Research article

Soil seed bank distribution and restoration potential in the vegetation of Buska Mountain range, Hamar district, southwestern Ethiopia

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HIGHLIGHTS

- Seed banks play an important role in ecosystem resilience serving as a reservoir of regeneration potential.
- Based on the findings of this study, the new plant recruitments could be predicted.
- It produced a suggestion on the restoration, biological variety conservation and vegetation succession for the maintenance of biodiversity in arid climatic regions.
- In view of the ever-increasing effects of climate change in rangelands in dry regions, like ours, the study’s findings could be an invaluable source of awareness.

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ABSTRACT

The seed banks are vital components for the reestablishment of degraded lands since they are used to predict the future coverage of vegetation and allow for the implementation of appropriate conservation measures in a particular area. The study was conducted in the Buska Mountains of the Hamar area in south-western Ethiopia and determined the composition, density and vertical distribution of soil seed banks under various land-use systems and soil layers. A total of 96 soil samples were involved in the study; four land-use types (grassland, forest, scrub and bare ground). Three distinct soil layers from each plot (0–3 cm, 3–6 cm, 6–9 cm depths) were sampled. Jaccard's Similarity Coefficient was applied to evaluate the correspondence between different land-use types and soil layers. One-way ANOVA was used to compute species density and composition respectively within land-use systems along with the seed bank and above ground vegetation. Fifty six (56) species within 27 plant families and 50 genera were recorded. Twenty percent of the species was contributed by Asteraceae followed by Poaceae (16%). Herbaceous growth forms were the most dominant in the area, contributing about 78.6%. The total seedling density in the study plots was 8171 seedlings/m². Jaccard's Similarity Coefficient is relatively higher (0.52) between grassland and scrub, while the forest and bare land had the least amount of similarity (0.22). There was seen a higher similarity of species between the first and second soil layers and a decreasing density with soil depth. A substantial difference between the aboveground species and seed bank was recorded in the area. The lower resemblance between the standing vegetation and the seed bank infers a lower overall restoration potential and suggests other alternative regeneration mechanisms such as seedling plantation of priority indigenous plant species and avoiding anthropogenic disturbances.

1. Introduction

Human pressure is widely regarded as the primary cause of desertification in the world’s arid regions (Niwer et al., 2021; Abdi et al., 2013) and when combined with the complications of global climate change, it exacerbates the problem in dry lands (Konapala et al., 2020). The response of tropical forest ecosystems to natural or anthropogenic environmental changes is a major topic in ecology (Wang et al., 2014; Fischer et al., 2016). Because of the low precipitation, higher dependence on agriculture and natural resources, and limited ability to adapt, Sub-Saharan Africa is regarded as the most susceptible to the current climate change (Muringai et al., 2021; Bedeke, 2022; Thompson et al., 2010; Thornton et al., 2008). According to Treulde et al. (2007), despite the enormous importance of larger trees, they are being cut down for...
charcoal, firewood, and timber production in semi-arid eastern and southern African savannas, resulting in the loss of biological diversity and ecological stability, which may have an impact on the potential restoration of degraded semi-arid African savannas (Mitchell, 2013; Kotir, 2011; Tessaema et al., 2017).

Ethiopia is a tropical country with rapidly declining vegetation coverage due to anthropogenic factors such as increased land use for agricultural expansion, overgrazing, and illegal exploitation of forest products (Armaw and Molla, 2022; Muhammed and Elias, 2021; Sutcliffe et al., 2012; Senbeta and Teketay, 2001). The current changes in land use, as well as emerging livelihood adaptations, disturbances and climate change are likely to affect natural biodiversity and the regeneration/restore potential of plant species across the country’s ecosystems. Dry lands in Ethiopia, in particular, are vulnerable to climate change and unpredictability, a problem that affects various sectors, including biodiversity (flora and fauna), agriculture, human health, and water (Bogale and Tolessa, 2021; Gezie, 2019; Georgis, 2010; Seta, 2017). Prolonged heavy grazing pressures combined with drought in the country’s pastoral areas have reduced large areas of rangeland to bare soil, and plant populations in these areas are highly disturbed (Abdulaal et al., 2016; Oba et al., 2000).

According to Baskin and Baskin (2014), plant populations are represented not only by growing individuals aboveground, but also by a number of dormant propagules forming seed reserves in the soil. These viable seeds may persist in the area for some time even after plants have disappeared from the standing vegetation due to successional processes, where the above-ground and below-ground compositions are very different (Plue et al., 2021; Pekas and Schupp, 2013). There is a growing need for accurate data on the natural regeneration potential of the vegetation for scientific decision-making in environmental management (Haglund et al., 2011; Hölzel and Otte, 2004). Lemenih and Teketay (2006) stated that the seed banks are an essential part of biodiversity since they inform the public on the status of management, aid in biodiversity preservation, and restore ecosystems. When persistent understory seed banks are more diverse and have higher seed abundance, it suggests that degraded areas have a better ability to tolerate environmental disturbances and recover more easily combating the resulting effects of climate change (Mall and Singh, 2011; Tessaema et al., 2017). However, variables such as seed size; density, seed longevity, seed viability, germination strategies, and depth distribution in soil are the factors to be considered (Hill and Vander Kloet, 2005; Godefroid et al., 2006). Thus, a careful examination of the configuration of seed banks can also provide evidence on the relative abundance of recently recruited species and the future potential distribution of each species (Suding, 2011; Lemenih, 2004).

The composition, abundance and distribution patterns of the species and their life forms in the seed bank are all influenced by the floristic composition, the phenology of local vegetation, and disturbances at the forest edge (Grombong-Guatritani et al., 2004; Butler and Chazdon, 1998; Savadogo et al., 2017). Gaining adequate information on the restoration potential of natural forests along with the threatening factors is now a matter of urgency for implementing appropriate forest management measures that could minimize forest losses (Seddou et al., 2021; Linser and Wulfsehner, 2022). As a result, determining the state of the seed bank would be crucial for ecological stability and the potential restoration of degraded forest areas in the face of changing climate and global warming. The current drought in the study area has posed a significant challenge, threatening seed formation and maturity, as well as seedling production under the vegetation. Furthermore, no extensive ecological study of the area has been done.

The present study was carried out in the Buska Mountain range in Hamar district, South Omo Zone, Southwestern Ethiopia, with the goals of determining the composition, density, horizontal and vertical distribution of seed banks under various land-use types and soil layers along with a comparison of the recovered soil seed bank species to the standing vegetation, in order to assess the vegetation’s restoration potential and implications for biodiversity conservation.

2. Methods and materials

2.1. Description of study area

The vegetation of Buska Mountain Range is found in Hamar district, South Omo Zone, Southern Nations Nationalities and People Regional State (SNNPRS), Ethiopia. South Omo zone is one of the 13 zones in the regional state and located in the southwestern part of the country. The Zone is bordered on the south by Kenya, on the west by Bench-Maji zone, on the northwest by Kefa zone, on the north by Konta special district and Gamo-Gofa zone, on the northeast by Dirashe and Konso zones, and on the east by the Oromia region. Hamar district is one of the eight districts in South Omo zone and located 880 km south of Addis Ababa (the capital of Ethiopian) at 5°12′40″N latitudes and 36°20′10″E longitude (Figure 1).

The district has a semi-arid climatic condition and an altitudinal range of 380 m. a.s.l in the Erbore lowland to 2100 m. a.s.l at the summit of Buska Mountain, which is about 40 km northeast of Dimeka (the capital town of the district). In line with Pulsen (1990), Mesfin et al. (2017) and Mulugeta and Sheleme (2010), the major soil types of the district include: Cambisols (53%), Nitosols (17%) Ultisols (14.5%), Inceptisols (10%) and Entisols (7%). The vast majority of Hamar district is covered by dry and semi-arid climatic conditions, with an extremely variable mean annual precipitation of 757 mm, and average annual temperature of 22.7 °C. The district experiences bimodal rainfall, with the main rainy season occurring between March and May, and a shorter wet season occurring between September and October. The average monthly maximum and minimum temperature are 33.2 °C and 14.2 °C respectively (Figure 2).

Following the vegetation classification of (Ib et al., 2010), the dominant vegetation types in the area include Acacia-Commiphora woodland and bushland (Figure 3A), pockets of Combretum-Terminalia woodland (Figure 3B), and Dry evergreen Afrormontane and grassland vegetation type dominated by Olea europea subsp. cuspidata, and Juniperus procera which is restricted at the top of Buska Mountain (Figure 3C).

2.2. Data collection methods

Four land-use types (grassland, forest, shrub land and bare land) were identified in the study area based on the definition and categorization of land-use types used by Tolessa et al. (2017), Kebede and Mekuria (2018). As a result, eight main sample plots were considered from each of the four land-use types, for a total of thirty-two main plots. Each plot contains three soil layers and a total of 96 samples were collected from five 15 cm × 15 cm (225 cm²) points, one in the center and four at the corners of each sample quadrant in each land-use type. The seed bank samples were taken using a sharp knife and a spoon from the three successive depths of three centimeter thickness (0–3 cm, 3–6 cm and 6–9 cm based on Lemenih and Teketay (2006)). Samples from similar layers of the five points were mixed to form composite samples following Tesfaye et al. (2004). About a kilo of composite seed bank sample was collected from the five points was transported to a greenhouse at Ethiopian Biodiversity Institute (Figure 4A). The sample was sieved with a 2 mm mesh size before the beginning of the investigation based on (Beheshtean et al., 2007; Danou et al., 2011) in order to remove rough plant parts including leaves, pieces of wood and stones. The seeds with a diameter higher than 2 mm were recovered and re-deposited in the sieved soil samples. Then, in accordance with Lopez-Toledo and Martinez-Ramos (2011) and Lemenih and Teketay (2006), the soil was spread out in a circular plastic tray, watered every morning, and incubated for seed germination in the greenhouse. The germination experiment was kept for eight months until all anticipated seedlings were germinated (Figure 4B). The seedlings readily recognizable were identified, counted and discarded after recording following the methodology used by Tessaema et al. (2016) to reduce shade effect (Figure 4C).

Using the Ethiopian and Eritrean Flora as well as additional comparison with authorized specimens, seedlings that proved challenging to
identify in the greenhouse were recognized at the Ethiopian National Herbarium at Addis Ababa University. The appropriately pressed, dried, and labeled specimens were deposited in the Ethiopian National Herbarium.

2.3. Data analysis

The seedlings emergence method was applied in the present study following (Baskin and Baskin, 2014; Schuster et al., 2016) because it is the most widely used and more reliable method in the researches on soil seed bank. Consequently, the species composition, density, frequency and vertical dissemination of the emerged seedlings were investigated. To assess the restoration potential of each layer in the area, seedlings from similar soil layers were counted and brought together. Accordingly, the cumulative density per hectare as well as the collective density of seedlings/m² for each soil layer was analyzed. Furthermore, based on Tesfaye et al. (2004) and Perera (2005), the comparison in density of seedlings in different land use types and soil layers was compared.

Figure 1. Map of the study area showing Ethiopian Regional States, South Nations, Nationality and Peoples Region (SNNPR), Buska forest and the adjacent administrative units to the forest.

Figure 2. Climate diagram of the research area showing the rainfall distribution and temperature variation from 1999 to 2019 [Source of the raw data: Official unpublished document of the National Metrological Service Agency, Ethiopia (NMSA, 2019)].
The similarity of soil seed bank composition among different land uses and soil layers was investigated using Jaccard's coefficient of similarity, which can be calculated as follows:

\[ S_J = \frac{a}{a + b + c} \]

where \( S_J \) = Jaccard similarity coefficient

- \( a \) = Number of species common to both land use types/soil layers
- \( b \) = Number of species unique to land use type b/soil layer b.
- \( c \) = Number of species unique to land use type c/soil layer c.

The coefficient has a value from 0 to 1, where 1 indicates complete similarity and 0 shows a complete dissimilarity. Sorensen Similarity Coefficient between the standing species and the seed bank composition was estimated based on Sorenson Index (SI) using the formula:

\[ S_S = \frac{2C}{2C + a + b} \]

where \( S_S \) = Sorensen Coefficient of similarity, \( C \) = the number of species found in both the soil seed bank and the standing vegetation, where:

- \( a \) is the number of species in the soil seed bank, and
- \( b \) is the number of species in the standing vegetation. The coefficient lies between 0 to 1 which stands for no similarity or full similarity respectively.

The mean difference of seed bank species density and composition among the land uses and between the seed bank and above ground vegetation was computed using one-way ANOVA using SPSS software (Version 20) with post-hoc Tukey HSD test (at \( p < 0.05 \)).

3. Result

3.1. Composition and density of soil seed bank

A total of 56 species within 50 genera and 27 plant families were identified from the seed bank of the soil in the vegetation in Buska Mountain range. The Asteraceae family was found to be the most dominant plant family recovered, accounting for approximately 20% of the total species, followed by the Poaceae (16%). The Fabaceae and Solanaceae families each contributed about 7.2% of the species. Thus, these four most dominant plant families in the area contributed about 50 percent of the total species recovered from the area's soil seed bank. Herbaceous species were found to be the most common growth form (78.6%), followed by shrubs (16%), trees and climbers (3.6% and 1.8%, respectively) (Figure 5).

Calpurnia aurea, Rhus natalensis, Solanum incanum, Dodonaea angustifolia, Croton macrostachyus, Solanum marginatum, and Juniperus procera are some of the woody species found in the study area's soil seed bank. Regarding the species composition across land uses, the forest had the most species rich (51), subsequently the grassland (45 species). Conversely, the bare land soil seed bank had the lowest composition (38...
species). However, the highest density (3451 seedlings/m²) was recorded for grassland, followed by the forest (2155 seedlings/m²), shrub land (1839 seedlings/m²), whereas the lowest density (726 seedlings/m²) was recovered from bare land (Figure 6).

In terms of vertical distribution, the first layer had the highest seed bank density when compared to the other layers in all of the land use types studied. As a result, this layer has scored the highest overall percentage density, while the third layer had the lowest density in the area (Table 1).

*Alchemilla abyssinica, Digitaria ternata, Cynoglossum lanceolatum, Oxalis procumbens, Pennisetum thunbergii,* and *Dodonea angustifolia* were the first six most common and dominant species observed in the area, accounting for 16.7%, 15.6%, 12.5%, 10.5%, 9.4%, and 9.4% of the density respectively. The record for the frequency of seedlings for each land use type, on the other hand, revealed variation under different land use types. As a result, the most common species in grassland include: *Anagallis arvensis* 12 (8%), *Alchemilla abyssinica* 9 (6%), *Argemone mexicana* 9 (6%), *Centella asiatica* 8 (5.3%), *Digitaria ternata* 7 (4.6%), *Poa schimperiana* 6 (4%), *Rhus natalensis* 6 (4%) and *Plantago lanceolata* 5 (3.3%). The least common species in this land use type, on the other hand, are *Vatovaea pseudolablab* (0.7%), *Achyranthes aspera* (1.3%), *Oxalis procumbens* (1.3%), *Sonchus oleraceus* (1.3%), and *Tagetes minuta* (1.3%).

**Figure 5.** Habits and proportions of plant species found in soil seed bank.

**Figure 6.** Density of species in soil seed banks at various land-use types and soil layers.

Cynoglossum lanceolatum (5.7%), *Galinsoga parviflora* (5.7%), *Juniperus procera* (4.9%), *Laggera crispata* (4.9%), and *Tortilis arvensis* (4.1%) are the species with the highest relative frequency in the soil seed bank sampled from forest, while the least frequent species in this land use type include *Ageratum conyzoides, Artemisia abyssinica,* *Poa schimperiana* and *Rhus natalensis*, each of which contribute only 0.82% of the seedlings in this land use type. In terms of shrub land, the species with the highest frequency were *Solanum incanum* (8.4%), *Dodonea angustifolia* (7.4%), *Senna occidentalis* (7.4%), *Caylusea abyssinica* (6.3%), *Ocimum gratissimum* (6.3%), and *Leucas martinicensis* (5.3%), while *Bidens pillosa* and *Ageratum conyzoides* contributing the lowest frequency. The species frequently recorded from bare land include: *Bidens pillosa* (6.4%), *Ageratum conyzoides* (4.8%), and *Dichrocephala integrifolia* (4.8%). Most of the species recorded frequently in other land uses were very rare or absent in this land use type.

### 3.2. Species composition and similarity among land use types and soil layers

The plant species recovered from only the first layer include: *Acmella caulirhiza,* *Calpurnia aurea,* *Croton macrostachyus,* *Conyza species* and *Juniperus procera*. Species including *Crotalaria incana, Dodonea angustifolia, Linum usitatissimum,* and *Rhus natalensis,* *Senna occidentalis,* and *Solanum*...
incanum, Solanum marginatum, Vatovaea pseudolablab and Vernonia amygdalina were distributed between the first and second soil layers. Thus, the majority of the woody species found in the area’s soil seed bank were noticed to be restricted to the first two soil layers. However, most of the herbaceous plant species recovered from the study area were distributed in all the three soil layers.

The value of Jaccard’s similarity coefficient (JCS) revealed a higher similarity in species composition between grassland and shrub land (0.52), followed by forest and shrub land (0.47), while the forest and bare land had the lowest coefficient of similarity (Table 2).

On the other hand, the degree of Jaccard’s similarity among the soil seed bank layers depicted a relatively higher similarity between the first and the second layers. Conversely, the first layer and the third layers were the least similar (Table 3).

When crosschecked across the above-ground species of the vegetation encountered in the main plots, the total number of aboveground species in these plots was 158, while, the total number of the retrieved species from the study points was 54. Only 26 of the plant species documented from the area were shared between standing vegetation and soil seed bank. The finding also revealed that only about 9.5% of woody species existing in the aboveground vegetation were restored from the seed bank. All of the woody species found in the soil seed bank, however, were also encountered in the standing vegetation. In the Jaccard’s and Sorensen coefficients of similarity between the soil seed bank and standing species, 130 species specific to aboveground and 28 species identified from seed bank were used for comparison in addition to the common species to aboveground and seed bank. However, relatively greater similarity index was noticed between the soil seed bank and above ground vegetation in grassland than the other land-use types (Table 4).

Moreover, Sorensen similarity coefficient between the seed bank and standing species was computed for each plot in different land use types (Table 5).

The variation in seed density and composition within the land–use types as well as the seed bank species and standing vegetation were computed by one-way ANOVA with post-hoc Tukey HSD test (at $p < 0.05$). Accordingly, the finding revealed that there was a significant difference between the land-use types (Table 6) as well as a notable distinction between the seed bank and existing vegetation (Table 7).

Furthermore, agricultural expansion, debarking/ringing, over-grazing, abandoned fire, cutting for construction materials, and fuel wood extraction were among the frequently recorded factors threatening the regeneration potential and the vegetation of the Buska Mountain range in general.

4. Discussion and conclusion

4.1. Discussion

Seed banks are reservoirs of seeds capable of sprouting when conditions in the soil are favorable Zhang et al., 2021; Jaganathan and Dalrymple, 2016). The result of seed bank in the Buska Mountain range showed a significant number of species (56) dominated by herbaceous species over the woody species. The dominance of herbs, as stated by (Ares et al., 2009; Wienk et al., 2004) might be associated with the fact the presence of disturbances in the area. It also indicates that their persistence under harsh condition and can actively return to the ecosystem without the need for re-introduction (Girard et al., 2017; Durak et al., 2022). On the other hand, Savadogo et al. (2017) stated that sedges, grasses and herbs have smaller seeds than many woody species, and species with smaller sized seeds have a supplementary chance of becoming buried in the soil layers that are deeper, which was in line with the findings of the present study. This idea is further supported by the fact that the pioneer species produce a large number of seeds, contributing to the high density of small seeds in soil seed banks (Eksarasi et al., 2021).

In contrast, the predominance of herbs in the seed bank is brought about by the slower rate of reproduction of some tree species, their larger

| Land-use types   | Total density | %   | Layer 1 | %   | Layer 2 | %   | Layer 3 | %   |
|------------------|---------------|-----|---------|-----|---------|-----|---------|-----|
| Grassland        | 3451          | 42.2| 1339    | 16.4| 1123    | 13.7| 989     | 12.1|
| Forest           | 2155          | 26.4| 833     | 10.2| 667     | 8.1 | 655     | 8.2 |
| Shrub land       | 1839          | 22.5| 728     | 8.9 | 589     | 7.2 | 522     | 6.4 |
| Bare land        | 726           | 8.9 | 320     | 3.9 | 205     | 2.5 | 201     | 2.4 |
| Total            | 8171          | 100 | 3220    | 39.4| 2584    | 31.5| 2367    | 29.1|

| Land use types   | Species exclusive to soil seed bank flora | Species exclusive to standing flora | Species in common | JCS | Ss  |
|------------------|------------------------------------------|-----------------------------------|------------------|-----|-----|
| Grassland        | 24                                       | 48                                | 11               | 0.13| 0.23|
| Forest           | 27                                       | 57                                | 10               | 0.10| 0.19|
| Shrub land       | 22                                       | 60                                | 10               | 0.11| 0.20|

Where, $JCS = Jaccard’s Coefficient of similarity and $Ss = Sorensen similarity.

| Land use types   | Plots   | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   |
|------------------|---------|-----|-----|-----|-----|-----|-----|-----|-----|
| Grassland        | 0.23    | 0.27**| 0.26 | 0.21 | 0.22 | 0.12 | 0.07 | 0.22 |
| Forest           | 0.14    | 0.15 | 0.14 | 0.07 | 0.13 | 0.08 | 0.11 | 0.09 |
| Shrub land       | 0.09    | 0.17 | 0.09 | 0.14 | 0.25 | -   | 0.16 |    |
Table 6. Analysis of variance (ANOVA) for seed bank density per land-use showed a significant dissimilarity between land use types (sig. at p < 0.05).

| Multiple comparisons | Density per land use for seed bank species |
|----------------------|------------------------------------------|
| Tukey HSD            |                                          |
| Land use type        | Compared with                            | Mean difference | Sig.  |
| Grass land           | Forest                                   | 432.000*        | .009  |
|                      | Shrub land                               | 537.333*        | .002  |
|                      | Bare land                                | 908.333*        | .001  |
| Forest               | Grass land                               | −432.000*       | .009  |
|                      | Shrub land                               | 105.333         | .008  |
|                      | Bare land                                | 476.333*        | .000  |
| Shrub land           | Grass land                               | −537.333*       | .002  |
|                      | Forest                                   | −105.333        | .008  |
|                      | Bare land                                | 371.000*        | .002  |
| Bare land            | Grass land                               | −908.333*       | .001  |
|                      | Forest                                   | −476.333*       | .000  |
|                      | Shrub land                               | −371.000*       | .002  |

* The mean difference is significant at the 0.05 level.

Table 7. Analysis of variance (ANOVA) showed a significant difference in composition between land use types (of seed bank) and standing species (sig. at p < 0.05).

| Multiple comparisons | Number of species per land use types (above and below ground composition) |
|----------------------|--------------------------------------------------------------------------|
| Tukey HSD            |                                                                          |
| Species in seed bank | Compared with                                      | Mean difference | Sig.  |
| (belowground)        |                                           |                |       |
| Grass land           | Grass land above                                                      | 35.333*        | .000  |
|                      | Forest below                                                          | −2.000         | .997  |
|                      | Forest above                                                          | 26.333*        | .001  |
|                      | Shrub land below                                                      | 1.667          | .999  |
|                      | Shrub land above                                                      | 17.333*        | .020  |
| Forest               | Grass land below                                                      | 2.000          | .997  |
|                      | Grass land above                                                      | −33.333*       | .000  |
|                      | Forest above                                                          | −24.333*       | .002  |
|                      | Shrub land below                                                      | 3.667          | .957  |
|                      | Shrub land above                                                      | −15.333*       | .043  |
| Shrub land           | Grass land below                                                      | −1.667         | .999  |
|                      | Grass land above                                                      | −37.000*       | .000  |
|                      | Forest below                                                          | −3.667         | .957  |
|                      | Forest above                                                          | −28.000*       | .000  |
|                      | Shrub land above                                                      | −19.000*       | .011  |

* The mean difference is significant at the 0.05 level.

Understanding the quantity, distribution, and diversity of soil seed banks is critical for developing conservation and re-establishment programs in degraded ecosystems, particularly in arid and semi-arid environments. The soil seed bank from the vegetation of the Buska Mountain Range yielded 56 species from 50 genera and 27 plant families. The four most dominant plant families, Asteraceae, Poaceae, Fabaceae, and Solanaceae, contributed about 43 percent of the total species retrieved from the soil seed bank in the area. The outcomes of this study also revealed that herbaceous species had the maximum density per plot, while woody species had the lowest number of seedlings recovered from a seed bank. Grassland had the largest density of species, whereas bare land contributed the lowest seedlings density in the area. With increasing depth of soil layers, a diminishing trend of species distribution was observed. The result of the study also showed that there was little correspondence between above-ground and seed bank species, indicating that natural regeneration of species lost from the above-ground flora is difficult, implying the establishment of a nursery and seedling production for plantation is better for the sustainable management of the area's priority indigenous plant species.

Based on the study’s findings, the following recommendations are made: (i) The lower similarity levels between the seed banks and standing vegetation suggests the requirement to strengthen the forest protection and management as there was potentially low restoration ability; and (ii) Plant flowering, seed dispersal, germination, seedling establishment, plant mortality and other processes can be affected by disturbances such as fire, overgrazing and human disturbances observed in the area. As a result, avoiding such turbulences should be in place by implementing measures such as...
firebreaks and other management guidelines in the area. (iii) The already initiated in-situ conservation activities of biodiversity in the area by Ethiopian Biodiversity Institute and other stockholders, for instance, for restoration of degraded lands and management of the natural vegetation should be strengthened and authorized to ensure the sustainability of such a vital biodiversity despite its situation in insubstantial arid climatic region.

Declarations

Author contribution statement

Melesse Bekele: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Professor Ssebebe Demissew; Professor Tamrat Bekele; Dr. Feleke Woldeyes: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed materials and analysis tools.

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Data availability statement

Data included in article/supp. material/referenced in article.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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