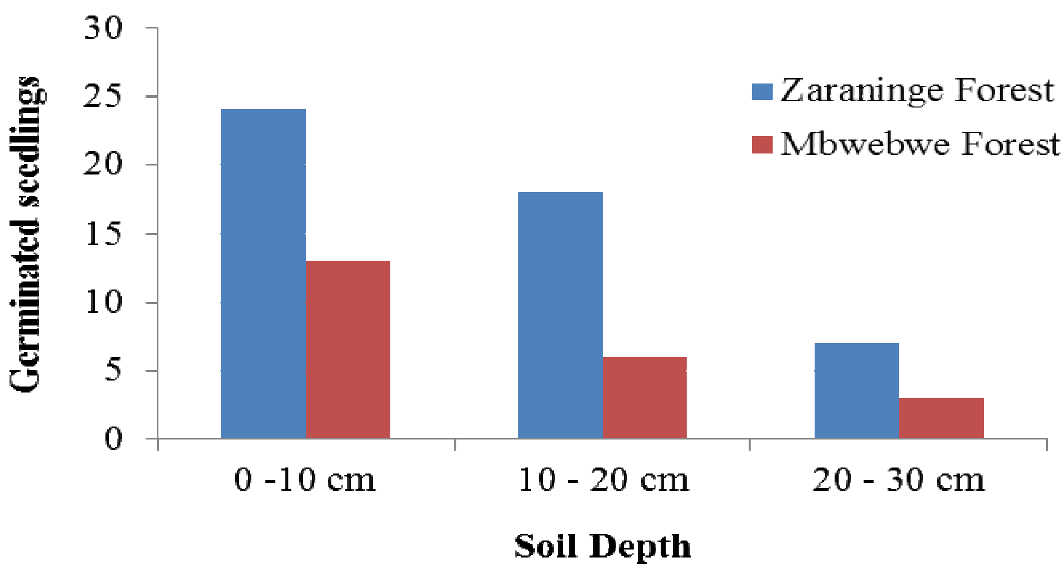

Fig 1: Number of seeds germinating within 90 days from soils sampled from Zaraninge and Mbwebwe Coastal forests, Bagamoyo District Tanzania.

4. CONCLUSIONS

Most of the soil seed bank in Zaraninge and Mbwebwe forests is dominated by annual plants. The number of germinants significantly decreased with increasing soil depth in both forests (*P*=.05) as

most seeds germinating from the 0-10 cm and in 20-30 cm soil depth. Therefore, forest restoration through natural soil seed bank in the coastal forests may greatly depend on seed bank at the surface soil horizons. The soil seed bank may as well be a major repository of threatened plant species.

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