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Impact of different Exotic tree plantation species on soil seed bank composition, distribution, and density in the central highland of Ethiopia

Yadesa Bato [1], Tamrat Bekele [2], and Sebsebe Demissew [2]

[1]Ambo University, College of Agriculture and Veterinary Science, Forestry Department, Ambo, Ethiopia.
[2]Addis Ababa University, College of Natural Science, Plant Biology and Biodiversity Management Department, Addis Ababa, Ethiopia
Corresponding author: *yadesabato2020@gmail.com*

Abstract

The presence of seeds in the soil plays a critical role in restoring degraded vegetation and the ecosystem. The objective of the study was to evaluate the impact of different exotic tree species plantations and adjacent natural forests on seed banks' composition, distribution, and density in the central highland of Ethiopia. The forest land-use systems included natural forests, and four exotic tree plantation species (Eucalyptus globules, Cupressus lusitanica, Grevillea robusta, and Pinus patula). The study was conducted in a systematic sampling design, with five replications. From a total of 1293 emerged seedlings, 81 plant species were identified from the seed bank (31 families and 67 genera). The analysis of variance (ANOVA) for soil seed species composition and density/m^2 showed significant variations in both forest land-use systems and soil depths ($P<0.001$). In all forest land-use systems, the number of germinated species ranged from 29-57 species, and density/m2 was between 1625-3250. The highest numbers of species, as well as density/m2, were recorded in natural forests and the lowest in E. globulus plantations. The number of seeds, species, and seed density decreased with increasing soil depths in all forest land-use systems. Jaccard's coefficients of similarity among all five forest land-use systems ranged between 0.28–0.53. Different species of exotic tree plantations showed various influences on soil seed bank composition and density. Therefore, the concerned bodies should select the appropriate multipurpose tree species of fast-growing and positively friendly soil seed species composition and density for establishing exotic tree plantation forests.

Keywords

exotic tree plantation,
seed density,
soil seed bank,
species composition,
species distribution,
Yerer forest

1. Introduction

The world faces severe environmental, social, and economic challenges of unprecedented complexity by the factors of forest degradation and deforestation, biodiversity loss, soil degradation, water degradation, and climate change (UN General Assembly 2011). Forest degradation and deforestation are worldwide environmental problems resulting from human activities that have begun to threaten the sustainability of Earth's life support systems (Lubchenco, et.al., 1991, FAO, 2007). In developing countries, several socioeconomic and environmental challenges have strongly affected the capacity of forests to provide ecosystem services through deforestation and forest degradation (Demel Tektay 2001).

High rates of deforestation and forest fragmentation are the consequences of observed LULCC, which lead to biodiversity loss (Millenium Ecosystem Assessment, 2005). The loss of forest cover and biological diversity due to human activity pressure is a growing concern in numerous parts of the world (Singh et al., 1997; Hegde and Enters, 2000). Loss of forest cover and plant biodiversity may seriously jeopardize/ risk the functioning of forest ecosystems (*i.e*. the activities, processes, or properties of forests, such as decomposition of organic matter, soil nutrient cycling, and water retention), and consequently the ability of the forest to provide ecosystem services *(*Millenium Ecosystem Assessment, 2005, Duffy, 2009*)*. Deforestation, forest degradation, and forest fragmentation are continuous global phenomena events, but they are severe in the tropical region by anthropogenic activities (Wright, 2005). Roughly half of the tropical closed-canopy forest has been eliminated and the land transformed to other land-uses (Wright, 2005).

Ethiopia has lost the majority of its forest resources by forest degradation, and conversion of forest land use to other non-forest land uses, especially during the 20th century (USAID, 2008). The floral diversity of a country is currently failing under fully threatened by the association of forest degradation, and conversion of forest land use to other non-forest land-uses problems (USAID, 2008). Declining areas of natural forests in Ethiopia stimulated special plantings with fast-growing tree species to supplement the local wood materials called compensatory plantation forests (FAO 2010, FRA 2015). Forest plantations are established through planting and/or deliberate seeding in the process of forestation with fast-growing and short rotation periods of tree species characterized as even-aged monoculture stands with a broad range of management intensity (FAO 2010, FAR 2015). Plantation forest establishments carried out by using non-native species have both advantages and disadvantages (Lugo & Waide, 1993). Afforestation and reforestation programs have helped to reverse the decline of forest resources covered by different factors, which have resulted in the severe shortage of wood products, fuel wood, charcoal, construction materials, and soil degradation (Lalisa Duguma, and Hager, 2009). At the same time, afforestation and reforestation have led to increasing forest coverage areas in some areas which result in reducing the national net forest loss by lowering human pressure on natural forests. Currently, tree plantations are providing function as an alternative site for the renewal of native plant species (Senbeta, Teketay, & Näslund, 2002) and contribute to the preservation of biodiversity by offering conducive environmental conditions to understory native vegetation (Boothroyd-Roberts, Gagnon, & Truax, 2013).

The soil seed bank is defined as the natural storage of mature viable seeds that exist in the leaf litter, on the soil surface, or buried in the soil of many ecosystems, which represents the memories of the past plant community and serves as a repository for the future production of subsequent generations of plants to enable their survival in the surrounding area (Whittle et.al. 1997, Swaine 2001, Walck, 2005, Fisher et. a., 2009). Seed banks are formed by seeds, which are derived from either produced on-site by the present or past existing plants or carried to the site by dispersal agents from somewhere and accumulated in the soil, and viable for short or long periods (Brhane et al., 2006, Carlo and Aukema, 2005, Hirsch et al., 2012). The soil seed bank is one of the ecological parts that shape the dynamics of vegetation in land-use change. Because through time the degraded vegetation becomes recovers or re-establish to return to its original nature, which is determined by the existing potential of soil seed bank composition and density in the area (Zhan, 2007, Duncan, 2009, Williams, 2009). Soil seed banks (SSB) can be important components in the process of restoration and rehabilitating degraded lands (Hirsch et al, 2012). The soil seed banks (SSB) study provides information on the past population and structure of vegetation dynamics and forecasts the future regeneration potential of degraded land based on the existing capacity of seed bank composition and density under different land-use systems (Demel 1998, Aponte et.al., 2010).

The ongoing expansion of fast-growing and short-rotation exotic tree species plantations by farmers, enterprises, private, and the government has been focused on two major debates among scholars concerning the environmental impact, and the economic role of the species (Sasikumar et al., 2002, Florentine and Fox, 2003, Muluneh Mengist et. al. 2011). Among the contradicting ideas concerning the impact of fast-growing exotic tree species plantation on the environment: some researchers reported that fast-growing exotic tree plantation species have been a negative impact on the soil seed bank composition, and diversity via shade effect, and allelopathic effects, which contribute to creating unfavorable environmental conditions to hinder/limit the long life and regeneration capacity of native species diversity in soils (Feyera Senbeta et al. 2002, Sasikumar et al., 2002; Florentine and Fox, 2003). On the other hand, other workers stated that exotic tree plantation species on degraded land by afforestation or reforestation program could be a positive effect on native plant species restoration enhancing by providing habitat shelters, and creating the opportunity for native plant species composition and diversity via seeds and fruits dispersal facilitate in the area by dispersal agents attracting, and serve as shelter to dispersal agents, particularly birds, and mammals (Feyera Senbeta and Demel Teketay, 2002; Hartley 2002; Cusack and Montagnini 2004; Carnus et al., 2006; Brockerhoff et al., 2008).

Concerning the study of the soil seed bank species composition and density information are very important to the forest because they indicate that to develop the appropriate plan and strategies to conserve and manage the area for the future native vegetation species regeneration to recover the plant community. However, there is limited scientifically well-organized and documented information and scarce knowledge concerning the impact of different exotic tree species plantations on soil seed bank species composition and density in Yerer forest and its surrounding area. Therefore, the present study aims to evaluate: 1) the variation of seed banks composition, distribution, and density horizontal as functions of different exotic tree species plantations, 2) the variation of seed banks composition, distribution, and density vertical as functions of soil depth layers, and 3) the seed banks species similarities among different exotic tree species plantations in the central highland of Ethiopia. Specifically, the studies aimed to answer three questions: (1) what is the impact of different exotic tree species plantation forests on soil seed banks (SSB) composition, distribution, and density/m^2 (2) what is the impact of soil depth layer variations on soil seed banks (SSB) composition, distribution, and density/m^2 (3) What the similarities of seed banks composition among different exotic tree species plantation forests in the central highland of Ethiopia.

2. Materials and Methods

2.1. Description of the study area

Location and Climate

Yerer forest is one of the remaining montane evergreen natural forest and plantation forests with different exotic tree species established in different parts separately by Oromia Forest and Wildlife Enterprise (OFWE) in the eastern central highland of Ethiopia. The study area is located geographically between 8°52’00’’- 8°55’00’’ N latitude and 38°59’30’’ - 38°95’15’’ E longitude, with the altitudinal range between 2000 and 3100 m.a.s.l. (Figure 1). Meteorological data (1988 – 2019) showed that the mean annual rainfall of the study area is 907 mm/yr which is characterized by a bimodal rainfall having a long dry season (6-8 months), and the mean annual minimum and maximum temperatures were 11.1 ^{0}C, and 29.5^{0}C, respectively National Meteorology Service Agency (2019).

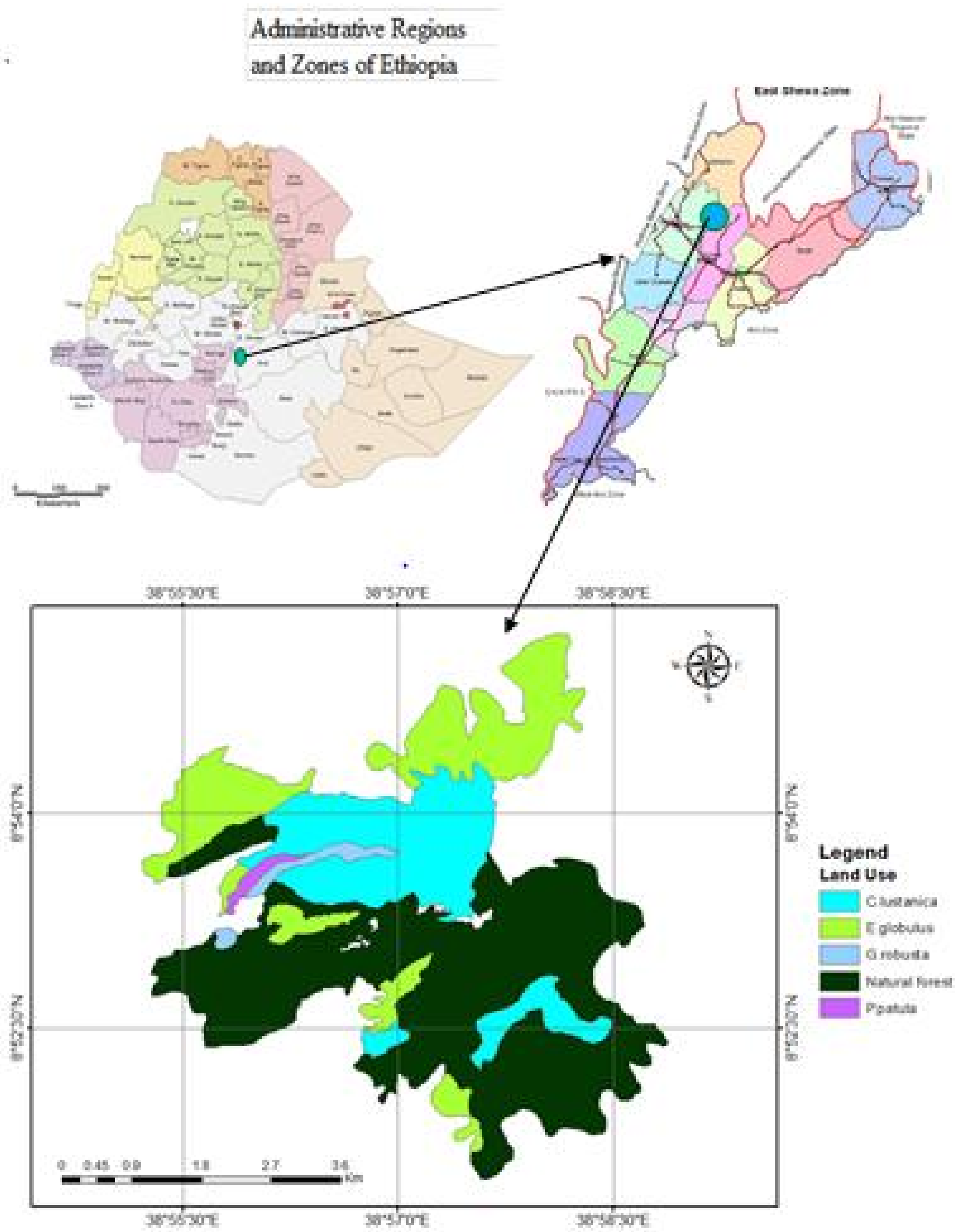

Figure 1 Images represent: A) Map of Ethiopia, B) Map of East Shewa Zone in Oromia Regional State, C) Map of study area of Yerer forest (developed using ArcGIS 10.4.1 Software).

Land-use systems

In the Yerer area, the major forest land-use systems are natural forests, and exotic tree species plantation forests (*Eucalyptus globulus, Cuppressus lustanica, Pinus patula, and Grevillea robusta*). In the present study context definition: A natural forest is the forest land that is composed primarily of the indigenous (native) tree, shrubs, lianas, climbers, and other herbaceous plant species, which may include both closed forest and open forest. exotic tree species plantation is described as the forest stands established artificially by non-native tree or shrub species in reforestation and afforestation programs for industrial and non-industrial purposes. Yerer Mountain natural forest consists of a mixed deciduous native species forest and established plantation forests, and covers an area of 3254 ha of which 1793 ha is plantation forest, and 1461 ha is covered by natural forest and others.

Figure 2 Images represent: The five different Forest land-use systems (FLUS) in Yerer area, a central highland of Ethiopia

2.2. Sampling Design

Different forest land-use systems (FLUSs) were selected, namely: natural forests, and four exotic tree plantation species (*Eucalyptus globulus*, *Cupressus lusitanica*, *Grevillea robusta*, and *Pinus patula*) (Figure 2). In this study, the five forest land-use systems (FLUSs) were considered as treatments and the quadrat samples in each FLUS were considered as a replication. A systematic sampling design was used to determine the soil seed bank species composition and density with transect lines laid in each FLUS. Three transect lines were delineated and laid parallel to each other along the altitudinal gradient in each FLUS separately. The soil samples were collected by arranging the sample quadrats at a 50-meter distance between two adjacent transect lines, and between the consecutive interval of quadrats on a transect line to avoid biased sample selection.

2.3. Soil sampling procedure, and sample preparation

For soil data collection, the site selection of forest land-use systems (FLUSs) was considered as the relative similarity of each FLUS as criteria in their topography, altitude, aspect, slope, and areas free from erosion exposed. For soil data collection the main square sample quadrat of 20 m x 20 m ($400m^2$) area was established with twelve (12) replication quadrats in each forest land-use system. The soil samples were collected in five replicates of subquadrats with a 1m x 1m area within each main square quadrat by arranging four (4) subquadrats at each corner and one (1) at the center of the main quadrat. The soil samples were collected close to the center of each subquadrats by carefully digging with a sharp knife by measuring the 10 cm x 10 cm surface area. The soil samples were taken in three depth layers, each layer is 5 cm thick (0-5cm, 5-10cm, and 10-15cm), a totally of 15cm in depth. Besides these, the litter layer was also included with the soil samples as the 4th layer because it was expected to contain a high number of seeds (Esmailzadeh et al., 2011).

The collected five soil samples from each main quadrat were combined in their corresponding depth layer categories and mixed thoroughly to form one representative composite soil sample per the main quadrat to reduce variability within the quadrat and to avoid contamination between depth layers. The composited soil sample for each soil layer was again divided into five equal parts and among them; one sample was randomly selected for seedlings emergence trials. The collected soil samples from each forest land-use system at each depth layer were packed into plastic bags and transported to the study area close to Oromia Forests and Wildlife Enterprise's permanent nursery site to further investigation in the greenhouse.

2.4. Seed Bank determination

For the assessment of the species composition and density of the seed banks, the study used the seedlings emergence method because of its ability to determine the viable fraction of readily germinable seeds (Espeland et al., 2010). The number of viable seeds in each soil sample was estimated through the germination trial method. The germination trial method provides an estimate of the potential use of in-situ seed banks as opposed to sowing seed as a source of materials for vegetation restoration efforts.

The seedlings emergence trial commenced at the beginning of February 2017 and was carried out in the greenhouse at the Oromia Forests and Wildlife Enterprise permanent nursery site adjacent to the study area. The composited soil samples were spread on 20 cm diameter and 8 cm depth circular plastic pots for germination. Each composite soil sample was placed in a separate tray container for each soil depth layer' in a non-temperature controlled greenhouse. The trays were watered daily to keep the soil samples moist. The tray was kept and observed until the emergence of seedlings stopped. Seedling recruitment was terminated after six (6) months (from the beginning of February to the end of July 2017).

2.5. Emerged seedlings of seed bank data collection

The emerged seedlings were identified, counted, recorded, and discarded on a two-weekly basis. To avoid differences in light exposure of seedlings, the position of the trays was changed every two weeks following the method used by Esmailzadeh et al. (2011).

2.6. Emerged seedlings identification

Most of the emerged seedlings species were identified in the field by using botanical keys and local knowledge. Seedlings that were difficult to distinguish timely were transplanted into other germination trial pots with labels for continued growth until they were possible to identify. However, some species that were difficult to identify in the field, the grown seedlings in a transplanted pot, the specimens were collected following standard herbarium technique. Specimens were allotted collection numbers (code number to each specimen) concerning sample quadrat pressed, and dried properly for identification at the National Herbarium of Ethiopia, Addis Ababa University. The collected specimens were identified by using taxonomic keys in the Flora of Ethiopia and Eritrea volumes 1–8 (Hedberg and Edwards, 1995; Edwards et al., 1995; 1997; 2000; Hedberg et al., 2003; Hedberg et al., 2004).

2.7. Data Analysis

The species composition and density of seeds in the soil were determined by organizing the data obtained from seedlings' emergence response. The density of seeds/m^2 was derived from the total number of emerged seedlings in soil samples per germination tray was summed/ added for each sample quadrat of 10cm x 10cm area and converted to m^2 area. Total numbers of seedlings were expressed as seed density/ m^2. On the other hand, the soil seed species composition and seed density distribution across the vertical soil depth in each forest land-use system were analyzed based on the total numbers of seedlings emerging in response in similar soil layers. The means differences between the total number of species composition and seed density were tested by one-way ANOVA among the five forest land-use systems using SAS software (Version 9.4). The main effects of land-use systems on seed bank species composition and seed density were tested at a significant level (P<0.05). Duncan's multiple range tests were used to compare differences between means of species composition and seed density between forest land-use systems. The least Significant Difference (L.S.D.) test was used for comparisons among means.

Jaccard's similarity index/ Coefficient (Krebs 1989) was used to calculate seed banks species composition similarity among five different forest land-use systems species identified from emergency seedlings response:

$$JI = \frac{a}{a + b + c}$$

JI: Jacard's index, a: number of common species in both land-use systems (LUS), b: number of species that exist only in first LUS, c: number of species that exist only in second LUS.

3. Results and Discussion

3.1. Seed bank species composition, density, and distribution pattern horizontal across exotic tree species plantation forests

A total of 1293 seeds were germinated from the soils sampled of five forest land-use systems (natural forest, *Eucalyptus globulus*, *Cupressus lusitanica*, *Grevillea robusta*, and *Pinus patula* plantations) that varied between the minimum 195 and maximum of 390 seedlings. The highest numbers of germinated seedlings were observed in natural forests (390), followed by *P. patula* (255). However, the least number of germinated seedlings from sampled soils were observed in *the C. lusitanica* plantation forest (195), followed by *E. globulus (212)*, and *G. robusta* (241). In the study area, under the same environmental conditions, the different forest land-use systems (FLUS) responded to the different results of seed bank composition, and density. This implies that the forest land-use system (FLUS) practices highly significantly influenced the quantity of species composition, seed density, and distribution of species in soil seed banks.

Table 1: Total number of germinated species recorded in the different forest land-use systems with their growth habit indicated.

Plant growth	Land-use Systems Categories				
habit	Natural forest	*C. lusitanica*	*E. globulus*	*G. robusta*	*P. patula*
Tree	4	1	1	0	0
Shrub	16	8	6	7	4
Climber	2	1	0	1	1
Herb	31	19	19	22	25
Grass	4	4	3	7	5
Total number of species					
	57	33	29	37	35

From the total emerged seedlings, a total of 81 species were identified in seed banks belonging to 31 families and 67 genera. The largest families were Asteraceae (with 12 genera and 14 species) followed by Poaceae (with 5 genera and 9 species), Fabaceae (with 6 genera and 8 species), Lamiaceae, and Cyperaceae (with 3 genera and 3 species for each). In the study area, the recorded plant species composition includes 48 non-woody (59.26%) and 33 woody (40.74%) (Table 1 and Figure 3**)**. The possible reasons for the very low proportion or absence of woody species seeds than herbaceous seeds in the soil under different forest land-use systems are directly associated with some woody species seeds lie on the ground surface and remaining exposed to the predation and harsh micro-climatic conditions that enhance some seeds decomposition and the persistent nature of seeds of some woody species enables their seeds to store in the soil without germinating for a long period. Similar results were also reported by other researchers of Tekle and Bekele (2000); Senbeta, and Teketay (2001); Lemenih and Teketay (2006), Assefa et al. (2014).

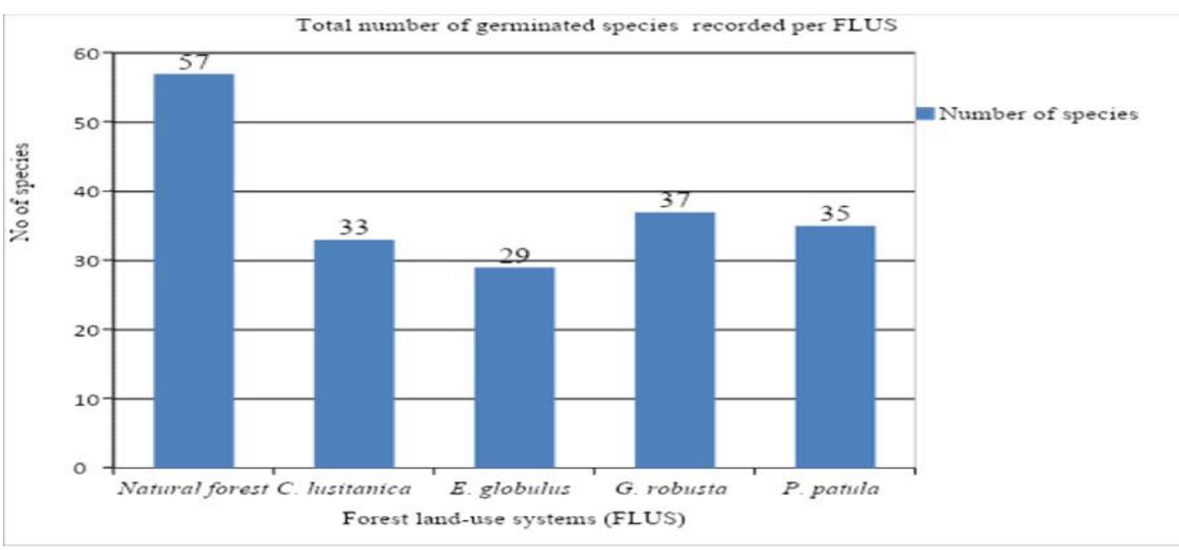

Figure 3: The total number of germinated seed bank species in the different Forest land-use systems

In the study area, the overall mean value of seed bank species composition number, and seed density/m^2 under different forest land-use systems varied between 29 and 57, and between 1625 and 3250, respectively (Table 1 and Table 2). The seed bank species composition and seed density/m^2 showed significant differences in numerical values among all forest land-use systems. The probable reason for the variation of species composition, and seed density/m^2 among different forest land-use systems might be happened due to the variation of input and output of seeds in the soil, long and current land-use history, previous and current existing vegetation history, land management practices, and the access and availability of seeds dispersal from a nearby and faraway distance. This agrees with the finding reported by Senbeta and Teketay (2002), Lemenih and Teketay (2006), and Assefa et. al., (2014).

Among the majority of common native species in the seed banks, 14 species are found in all five forest land-use systems. This indicates that the better distribution of seed bank species under different forest land-use environments, these probable due to the seed banks' storage capacity for a long period from the prior existing vegetation of the area, similar seeds input in soils by different seeds dispersal agents, and the species have a resistance capacity to adapt different land-use micro-environmental conditions to germinate. Other researchers also noted that different species in seed banks required different ecological growth requirements (micro-climate, soil nutrients, water) to germinate, survive, and grow under different land-use systems (Senbeta, and Teketay, 2001, Lemenih and Teketay, 2006, Assefa et al., 2014).

Table 2: Least significant mean number of germinated species per soil sample and seed density/m^2 in different land-use systems

Land-use systems (LUS)	Mean no. of species/soil sample	Mean Seed density m^{-2}	No. of species/ soil sample		Seed density m^{-2}	
			Maximum	Minimum	Maximum	Minimum
Natural forest	13a	3250a	20	11	3667	2767
C. lusitanica	8cd	1767e	16	7	2000	1667
E. globulus	7d	1625e	13	6	1933	1367
G. robusta	10bc	2165d	16	8	2533	1800
P. patula	9c	2008dc	15	8	2433	1367
LSD	1.12	353.48	-	-	-	-
CV	17.00	13.01	-	-	-	-
Significance	0.001	0.001	-	-	-	-

The analysis of variance (ANOVA) for plant species composition and seed density/ m^2 in soil seed bank indicated that there was a very highly significant difference horizontally as a function of forest land-use systems (p<001) for natural forests and other plantation forests. The distributions of seed bank species composition and seed density/ m^2 in the study forest land-use systems were observed as natural forest > *G. robusta* > *P. patula* > *C. lusitanica* > *E.globulus* plantation forest (Table 2). Among the five forest land-use systems, the highest species composition and seed density/m^2 were recorded in the natural forest land-use systems with numerical values of 57, and 3250, respectively. In the seed bank, 12 species found only in a natural forest, but not found in other forest land-use systems are *Ageratum conyzoides*, *Clematis simensis*, *Dodonaea angustifolia*, *Erica arborea*, *Heteromorpha arborescens*, *Hypericum revolutum*, *Juniperus* *procera, Olea europaea* subsp. *cuspidata, Phytolacca dodecandra, Pittosporum viridiflorum, Rhus vulgaris,* and *Vernonia amygdalina.* The possible reason for the highest species composition and density/m^2 in the natural forests could be attributed due to the low disturbance of natural forests by human and domestic animals because of its under control from external intervention, the availability of seeds input in the soils from nearby parent plants, the accessibility of different seeds dispersal by different wild animals and birds, seeds output/loss from the forest by predators and erosion, and good environmental favorable conditions to store seed banks with their viability for a short and long period without damaging. Other researchers like Shen et al., (2007), Walck et al., (2005), Tefera (2011), Assefa et al. (2014) reported similar ideas.

In the study of forest land-use systems (LUS), the lowest species composition and seed density/m^2 were observed in *E. globulus* and *C. lusitanica* plantation forests with numerical values of 29, 1625, 33, and 1767, respectively. The possible reasons for the lowest species composition and seed density/m^2 in these plantation forests could be associated with the relative shorter survival of vegetation species seeds in the soil, the lower proportion of mature parent plant species in the aboveground vegetation in the FLUSs, low external seeds inputs by dispersal due to unattractive dispersal agents by exotic tree plantation, and these exotic tree plantation forests may be imposed or influenced on the viability of seeds in the soils under them by induced unfavorable environmental conditions. Similarly, Matthew et al., (2004); and Ferreira et al., (2006) reported that the presence of exotic woody species in flora may relatively become a source of invasion and risk for seed banks' survival.

Exotic tree plantation forest land-use systems were overall less species composition in seed bank than natural forest. The seed bank species (12) of *Asparagus africanus*, *Barleria parviflora, Coelachyrum poiflorum, Crotalaria spinosa, Cupressus lusitanica, Cynoglossum coeruleum, Eucalyptus globulus, Hypericum quartinianum, Lippia adoensis, Maytenus arbutifolia, Ocimum lamiifolium,* and *Pennisetum riparium* are recorded only in plantations of exotic tree species but not observed in natural forest. This could be attributed due to the variation of seed inputs and outputs in the soil seed bank, temporal seed dispersal distribution, magnitude, and intensity of disturbances by human and domestic animals interferences. Perera, (2005) pointed out that the variation of seed rain and seed deterioration under different standing vegetation stands contribute to the difference in species composition and seed density in soil seed banks.

3.2. Seed bank species composition and seed density distribution pattern vertical in soil layers

The analysis of variance for species composition and seed bank density/m^2 of the soil seed bank revealed a significant difference vertically as a function of soil depth layers ($p<0.001$) in all forest land-use systems. The overall vertical distribution of species composition and seed densities in the soil showed a similar trend gradually decreasing with increasing soil depth in all forest land-use systems. This means, the seed bank species composition and seed density decrease with increasing soil depths downward (0-5 cm > 5-10 cm > 10-15 cm) in all forest land-use systems. The factors contribute to the decline of seed bank species compositions and density with soil depths increase due to the regular seeds rain in the upper surface soil by different seeds dispersal agents for accumulation in the upper soil layer, some matured small-sized and low mass seeds have required more time to become deeply buried in lower soil depth due to its floating on the upper surface, and the slow movement of seeds vertically down in soil profiles by secondary dispersal agents and seeds percolate by water. Similar results were also observed by other workers (Senbeta and Teketay, 2001; Assefa et al., 2014, Sileshi and Abraha, 2014, Assefa and Abraha 2014). Lemenih & Teketay, (2006) observed a declining trend of species composition richness in seed banks with increasing soil depth under different land-use in Ethiopia.

Table 3: Least significant mean values of the number of germinated species/ soil sample and seed density/m^2 in soil seed bank across soil depth layers

Soil depth layers	Mean number of germinated species/ soil sample	Seed density/m^2
litters	7d	135d
0 - 5 cm	16a	786a
5 - 10 cm	12b	421b
10 - 15cm	9c	283c
LSD	0.80	69.90
CV	11.00	24.83
SIGN.	0.001	0.001

The maximum seed density was recorded in the second soil sampling depth layer (0-5cm) for all selected forest land-use systems. However, the least seed density was observed in the lower soil sampling depth layer (10-15cm) in all forest land-use systems (Table 3 and Figure 4). A small number of seeds were found in the litter layer as compared to the other three soil depth layers.

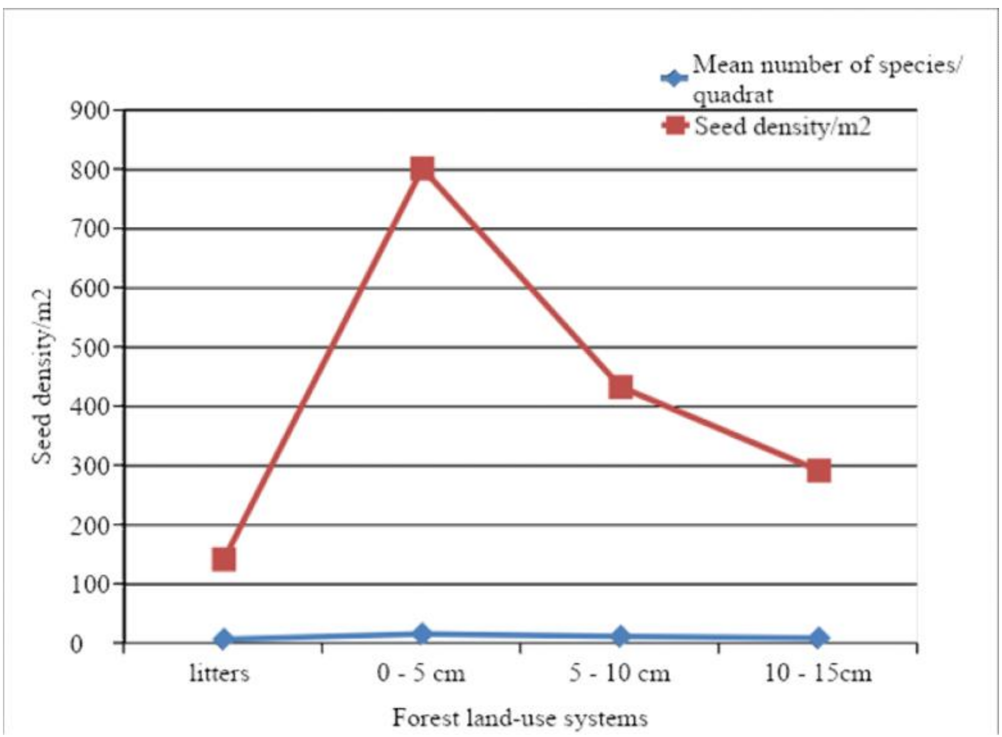

Figure 4: Mean number of species /quadrat and seed density/m^2 for each soil depth layer

Among the four soil layers, the recovery of seeds from the litter layer was lower than the three soil depth layers (0-5 cm, 5-10 cm, and 10-15 cm) in all forest land-use systems. This could be attributed due to the loss of seeds by herbivore animals from litter, the stayed of seeds on the upper surface of the soil for a long period may exposure to predators and predation, and the loss of seeds from the surface by wind and water erosion is leading to reduced accumulation of seeds in the litter's layer. The present finding agreed with the findings reported by other workers (Lemenih and Teketay, 2006, Assefa et al., 2014).

3.3. Seed bank species composition similarity among exotic tree species plantation forests

A Jaccard similarity index was used to compare the degree of species similarity in the seed bank of all five forest land-use systems (FLUS). The similarity in species composition of the soil seed bank between the five land-use systems ranged from JCS values of 0.28 to 0.53. The first and second highest similarities in species composition were recorded between *G.robusta* and *P. patula* (0.53), and between *G.robusta* and *E. globulus* (0.49), respectively (Table 4).

The overall species composition similarity indices in soil seed banks among all five land-use systems (FLUSs) ranged from 0.28 – 0.53. In the study area, the highest (> 50%) similarity or homogeneity of species composition in soil seed banks was observed between *G. robusta* and *P. patula* (JCS = 0.53). This implies that these forest land-use systems are shared commonly among more than 50% of plant species. The possible reasons for the highest vegetation species composition similarity or homogeneity in seed banks among some different land-use systems could be happened due to the existence of similar species seeds in the soils from the previous aboveground vegetation species similarity, the opportunity of similar species seeds inputs by dispersal mechanism with dispersal agents, and the similar soil environmental conditions that favor similar seeds store in soils for a short and long period. In contrast to the present finding Senbeta and Teketay, (2002) observed the lower species similarity among different exotic tree plantation forests in Ethiopia.

Table 4: Jaccard's Coefficients of similarity in species composition in the soil seed banks between Forest land-use systems

Forest Land-use Systems	Forest land-use systems				
	Natural forest	*C. lusitanica*	*E. globulus*	*G. robusta*	*P. patula*
Natural forest	-	0.38	0.35	0.41	0.28
C. lusitanica	-	-	0.43	0.42	0.45
E. globulus	-	-	-	0.49	0.42
G. robusta	-	-	-	-	0.53
P. patula	-	-	-	-	-

Of the total identified 81 plant species from the five different forest land-use systems, 14 (17.28%) plant species were found in all forest land-use systems. The common distributed plant species in all land-use systems are *Commelina benghalensis, Commelina diffusa, Cotula abyssinica, Trifolium decorum, Galinsoga parviflora, Guizotia scabra, Medicago polymorpha, Oplismenus hirtellus, Pennisetum thunbergi, Plantago Palmata, Andropogon abyssinicus, Fimbristylis Xomplanata, and Helichrysum splendidum,* however, 32 species (39.51%) were observed only in one FLUS. But the seed densities of these species varied among land-use systems. The commonly distributed plant species were dominated by herbaceous species (92.86%). Other workers also reported that different land-use systems composed some similar plant species (Joanne 2006, Lemenih and Teketay, 2006, Assefa et al., 2014).

However, the lowest species similarity or higher heterogeneity of species composition were observed between natural forest and *P. patula* (JCS = 0.28), and between natural forest and *E. globulus* (JCS = 0.35) (Table 4).

The different vegetation species composition between forest land-use systems could be occurred due to the disturbance intensity variation, seed inputs variation from different parent plants by dispersal mechanism, the accessibility of seed inputs variation from the current standing aboveground vegetation species, and the variation of soil environmental conditions that favor or impose seeds stored in soils for a short and long period. The present finding disagreed with Lemenih and Teketay, (2006) who reported that the higher species similarity (JCS = $\geq$ 32) between natural forests and different aged cultivation land of tropical dry Afromontane forests in Ethiopia.

4. Conclusion

The soil seed bank is one of the ecological components shaping the dynamics of an ecosystem by influencing the composition and formation of vegetation. The findings indicated that different species compositions and densities of seed banks have shown significant variations among forest land-use systems. The soil seed banks showed a total of 81 plant species that belong to 31 families and 67 genera. The highest species composition and seed density/m^2 were recorded in a natural forest, while the lowest species composition and seed density/m^2 were observed in the *E. globulus* plantation forest. Among the plantations of exotic tree species, *E. globulus* plantation influences seed bank composition and density. The overall vertical distribution of species composition and seeds densities in the soil was similar in all forest land-use systems with the highest densities occurring in the upper five centimeters of soil gradually decreasing with increasing soil depth. For the future appropriate native vegetation restoration under different forest land-use systems, the concerned bodies should give careful attention to urgent interventions, backed by appropriate conservation and management plan and strategies developing, and practical implementation on the ground.

Supplementary file

Appendix Table 1: Summary Lists of Plant species composition in the soil seed bank under different forest land-use in Yerer area of central Ethiopia.

Abbreviations

m. a.s.l.	Meter above sea level
cm	Centimeter
CV	Coefficient of variation
m	meter
FLUSs	forest land-use systems
SAS	Statistical Analysis Software

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Authors' contributions

All authors played a vital role to accomplish this manuscript. The corresponding author, YB develop the idea of the research, designed the research method, soil seed banks seedlings germination trial performed, data collection, statistical analysis, and wrote the manuscript. TB and SD contributed significant input into the successful completion of the manuscript by supervising the study, consistent and inspiring guidance, valuable suggestions; constructive comments, and reviews on the manuscript preparation.

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Competing interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The data can be available in Additional files and for detail please request the Corresponding Author.

Code availability

Not applicable

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