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Soil Seed Bank Study and Natural Regeneration Assessment of Woody Species in Dodola Dry Afromontane Forest, Bale Mountains

By

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Abstract

Soil seed bank status and natural regeneration of woody species of Dry Afromontane Forest of Dodola was studied from December 2004 to July 2005. The objective of the study is to assess the composition, density of seeds in the soil and naturally regenerating woody species of the Dodola forest. A total of hundred quadrates were established in the selected ten habitat types of Dodola forest. The quadrate size (20 m x 20 m) for trees and shrubs with height greater than 4 m, 5 m X 5 m for sapling, 2 m X 2 m seedlings, 1m X1 m germinates, and 2 m X 2 m for the herbaceous layer laid down in the main quadrats to examine similarity between standing vegetation and soil seed bank flora as well as natural regeneration of the study site. Soil samples were collected from the main quadrats measuring 15 cm X 15 cm and three separate soil layers each 3 cm thick (0 – 3 cm, 3 – 6 cm, 6 cm – 9 cm). Results from soil seed bank study show that a total of 56 plant species were obtained from the seed bank, *Juniperus procera* have the highest viable seed density than the remaining tree species. There is significant variation in seed density between habitat types
(P< 0.024). The highest seed bank density was recorded in the first sampling layer (0 -3 cm) of nine habitat types. Similarity between standing vegetation and soil seed bank show that there was negligibly low similarity (JCS = 0.109 – 0.33). Analysis of natural regeneration of woody species shows that a total of 31 woody species and 41,092 individuals\ha were recorded. Highest seed density of naturally regenerating woody plants and highest number of species were recorded in
Erica – Hypericum and *Riverine* habitat types respectively. *Myrsine africana* is a species with highest number of plant from naturally regenerating woody species. The highest class distribution of *Hagenia abyssinica* dose not have germinant and seedling population. From the ten habitat types *Farmland* and *Grassland* habitat types show lower and no naturally regenerating individuals respectively. These indicate that reliance on the soil seed banks fro the recovery of most native woody flora may be difficult in *Grassland* and *Farmland* habitat types of Dodola forest.

1. Introduction

Vegetation found on highland areas of Africa is referred as Afromontane vegetation. The Afromontane vegetation of Africa covers a total area of 715,000 km^2 (White, 1978). The Afromontane region is centre of diversity with a total of 4,000 or more plant species, of which over 3000 are endemic (White, 1978). According to Cotzee (1978) the East African Mountains have the richest and most diversified tree flora. The Ethiopian High lands are the largest mountain complex in Africa and comprise over 50% of the African land area covered by

Afromontane vegetation (Tamrat Bekele, 1993; Demele Teketay, 1996). The flora of Ethiopia is estimated to contain between 6,500- 7,000 species of higher plants, out of which about 12% are endemic (Tewolde Berhan G. Egziabher, 1991). The Ethiopian highlands are comparatively drier and also make island surrounded by arid and semi-arid lowlands. Hence, they have their own unique and endemic species (Taddesse Woldemariam *et al,* 2000).

However, different studies revealed that the natural forest and woodland resources have been declining both in size (Deforestation) and quality (degradation) in an alarming rate from time to time. The current annual rate of deforestation is estimated between 150,000-200,000ha (EFAP, 1994). Due to this a closed high forest of the country declined to less than 2.3% (EFAP, 1994).

The main reasons for the destruction and/or reduction of the forest area are clearing of forests for the expansion of agricultural land and cutting of trees for various purposes, mainly for fuel wood, charcoal, and construction materials (both for consumption and sale), burning associated with traditional agriculture, etc. The loss of forest cover has resulted in soil erosion, land degradation, loss of biodiversity, and impoverishment of ecosystems which in turn affected, and still continue to affect human and plant as well as animal welfare (Demel Teketay, 1996).

Forests deliver any of the functions of protection or conservation, only if it is in normal and good natural ecological conditions (Gottle and Sene, 2004). Therefore, there is a need to restore the natural vegetation.

This could be achieved by appropriate management and use plans that include ecologically sound restoration or rehabilitation measures. There are diverse approaches and techniques to restore land and vegetation. Natural regeneration assessment of woody species and study soil seed bank potential are among the approaches which closely linked and play a significant role in restoration and conservation of the forest with low cost in the form of in-situ conservation system. Soil seed bank in restoration management is acknowledged as low cost restoration technique since it disposes many of the problems associated with collecting, storing and sowing seeds as well as transplanting individual seedlings raised in a nursery (Van der valk and Pederson, 1989).

According to McDonald *et al.* (1996), the maintenance of plant community diversity, and the restoration of native vegetation can be achieved by the presence of well-composed seed banks. Soil seed banks also play major ecological role in fire-prone ecosystems. Seeds buried in the soil are well protected from the direct effect of fire as the soil provides insulation from high surface temperatures during the course of fire (Keeley, 1992). In addition to regeneration seed banks are also known for maintaining a gene pool, which ensures continual occupation of a site after disturbance that in turn is a complementary mechanism of regeneration involved in the maintenance of floristic diversity.

Natural regeneration involves recruitment, survivorship, and growth of a very large number of species that may differ in their modes of life and the roles they play in regeneration. Changes in spatial and temporal patterns of vegetation in a given location will be influenced by the interactions of resource levels, colonization patterns, and each species ecological properties

(Bazazes, 1991). The natural regeneration of forest in forest ecosystems is fundamental for evolution (Ackezell, 1994).

Therefore, assessment of natural regeneration and soil seed bank study are very crucial to rehabilitate the degraded natural forest. The Dodola natural forest where this study was conducted is one of the natural forest priority areas in the country, but it's highly degraded and encroached by human (Tewdros Tsegaye, 2004). Scattered individual household, settlements, Small patches of farmland and open pasture fields are its features. Overgrazing and continuous human interference may lead to an irreversible change in the function of forests (Trainer, 1996).

The dominant species of the site were *Juniperus procera* L. and *Podocarpus falcatus* (Thunb.) Mirb. (Kitessa Hundera, 2003). Most of the dry afromontane forest types are mainly dominated by these two coniferous species *Juniperus procera* and *podocarpus falcatus* (Tamrat Bekele, 1994). The productivity of the Dodola forest is low due to the past mismanagement practices and overexploitation by government and local communities. Moreover, the increasing population in the area with 7.5-persons/ family's has an implication of an increasing demand of more land, which threatens the remnant natural forest (Terefe Tolossa, 2001). Loggining, expansion of agricultural lands and grassland, and the growing demand for forest products, population growth and illegal cutting increased the declining rate of the Dodola forest (Tewdros Tsegaye, 2004).

To conserve the remnant natural forest different efforts have been made by IFMP (Integrated Forest Management Project) with the guiding principle of the WAJIB approach (WAJIB is coined from Afan Oromo and stands for "Walda Jiraattota Bosonaa" that means forest dwellers Association). It is granting long-term exclusive use rights to forest dwellers in the state- owned forest (IFMP, 1999). However, this approach lacks basic information about natural regeneration potential and soil seed bank of the forest, which are important for sustainable rehabilitation, and conservation of the natural forest. Therefore, this study deals with the assessment of soil seed bank potential and natural regeneration of woody plant species in the remnant Dodola Afromontane forest.

2. Objectives of the study

2.1 General objective:

The main objective of this study is to conduct ecological studies with particular reference to soil seed bank status and natural regeneration of woody species in Dodola Dry Afromontane forest.

2.2 Specific objectives:

a) to study the soil seed bank (composition, vertical distribution and density) within the Dry Afromontane forest of Dodola.

b) to assess the composition, density, height class distribution of naturally regenerating woody species populations in Dodola forest

c) to compare similarity between above ground and soil seed bank flora.

d) to see the effects of different habitat types on soil seed bank and naturally regenerating woody species.

e) to provide a baseline information on management options for the conservation of the remnants dry Afromontane natural forest of Dodola.

3. Literature Review

This section meant to discuss some issues related to soil seed bank and natural regeneration of woody vegetation. The parts included are: Meaning of soil seed bank, dispersal and distribution of seeds in the soil, Seed longevity in the soil, Ecological significance of soil seed banks, natural regeneration of woody species, Methods used for soil seed bank and natural regeneration of woody species assessment and review of Soil seed bank and natural regeneration studies conducted in Ethiopia.

3.1 What is soil seed bank?

Seeds, which are defined as ripened ovules, are suited for essential roles in plant's life as a means of multiplication, dispersal and stress avoidance (Fenner, 1985). Sexually reproducing plants produce seeds, which disperse from the mother plant by different dispersal mechanisms and be incorporated into the soil.

Various investigators who performed their best investigations on seeds found in the natural environment defined soil seed banks based on their different investigations. Harper defined the soil seed bank as the store of seeds buried in the soil (Harper, 1977). All viable seeds present under and on the surface of the soil or associated with the soil litter constitute the soil seed bank and form part of the species composition of the standing vegetation (Lack et al., 1989). According to Roberts (1980) the viable seeds that occur on the surface and under soil associated with the soil litter are known as seed bank.

The term seed bank was also used to describe the seed population in the soil by the work of Hyatt (1999) as a buildup of viable but seeds, which are not germinated in or on the soil. 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.

3.1.1 Dispersal and Distribution of seed in soil seed bank

Sexually reproducing plants produce seeds, which disperse from the mother plant by different mechanisms, and be incorporated into the soil and become part of a store or bank of seeds (Silvertown, 1982).

The dispersal mechanisms of seeds vary in different plants though the purpose is the same i.e. incorporating to the soil providing the means by which a species colonize sites suitable for its growth. The dispersal of seeds is commonly influenced by abiotic and biotic factor. The abiotic factors include dispersals due to gravity, wind, water, as well as structure and characteristics of soil; where as the biotic factors include dispersal by means of different animals including human beings (Carey and Watkins, 1993). The effectiveness of seed dispersal agents depends mainly on the number and quality of seeds dispersed (Barnes, 2001).

When seeds fall to the ground, they can enter the soil in a number of ways including falling into cracks and being buried by insects and mammals. As long as the seeds, dispersed by different dispersal mechanisms, remain buried in the soil they maintain their dormant state. If the buried seeds face certain factors, which bring them to the surface, they will normally germinate; giving rise to plants whose parents may have existed many generations before (Fenner, 1985).

Once seeds incorporate into seed banks they face different environmental conditions, which entirely determine their fates. The fates of a seed population in the soil depend upon the flux of seeds into an area by dispersal and the loss of seeds through the activity of predators and pathogens, senescence, and germination (Fenner, 1985; Carey and Watkinson, 1993).The ways by which the buried seed population acquires its depth distribution are rather obscure. Some seeds, particularly small size ones; undoubtedly move down in the soil profile of lose-textured soils with percolating rainwater (Harper, 1977).

Seeds in seed banks are found distributed at different depths starting from the upper soil surface. Seeds on the soil surface have a reduced number in different seed banks since they might suffer from high mortality due to high temperature and predation. The number of seeds recorded from varying profiles shows a variation in density of seeds in seed banks, which reflects their distribution. The investigations on soil seed banks in dry Afromontane forests of Ethiopia depicts that in the analysis of the vertical distribution of seeds the higher densities are found recorded in the upper 3 cms of soil and gradually a decrease in densities with increasing depth is also recorded (Demel Tekety & Grenstorm, 1995). For tropical rain forests, it is reported that there is a decline in the seed bank density and species with increasing soil depth (Dalling *et al*, 1997).

3.1.2 Seed longevity in the soil

For an ecologist the longevity of seeds in the soil is very important. The persistence of seed banks in the soil is a major component of the phenomenon of plant succession and plays an important role in the evolution of plant communities (Hendry *et al.*, 1995). The capacity of seeds to remain capable of germination is termed as seed viability. When an embryo in a mature seed remains alive, the seed is said to be viable (Pandey and Sinha, 1972).

Depend on internal and external environmental factors as well as species to species the period of seed viability in the soil varies. The longevity of seeds in soil commonly depends on the conditions through which they pass; for example, some seeds can stay long in the soil if kept in dry atmosphere. Viability is also affected by ageing; with increase in age viability of seeds decreases till stops completely. The common reasons for loss of viability are denaturation and inactivation of proteins and enzymes, over drying and exhaustion of reserve foods of dormant seeds due to respiration (Rajan, 2000).

The longevity of seeds in the soil seed bank associated with the principle of dormancy caused by either seed coat, condition of embryo, light sensitivity, or chemical inhibitors. The dormancy generally helps the embryo to pass adverse environmental conditions (Rajan, 2000). Evidences of longevity in seeds come from archeological sites, dated herbarium sheets, or experiments on shelf-stored seeds or seeds buried in the field. However, only viability tests of seeds, which have been subjected to the moisture, temperature, and gaseous compositions of soil under field condition provide results of ecological importance (Demel Teketay, 1996).

3.1.3 Significance of soil seed banks

The seed banks found in different environments represent a record of past as well as present vegetation growing on the area and nearby. If an existing vegetation stand is destroyed by various causes, the seed bank will immediately serve as a source from which new vegetation arises (Harper, 1977). In addition their significance in regeneration of lost vegetation, seed banks are also essential in rehabilitation of a degraded land.

An investigation of the seed composition of seed banks is ecologically important in predicting the initial composition of the pioneer vegetation in an area, particularly on exposed or cleared sites. The information on the relative abundance of recently recruited species and the potential distribution of each species can also be obtained from careful investigation of the composition of seed banks (Van der Valk and Pederson, 1989). Different researchers reported the significance of seed banks in agriculture, forestry and conservation practices. Knowledge of species composition of a seed bank helps in agricultural practices to use selective chemicals as herbicides to control weeds. In forest management natural seed banks as seed sources is valuable in tropical forestry (Fenner, 1985). Some of the ecological significance of soil seed bank is explained briefly below.

3.1. 4 Importance of SSB for regeneration of plant community

Soil seed banks serve as a source of regeneration of plant communities. Seed banks have been exploited to manage the composition and structure of existing vegetation and to restore or establish native vegetation (Van der valk and Pederson, 1989).

Knowledge about the dynamics of soil seed banks and seedling populations provides clues about the potential of a plant community to regenerate after disturbance (Demel Teketay, 1996). The seed banks hence reflect the history of the vegetation and have the potential to contribute to its future through regeneration. For a good understanding of a natural vegetation in any plant community gathering information on the quality and quantity of seed rain, germination requirement of seeds, longevity of seeds in the soil, losses of seeds to predation and deterioration, presence and absence of persistent soil seed banks or seedling banks, and sources of regrowth after disturbances, etc (Demel Teketay, 1996). One of the most common methods of reproduction in most plant communities is therefore, regeneration from seeds of the soil seed bank (Fenner, 1985).

In areas where there is frequent disturbance the soil seed banks is the main establishing factor that serves to ensure species survival and success. The regeneration of plant communities from seed banks depends on the viability of the seed and on the frequency of ‘safe sites’, not only on the viability of seeds (Harper, 1977). A ‘Safe site’ is considered as that zone in which a seed may find it self and which provides the resources which are consumed in the course of germination, the conditions required for proceeding germination process and the stimuli required for breaking of seed dormancy. Furthermore, a safe site is one from which specific hazards are absent such as predators, competitors, toxic soil constituents and pathogens.

Generally the regeneration of plant communities depends on conditions, which are localized to the environment of that seed bank (Harper, 1977). For ecologists and applied biologists the aspect of greatest significance is the role of the seed bank in determining the future vegetation through the principle of regeneration, especially after natural or deliberate perturbation (Fenner, 1985).

3.1.5 Importance of SSB in fire prone areas

Even if seeds naturally serve as storage of the plant life cycle protected from Environmental hazards including fire, many plants in fire prone ecosystems survive fire by storing their seeds in the canopy for more than a year to escape fire. Soil seed banks, which are the homes of viable seeds, have considerable significance in Fire-prone ecosystems. To tolerate fire seeds must be protected from direct heat either being enclosed with in fruits in the plants canopy or more preferably buried in soil seed bank (Keeley, 1992).

Soil seed banks hence are considered as ecologically significant since they play major role on the survival strategies of plants, which reduce mortality of seeds, by fire. The intensity of fire in an area and the depth of seed burial in seed banks are the common factors, which determine mortality of seeds by fire (Keeley, 1992).

There are different gaps formed in vegetation ecosystem. The gaps formed by slashing of vegetation or burning in an ecosystem may quickly be colonized by plants recruited from the soil seed bank, from seed rain originating from the surrounding vegetation as well as from pre existing seedlings and sprouting shoots which may have escaped from disturbance (Demel Teketay, 1997b).

If vegetation is burned the regeneration process possibly proceeds as long as there are soil seed banks but when the clearing of forests is followed by permanent cultivation, almost all of the woody and part of the herbaceous components of forest soil seed banks diminish through time and become mostly dominated or replaced by herbaceous species (Demel Teketay, 1996).

Soil seed bank contribution to the restoration of cleared or burned areas and its composition basically depends on two important reproductive traits of the plant. These are the capacity for seed dormancy, i.e., whether the species has persistent or short-lived seed in the soil and the potential for wide spread seed dispersal (Dalling et al., 1997).

The significance of soil seed banks in forest restoration particularly for regeneration after disturbance by different factors including fire is important. Seed banks play a great role for the restoration of natural forest vegetation even after severe disturbances (Demel Teketay, 1996).

According to Minassie gashaw (2000), fire has impact on the type of vegetation and species compositions of fire prone area.

Generally seed banks have got a crucial role in fire-prone areas in regeneration of vegetation hence knowledge about dynamics of soil seed banks of fire prone ecosystems provides clues about the potential of a plant community to regenerate after disturbance.

3.1.6 Soil Seed bank sampling Methods

Ecology, like other branches of science relies upon sampling as a convenient method of studying floristic composition of seeds buried in the soil as well as to those in the vegetation survey. Because of such a reason, some knowledge of the theory of sampling is fundamental.

The soil samples collected to asses seeds in soil seed bank consider horizontally and vertically in order to examine the variation in the depth and horizontal distribution of seeds in the soil.

Usually soil blocks are sampled of a size, for instance of 15 cm x 15 cm (Tefera Mengistu, 2001; Mulugeta Lemenih, 2004; Alemayhu Wasse and Demel Teketay, 2006). To analyze vertical variation of seeds in the soil seed banks the soil block is then divided into several layers, for example: (1) 0-3 cm (0: soil surface or litter layer), (2) 3-6 cm (3) 6-9 cm (4) 9-12 cm; (1) and (2) are sometimes difficult to classify. In most literatures the soil block is divided into three or four layers with 3cm thick particularly on studies made in Ethiopia (Demel Teketay *et al.,* 1995; Tefera Mengistu, 2001; Feyera Senbeta *et al.,* 2002).

3.1.7 Methods to determine soil seed bank status

There are various methods involved in determining soil seed bank. The techniques that have been adopted by many authors are seedling emergency method, the sieving and floating methods. In Ethiopia usually seedling emergency and sieving methods were used for identification and isolation respectively (Demel Teketay and Granstrom, 1995; Demel Teketay, 1996; Mekuria Argaw *et al*., 1999; Feyera Senbeta and Demel Teketay, 2001).

To identify the seeds separated from the soil first the seeds are kept in paper bags, while seeds of constituent species of a plant community under which the soil layers were sampled are kept in other bags. The former seeds are identified using the latter and other stored seed specimens.

The seeds recovered by sieving were collected into paper bags and identified using local reference material (Feyera Senbeta & Demel Teketay, 2001).

After isolation of seeds from the soil viability of the seeds are very important. Since only living seeds are normally considered to contribute to the seed bank, their viability has to be tested. Seeds showing external evidence of damage or disease can be recognized its viability without further test. To determine viability of seeds in the soil researchers use dissecting/ cutting seeds. Seeds with firm and white contents are considered as viable (Demel Teketay, 1996).

In Seedling emergence method the samples are spread in trays and kept under conditions known to promote the germination of as many species and individuals as possible. The samples are usually spread on top of sterile nutrients necessary for the emerged seedlings to grow, although this is not necessary if seedlings are removed soon after germination. Sometimes the plants have to reach maturity or flower before they can be identified (Mc Donald *et al.,* 1996; Demel Teketay, 1996; and Mekuria Argaw *et al.,* 1999).

Unidentified seedlings are removed from the experimental trays, planted into separate pots and grown to flowering so that they can be identified. Plants are counted, identified and removed as soon as possible to prevent competition for light with new seedlings (Thompson and Grime, 1979).

3.2 Natural Regeneration of Woody Vegetation

Regeneration of the forests involves recruitment, survivorship, and growth of a very large number of species that may differ in their modes of life and the roles they play in regeneration. The natural regeneration of forest ecosystems is fundamental for evolution (Ackzell, 1994).

Regeneration assessment is an important part of forest survey which serves in evaluating stocking, competition problems and the composition of the forest to make a decision weather the area is well established with the desired species and less competition.

For restoration or rehabilitation of forest knowledge about the factors, which prevent or promote seedling establishment of woody species are very crucial. Different characteristics of the parent plants can increase the chances of seedling survival, although seedlings depend on their own morphological and physiological characteristics to cope with the various factors threatening their survival (Fenner, 1987). In most of the woody plants in dry Afromontane forests the lack of persistent soil seed banks affect the formation of populations of seedlings on the forest floor (Demel and Granstrom, 1995).

3.3 Soil Seed Bank and Natural Regeneration studies in Ethiopia

Natural forests particularly dry Afromontane forests in Ethiopia have been and continue to be subjected to natural and human-induced disturbances, which resulted in their degradation or complete destruction. The loss of forest results to soil erosion, land degradation, loss of biodiversity and impoverishment of ecosystems. So, alleviating the problem of deforestation is a necessity and not an option in Ethiopia, especially if most of the livelihood and economic development are to continue to emerge from the agricultural economy.

Therefore, knowledge about the dynamics of soil seed banks and seedling populations provides various clues for restoration and conservation of the natural forest. Seed bank can play an important role in the rehabilitation of degraded land and help to prevent soil erosion by enabling a protective covering of vegetation to develop quickly (Van der Valk & Pederson, 1989).By understanding the significant role of soil seed bank and naturally regenerating woody species for conservation and restoration of the forest recently few studies were conducted on soil seed banks and natural regeneration of woody species in Ethiopia. The investigations in different ecosystems focused on species composition, density, spatial and temporal heterogeneity and longevity of seeds in the soil as well as their potential in the regeneration of natural forests (Demel Teketay & Granstrom 1995; Demel Teketay, 1996), effect of clearing and conversion of dry Afromontane forests into arable lands (Demel Teketay, 1997a).

Soil seed banks have also been investigated in an Acacia woodland in the rift valley (Mekuria *et al*., 1999), highly degraded sites (Kebrom Tekle & Tesfaye Bekele, 1999) and in plantation stands and the adjacent natural forests of Menagesha-Suba forest sites (Feyera Senbeta and Demel Teketay, 2001). The role and status of soil seed banks had been investigated in enclosures of degraded dry land hillsides in central and northern parts of Ethiopia (Tefera Mengistu, 2001).

Seedling populations and regeneration of woody species in natural forests (Demel Teketay, 1997b; Berhanu Mengesha, 1997), and natural regeneration of some selected tree species in Harena forest, Southeastern Ethiopia (Getachew Tesfaye *et al*., 2002).

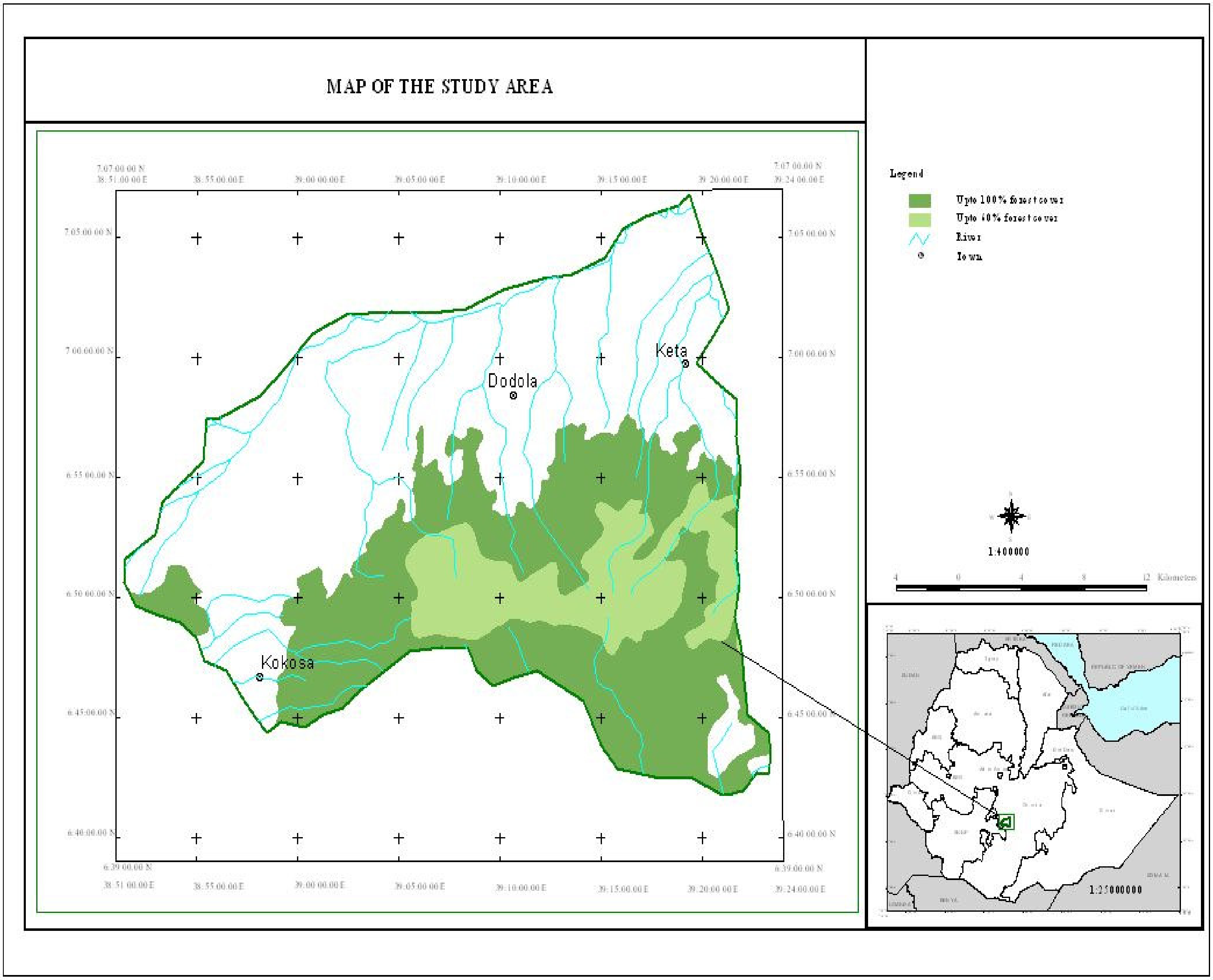
According to Demel Teketay (1997b) the formation of seedling banks under the forest canopy is the major regeneration route of most woody plants, especially climax species, in dry Afromontane forests of Ethiopia. Although natural disturbances and human exploitation, such as careful selective cutting, may promote regeneration of the forest from seedlings, excessive exploitation of species or clearing and conversion of the forest areas into permanent cultivation, which is a common practice in Ethiopia, will prevent regeneration (Demel Teketay, 1997b).

4. Materials and Methods

4.1 The study area

4.1.1 Location

The Dodola forest is found at the northern part of the Bale Mountains, which itself belongs to the Arsi Bale massif. This forest is situated 320 km southeast of Addis Ababa. Geographical location of the study area is between latitudes 6^0 50’ and 7^0 01' N and longitudes 39^0 06' and 39^0 11' E, within altitudes of 2,400 m above sea level at the foot hills of a mountain range with peaks reading over 3,550 m (Fig. 1). Administration wise, the study area is found in Oromia regional state, Bale Zone, Dodola Woreda.


MAP OF THE STUDY AREA
Legend
Upto 100% forest cover
River
Town
Dodola
Keta
Kokosa
1:400000
Kilometers
1:25000000

3.1.2 Topography

The Dodola forest has three topographic landscapes. The first type includes the plain lands of pastures and agricultural fields, which are found on the boarder valleys, following the lower sides of streams. The agricultural fields are also found on the foothills along pasture fields, which are mainly found in the lower altitudes and gentle slopes following rivers or streams. The mountain bases, narrow valleys and shoulders are the second feature; it ranges from gentle to steep slope. The third and the last physiographic feature are the ridges and the plateaus found at the top of the mountains and at higher altitude with maximum elevation of ca.3550 m a.s.l.

4.1.3 Geology and Soil

The Bale Mountains similar to other highland regions in the country derived from volcanic activities during the Cenozoic era, characterized by the eruption of flood basaltic lava (Mohr, 1971). The volcanic succession in Bale has been sub-divided into four major groups and the Dodola area belongs to the Dodola ignimbrites and Aroresa trachytes. This group of rock consists of rhyolitic ignimbrites, trachytes and ash flow tuffs, with fluvio-lacustrine intercalations within the ignimbrites (Asfawossen Asrat *et al.*, 1997).

The soil of Dodola area is of volcanic origin. Soils are well-structured, chiefly composed of loam or clay, extending to more than one meter depth on gentle slopes, valleys and depressions but being shallow on steep slopes and top ridges where rock-out crops are observed (Asfawossen Asrat *et al.*,1997).

3.1.4 Climate

According to Uhlig (1992), the temperature of the Dodola area shows a wide daily variation with low seasonal fluctuation, which is characteristic for mountainous regions in the tropics. There is no metrological station in the area covered by the Dodola forest but the climatic data for the Dodola town recorded by the Adaba-Dodola Integrated Forest Management Project (IFMP) from 1997 to 2005 shows that the area has a mean annual rainfall of 782.8 mm, and mean annual temperature of 19.1^{0}c (Fig.2). The rainfall distribution is bimodal.

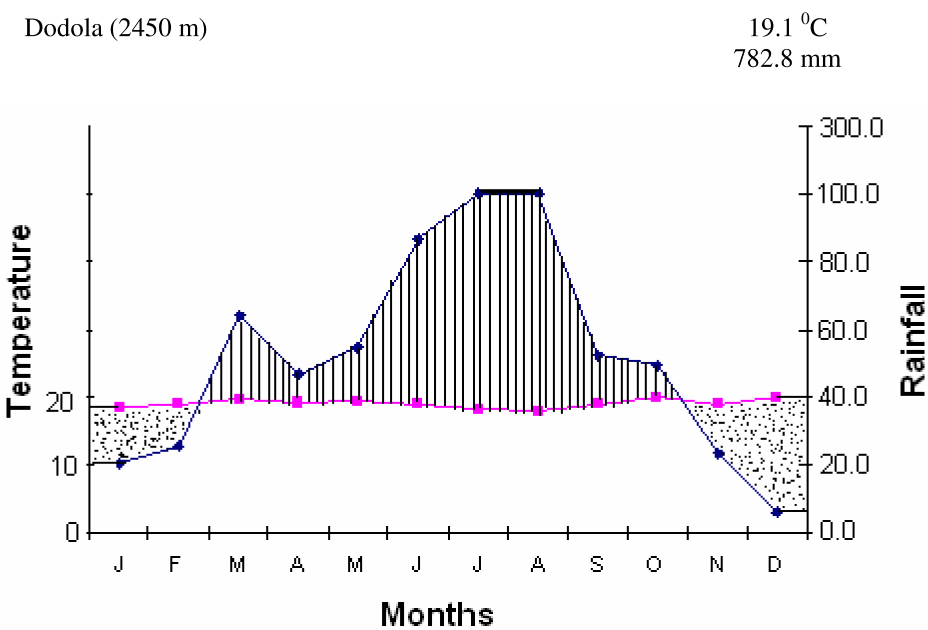


Figure 2: The Climatic Diagram of Dodola 2450 m a.s.l (after Walter, 1985)

4.1.5 Vegetation

The forest represents one of the rare surviving examples of the Afromontane forests. According to Friis (1992) the forest is classified into the dry evergreen Montana forest, and grassland mosaic of the highland plateau.

Plain and foothills of the Mountain that are accessible, productive and suited for agriculture are under cultivation. When the altitudinal gradient increases the farming activity decreases, the forest cover of the mountain slopes becomes thicker and gradually transpires to dense Afromontane forest.

Upto an elevation of 3000 m the forest is dominated by *Podocarpus falcatus* and *Juniperus procera* (Fichtmuller, 1997). Tree species such as *Maytenus addat*, *Galiniera saxifraga* and *Myrsine melanophleos* may also be as dominant as *Juniperus procera* in some parts of the forest (Sebsebe Demissew and Ensermu Kelbessa, 1995). The sub-Afroalpine vegetation is dominated by *Erica arborea* shrub land (Fig.3).

Figure 3: partial view of Dodola *Erica arborea* shrubland

4.1.6 Population

The majority of the population belongs to the Oromo Nation and predominantly follows the Islam religion. In the Agricultural plain much of the population depends on subsistence mixed farming of both livestock and agricultural crop production there are also many households engaged in collecting and selling forest products from this forest (Fig.4).

Figure 4: Views to show people using the forest for grazing and fuel wood

4.2 Methods of Data Collection

4.2.1 Sampling design

A reconnaissance survey and data collection was made between November 2004 and January 2005.The reconnaissance survey was made to obtain an impression about the internal variation of the study area. The survey indicated that the Dodola forest comprised a mosaic of four land-use types; the natural forest, farmland, grassland, and plantation. For the present study, based on the information obtained from the reconnaissance survey and floristic composition study of the Dodola forest (Kitessa Hundera, 2003) the study site was classified into ten habitat types. These habitat types were found at different altitudes, have different types and levels of disturbances and the land use system for some of the habitat types vary from each other. Therefore, the selected habitat types will give a chance to investigate soil seed bank and natural regeneration potential of the Dodola forest as well as to study the effects of the habitat types on soil seed bank and natural regeneration.

The selected habitat types were characterized and defined in the following way:

(a) **Erica- Hypericum (EHY):** is characterized by evergreen shrubs dominated by *Erica arborea* and *Hypericum revolutum*. The habitat type is found at altitudes above 3250 m.

(b) **Hagenia-Juniperus (HJ)**: The habitat type lies in altitudes between 2850 to 3100 m and characterized by *Hagenia abyssinica* and *Juniperus procera*.

(c) **Juniperus- Podocarpus (JP)**: This habitat type occurs at altitudinal ranges between 2650 and 2750 m and the upper canopy is dominated by *Juniperus procera* and *Podocarpus falcatus*.

(d) **Riverine (RV)**: The habitat type found along the riverside.

(e) **Forest edge (FE):** within 100 m of closed canopy forest (transition from the forest to other land use type).

(f) **Farmland (FL):** Formerly cultivated and abandoned for at least more than one year.

(g) Grassland (GL): Land covered by grass species accounting more percentage of the land; occasional herb species over 10 cm occurring with increasing frequency towards forest edge; grazed intensively by cattle and occasionally by horses.

(h) Natural gap (NG): An Opening within the dense forest caused by natural condition of the site, and branch or tree fall due to various reasons except by farming activities and fire.

(i) Fire gap (FG): This habitat type is an opening, which is caused by fire.

(j) Plantation (PL) : *Eucalyptus globulus* and *Cupressus lustanica* plantation which is previously covered by natural forest.

4.2.2 Vegetation data collection and plant identification

Above ground vegetation data was collected to examine similarity between above ground and soil seed bank floras. A total of 100 quadrats, ten in each habitat types were randomly laid down. The quadrat size for trees and shrubs was 20 m x 20 m. For the herbaceous layer a 2 m X 2 m sub-quadrat was established within the main quadrat.

In each quadrat all trees and shrubs with height > 4 m were identified, counted and height was measured using Sylva Hypsometer. For the herbaceous layer species were recorded with in 2 m x 2 m sub-quadrat. The altitude of each quadrat was recorded by using global Positioning System (GPS Garmen 12). Voucher specimens of each species in the quadrat and sub-quadrat were collected, numbered, pressed and taken to the National Herbarium (ETH), Addis Ababa University, for drying, identification and storage.

Identification of plant specimens was conducted in the National Herbarium (ETH), Addis Ababa University, by comparing with identified plant specimens. Keys and description of taxa in the flora of Ethiopia and that of East Africa were used to verify the identification that has been made by comparison with authenticated specimens housed at ETH. Nomenclature follows that of the published volumes of the flora of Ethiopia and Eritrea: Volume 3 (Hedberg and Edwards, 1989), flora of Ethiopia and Eritrea: Volume 2, part 2 (Edwards *etal.,* 1995), and flora of Ethiopia and Eritrea: volume 2, part1 (Edwards, *et al*. 2000).

4.2.3 Soil sampling

In order to investigate composition, density, and vertical distribution of viable soil seed bank, 300 soil samples (3 successive layers x 100 points) were taken from three soil layers (0-3 cm, 3-6 cm, and 6-9 cm). These samples were taken from five points measuring 15 cm X15 cm (one at the center and the other four at the corners) of each sample quadrats. Similar layers from these five points within a quadrat were mixed to form a soil composite in order to reduce variability within the quadrats. The composite sample for each soil layer was again divided into five equal parts among which one was randomly selected for further study. The soil samples were transferred to cotton bags and transported to the green house of Department of Biology, Addis Ababa University.

Soil samples were sieved with a mesh size of 0.5 mm and recovered seeds were identified at the Forest Research Center seed laboratory following the method used by Feyera Senbeta and Demel Teketay (2001). Viability of seeds recovered by sieving was determined by cutting tests following Demel Teketay and Granstrom (1995). Those seeds that have remained unidentified were germinated at the Forest Research Center seed laboratory. In the glasshouse, each soil layer was spread in a circular plastic tray and watered daily to stimulate germination of seeds that were not recovered by sieving. To facilitate proper drainage of water, the pots were perforated at the bottom. The minimum and maximum daily temperature in the glasshouse ranged between 17 and 39^0c respectively. To control and detect contamination of external seed rain, thin transparent plastic was stretched over the sample trays and a control tray was placed in the green house.

The emerging seedlings were identified, counted, recorded and discarded. Some seedlings were left to grow to a certain size for ease of identification. Soil samples were disturbed every seven weeks to expose covered seeds to light. Digital information (Photos) of the seedlings was taken to be included as a pictorial representation. Plant recruitment was monitored for six months (January to July, 2005).

4.2.4 Sampling for Natural Regeneration of woody species

To examine the natural regeneration status of woody species, individuals were categorized into four size groups following Mekuria Argaw *et al*., (1999). Individuals with a height grater than 4m were considered as trees/shrubs, individuals between 1.5 m and 4 m were considered as saplings, individuals with a height between 0.1 and 1.5 m were considered as seedlings, and individuals below a height of 0.1 m were considered as germinants.

Heights of all saplings (5 m x 5 m), seedlings (2 m x 2 m), and germinants (1 m x 1 m) were recorded using graduated stick meter and they were also counted.

Collection and identification of specimens were used following the same procedures mentioned above.

4.3 Data analysis

To investigate the effect of habitat types and the potential of soil seed bank and naturally regenerating woody species, in terms of species composition and density of naturally regenerating plants and soil seed bank flora, the data were analyzed in the following ways.

The composition and density of seeds in the soil was determined by combining the data obtained from sieving and germination. The density of seeds/m^2 was derived from the total number of seeds recovered from the soil samples. On the other hand, to analyze the depth distribution of seeds in each habitat type, the number of seeds recovered in similar layers were combined and converted to provide the density of seeds/m^2 at that particular soil depth.

One-way analysis of variance (ANOVA) through the use of SPSS/pc version 10 LSD tests were used to assess the differences in density of soil seed bank between habitat types.

To measure the similarities in species composition of the soil seed bank among the habitat types and also with the above ground vegetation of the habitat types; Jaccard's Similarity Coefficient (*Sj*) (Krebs, 1989) was calculated. Total naturally regenerating individuals are expressed as density per hectare. Jaccard's Similarity Coefficient was also calculated and used to measure the similarities in species composition of naturally regenerating woody plants among habitat types. Descriptive statistics was used to evaluate population structure of naturally regenerated woody species in different habitat types of the Dodola forest.

Arc-GIS soft ware was used to prepare map of the study area as well as distribution map of the plots.

5. Results

5.1 Soil seed bank

5.1.1 Soil seed bank species composition

The total number of species recorded from the ten habitat types was 56, representing 27 plant families, of which 18 were recorded from *Erica-Hypericum*; 20 from *Hagenia –Juniperus*, 23 from *Juniperus – Podocarpus*, from *Natural Gap*26, from *Fire gap* 23, from *Riverine* 33, 26 from Forest edge, 32 from *Farmland*, 12 from *Grassland*, and 28 from *Plantation*. Six tree species four indigenous (*Podocarpus falcatus*, *Juniperus procera, Acacia abyssinica and Vernonia amygdalina*) and two exotic species (*Cuprressus lusitanica* and *Eucalyptus globulus*) were recovered from seed bank flora. Among the identified plants, 38 species were herbs, which represents 67.8% of the total seed bank flora and also the highest number of herb species was recorded in all habitat types. Tree species were also found in all habitat types except in *Farmland* and *Grassland* habitat types (Fig 5).

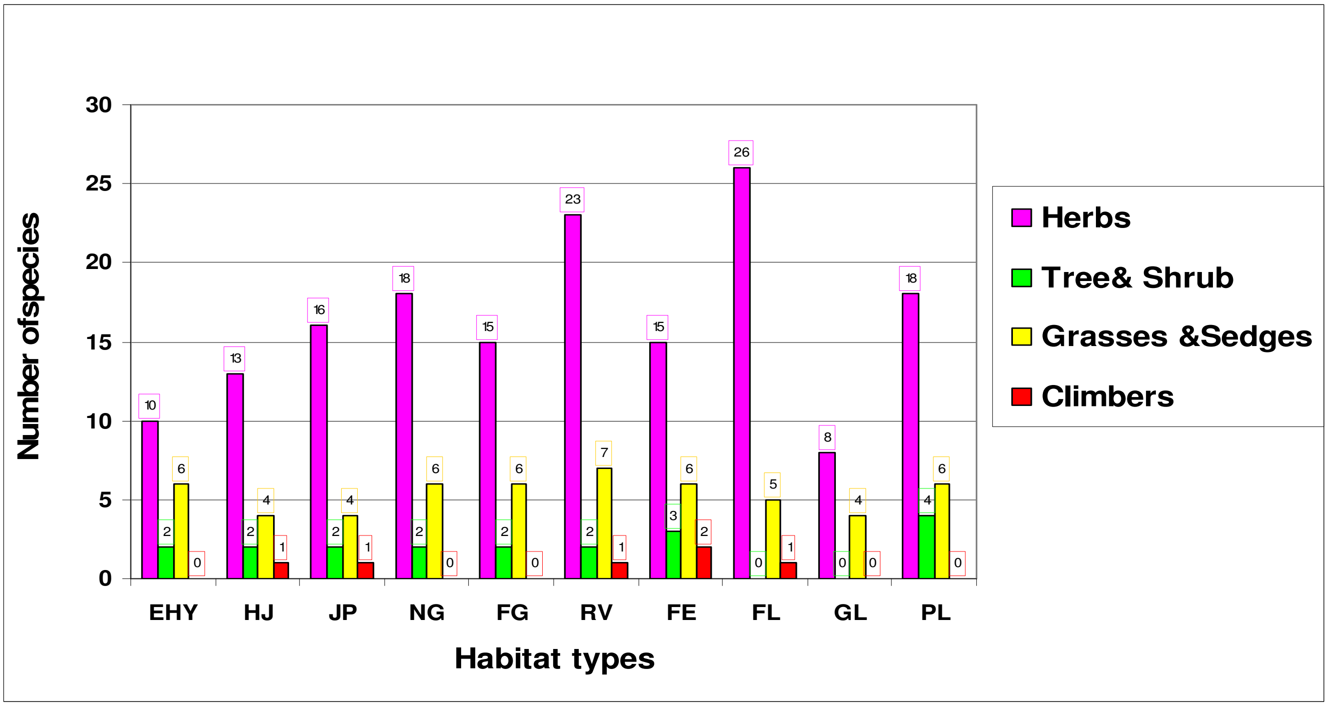


Figure 5. Number of species recorded from soil seed banks of the upper 9cm soil depth collected from ten habitat types (**KEY : EHY -** *Erica - Hypericum,* **HJ**- *Hagenia-Juniperus,* **JP**-*Juniperus-Podocarpus,* **NG** - *Natural Gap,* **FG**-*Fire Gap,* **RV**- *Riverine,* **FE** - *Forest Edge,* **FL** -*Farm Land,* **GL**- *Grass Land,* **PL** - *Plantation* **).**

5.1.2 Similarity of soil sandbank flora among ten habitat types and above ground flora

The similarity in species composition of the soil seed bank between the ten habitat types was generally low and ranged from *Sj* values of 0.27(between *Erica-Hypericum* and *Plantation* habitat types) to 0.66 (between *Natural gap* and *Fire gap* as well as *Natural gap* and *Riverine* habitat types). The second highest similarity in species composition (*Sj* = 0.63) was recorded between *Fire gap* and *Riverine* (Table1).

Table 1. Jaccard's coefficient of Similarities in species composition of soil seed banks between the habitat types

	EHY	HJ	JP	NG	FG	RV	FE	FL	GL	PL
EHY	-	0.46	0.54	0.39	0.45	0.42	0.46	0.37	0.38	0.27
HJ		-	0.50	0.44	0.52	0.51	0.48	0.46	0.33	0.38
JP			-	0.59	0.60	0.61	0.46	0.49	0.43	0.44
NG				-	0.66	0.66	0.50	0.40	0.48	0.38
FG					-	0.63	0.58	0.39	0.46	0.44
RV						-	0.48	0.61	0.38	0.51
FE							-	0.50	0.29	0.39
FL								-	0.32	0.51
GL									-	0.51
PL	-	-	-	-	-	-	-	-	-	-

KEY : EHY - *Erica - Hypericum*, **HJ-** *Hagenia-Juniperus*, **JP-***Juniperus-Podocarpus*, **NG -** *Natural Gap*, **FG-** *Fire Gap*, **RV-** *Riverine*, **FE -** *Forest Edge*, **FL -***Farmland*, **GL-** ***Grassland***, **PL -** *Plantation*

The similarity between the soil seed bank and above ground flora was very low (ranging from Sj values of 0.133 for *Juniperus - Hagenia* to 0.481for *Grassland*) (Table.2). Six tree species (*Acacia abyssinica, Cupuressus lusitanica, Juniperus procera, Podocarpus falcatus, Eucalyptus globulus and Vernonia amygdalina)* were represented both in the above ground vegetation and soil seed banks. *Podocarpus falcatus* and *Juniperus procera* were found in all habitat types except in *Grassland*, *Farmland*, and *Plantation* habitat types. On the other hand, *Acacia abyssinica, Cupuressus lusitanica, and Eucalyptus globulus* were found only in *Plantation* habitat type. Woody species that are commonly found in the above ground flora were not represented in the seed bank. For example, *Myrsine africana, Hagenia abyssinica,* *Hypericum revolutum, Erica arbora* are abundant species in the above ground flora but absent from seed bank.

Table 2. Jaccard's coefficient of Similarity between soil seed bank and aboveground flora

Habitat types	Common Species	Species exclusively to above ground flora	Species exclusively to soil seed bank	Jaccard similarity values
EHY	10	50	8	0.147
HJ	10	55	10	0.133
JP	14	53	9	0.224
FG	12	48	7	0.283
NG	17	41	12	0.246
RV	22	23	11	0.333
FE	13	52	14	0.164
FL	16	17	14	0.34
GL	13	8	6	0.481
PL	17	16	15	0.354

KEY: EHY - *Erica - Hypericum*, **HJ-** *Hagenia-Juniperus*, **JP-***Juniperus-Podocarpus*, **NG -** *Natural Gap*, **FG-** *Fire Gap*, **RV-** *Riverine*, **FE -** *Forest Edge*, **FL -***Farmland*, **GL-** ***Grassland***, **PL -** *Plantation*

5.1.3 Densities of seeds in the soil

The number of viable seeds in the soil samples (from both germination trial and sieving) corresponds to a seed bank density down to 9cm of 2881seeds/m^2 at *Erica - Hypericum*, 2120seeds/m^2 at *Hagenia-Juniperus*, 2285 seeds/m^2 at *Juniperus-Podocarpus*, 2595 seeds/m^2 at *Natural Gap*, 3017 seeds/m^2 at *Fire Gap*, 2497 at seeds at *Riverine*, 2325 seeds/m^2 at *Forest Edge*, 4733 seeds at *Farmland*, 4738seeds/m^2 at *Grassland*, and 3076 seeds/m^2 at *Plantation*. The highest total densities of viable seeds among habitat types were recorded in *Grassland* habitat type (i.e.4738 seeds\m2) where as *Hagenia-Juniperus* habitat type (i.e.2120 seeds\m2) had lower density of viable seeds. In *Hagenia-Juniperus*, *Juniperus-Podocarpus, Forest Edge*, and *Farmland* habitat types herbaceous species were dominant while in *Erica - Hypericum*, *Natural Gap*, *Fire Gap*, *Riverine*, *Grassland*, and *Plantation* habitat types grass and sedge specie were dominant (Table, 3).

Table 3. Density of viable seeds\m^2 in ten habitat types

No	**Life form**	**Habitat types**										
		EHY	**HJ**	**JP**	**NG**	**FG**	**RV**	**FE**	**FL**	**GL**	**PL**	**Total**
1	Trees	67	62	196	31	13	120	76	-	-	258	823
2	Herbs	378	1058	1369	1004	724	1124	1338	3160	1347	1276	12,778
3	Shrubs	-	-	-	-	-	-	9	18	-	18	45
4	Grass & sedges	2436	778	716	1560	2280	1249	889	1547	3391	1524	16,370
5	Climbers	-	222	4	-	-	4	13	8	-	-	251
	Total	2881	**2120**	2285	2595	3017	2497	2325	4733	**4738**	3076	**30,267**

KEY : EHY - *Erica - Hypericum*, **HJ-** *Hagenia-Juniperus*, **JP-***Juniperus-Podocarpus*, **NG -** *Natural Gap*, **FG-** *Fire Gap*, **RV-** *Riverine*, **FE -** *Forest Edge*, **FL -***Farmland*, **GL-** ***Grassland***, **PL -** *Plantation*

Densities of seeds in the soil collected from the ten habitat types of Dodola forest showed significant differences [One-way ANOVA: F (9, 90) = 2.269, P<0.024].

The five species with the highest soil seed density contributed 69% of the total estimated seed banks of *Erica - Hypericum* habitat type, 65% of *Hagenia-Juniperus*, 49.5% of *Juniperus-Podocarpus*, 55.5% of *Natural Gap*, 69% of *Fire Gap*, 60% of *Riverine*, 50% of *Forest Edge*, 69% of *Grassland*, 70% of *Farmland,* and 62% of *Plantation* (Table 4). *Juniperus procera* was the only tree species among the highest seed density of species of Dodola forest. Selected species were used to indicate their differential density and distribution pattern across the habitat types (Table 4).

Table 4. Soil seed density (seeds\m2) of species common to all the habitat types (*) and the six species with the highest soil seed density

No	Species	EHY	HJ	JP	NG	FG	RV	FE	FL	GL	PL
1	*Alchemilla abyssinica* *	18	147	173	129	116	187	116	89	22	44
2	*Cyperus nigricans**	1316	484	338	369	409	853	40	911	413	329
3	*Cyperus pauper*	164	142	116	236	53	102	-	329	-	178
4	*Eragrostis tenuifolia* *	471	49	116	431	1004	49	107	218	1542	911
5	*Trifolium rueppellianum*	-	258	196	120	142	124	-	373	569	213
6	*Stellaria media**	22	89	324	67	31	62	151	618	71	44
7	*Juniperus procera*	62	49	147	27	9	111	71	-	-	-
8	*Oxalis radicosa*	160	307	276	249	107	267	653	511	120	-
9	*Sporobulus africanus*	142	-	67	236	440	9	67	76	329	-
10	*Crassula alsinoides*	-	80	146	151	40	49	164	600	129	67
11	*Dichondra carolinensis*	-	-	13	111	9	22	98	9	342	236

KEY : EHY - *Erica - Hypericum*, **HJ-** *Hagenia-Juniperus*, **JP-***Juniperus-Podocarpus*, **NG -** *Natural Gap*, **FG-** *Fire Gap*, **RV-** *Riverine*, **FE -** *Forest Edge*, **FL -***Farmland*, **GL-** ***Grassland***, **PL -** *Plantation*

5.1.4 Depth distribution of seeds

The highest seed bank density was recorded in the first sampling layer (= 0-3cm depth) for all habitat types except Juniperus-Podocarpus & Plantation (Fig.6). Although the general anticipation is a gradual decrease in the density of seed bank along increasing depth gradient, higher number of seed bank was recorded for soil layer 6-9cm than 3-6 e.g. Riverine.

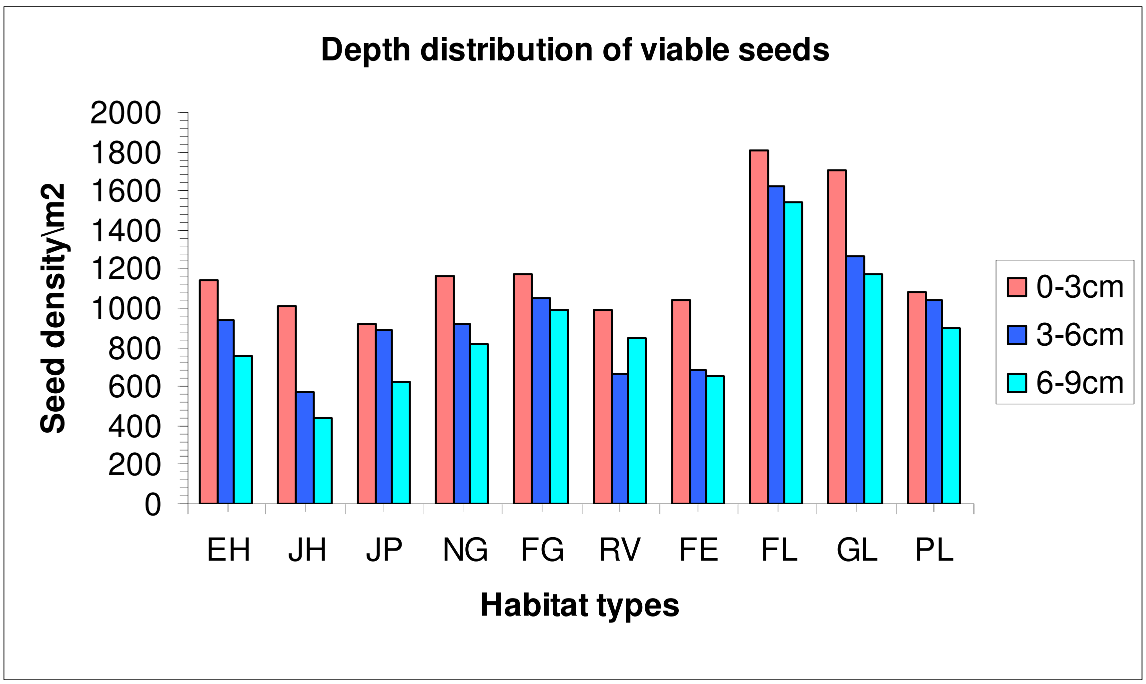


Figure 6. Depth distribution of seeds in ten habitat types (KEY: EHY - *Erica - Hypericum*, **HJ-** ***Hagenia****-Juniperus*, **JP-***Juniperus-Podocarpus*, **NG -** *Natural Gap*, **FG-** *Fire Gap*, **RV-** *Riverine*, **FE -** *Forest Edge*, **FL -***Farmland*, **GL-** ***Grassland***, **PL -** *Plantation***)**

5.1.5 Soil seed bank recovery Via Sieving

The total number of seeds recovered through sieving of soil samples from the ten habitat types was 238 seeds/m$^{2.}$ These recovered seed has been assigned to *Acacia abyssinica*, *Juniperus procera*, *Podocarpus falcatus* and *Cuperssus lusitanica*. The share of *Podocarpus falcatus,* *Cuperssus lusitanica* and *Acacia abyssinica* seeds was about 21%, 2.5% and 2% respectively, while that of *Juniperus procera* was 74.5%.

Viability test has revealed that 56.7 % (135) of the total recovered seeds are viable while 43.3% (103 seeds) are not viable. It was found that 77% of the viable seeds have belonged to *Juniperus procera* (Table 5). It is to be noted that all of the recovered seeds of *Acacia abyssinica* were found to be viable. *Acacia abyssinica* and *Cupurssaus lusitanica* seeds were recovered only from Plantation habitat type (Table 5).

Table 5: Viable and non-viable seeds recovered from the soil samples of ten habitat types (V: Viable seeds and NV: Non-Viable seeds)

Species	EHY		HJ		JP		FG		NG		RV		FE		FL		GL		PL		Total
	V	Nv	V	Nv	V	Nv	V	Nv	V	Nv	V	Nv	V	Nv	V	Nv	V	Nv	V	Nv	V
Acacia abyssinica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5
Cuperssaus lusitanica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	4
Juniperus procera	14	10	13	9	27	14	3	1	13	5	22	14	16	14	0	0	0	0	0	0	104
Podocarpus falcatus	1	4	3	5	11	14	2	2	3	2	1	1	1	2	0	0	0	0	0	0	22
Total	15	14	16	14	34	26	5	3	16	7	23	15	17	16	0	0	0	0	9	2	135

KEY: EHY - *Erica - Hypericum*, **HJ**- *Hagenia-Juniperus*, **JP-***Juniperus-Podocarpus*, **NG -** *Natural Gap*, **FG-** *Fire Gap*, **RV-** *Riverine*, **FE -** *Forest Edge*, **FL -***Farmland*, **GL-** ***Grassland***, **PL -** *Plantation*

5.2 Naturally regenerating woody species

5.2.1 Density and composition of naturally regenerating woody species

The total number of naturally regenerating species recorded was 31, representing 26 plant families, of which 52% were trees and 48% shrubs. Out of the total 31 species, 17 were recorded in *Erica-Hypericum*, 16 in *Natural Gap*, 14 in *Forest Edge*, 12 in *Hagenia-Juniperus*, 14 in *Fire Gap*, 6 in *Farmland*, and 5 in *Plantation* (Table 6).

Density of naturally regenerating individuals in Dodola forest was 41,092 per hectare (Table 6). The five species with the highest densities in Dodola forest were *Cupperssus lusitanica, Juniperus procera, Myrsine africana, Myrsine melanophleos*, and *Podocarpus falcatus* (Table 6). With the exception of *Cuperssus lusitanica*, which was recorded only in plantation habitat type, all other species (*Juniperus procera, Myrsine africana, Myrsine melanophleos*, and *Podocarpus falcatus*) were recorded in more than six habitat types, indicating that they are widely distributed in the forest.

The three species with high density in each habitat types were *Erica arbora, Juniperus procera, and Myrsine africana* in *Erica-Hypericum*; *Juniperus procera, Myrsine melanophleos, and Podocarpus falcatus* in *Hagenia - Juniperus*; *Juniperus procera, Myrsine melanophleos,* and *Podocarpus falcatus* in *Juniperus - Podocarpus*; *Myrsine africana, Osyris quadripartita,* and *Rhus glotinosa* in *Fire gap*; *Myrsine africana, Myrsine melanophleos,* and *Podocarpus falcatus* in *Natural Gap*; *Juniperus procera, Myrsine melanophleos, and Podocarpus falcatus* in *Riverine*; *Maytenus addat, Maytenus arbutifolia,*and *Myrsine melanophleos* in *Forest Edge*; *Discopdium penninervum*, *Rhus glitonisa* and *Rosa abysinica* in

Farm Land; *Cupperssus lusitanica, Dovyalis abyssinica,* and *Juniperus procera* in Plantation habitat type (Table 6).

Although the highest density of regeneration was expected for *Hypericum revolutum* species in *Erica - Hypericum* habitat type*, Juniperus procera* and *Myrsine africana* have turned out to be the most regenerating species. *Erica-Hypericum* habitat type had a higher density than all other habitat types. Species *Bersama abyssinica* was found only in *Forest Edge* habitat type. In *Farmland* and *Grassland* habitat types low and no number of naturally regenerating individuals were recorded respectively (Table 6).

Table 6. Density\ha of naturally regenerating woody species at ten habitat types of Dodola forest

Species	EHY	HJ	JP	FG	NG	RI	FE	FL	PL	GL
Bersama abyssinica	0	0	0	0	0	0	137	0	0	0
Buddleja polystachya	34	0	0	0	0	0	0	0	0	0
Cupressus lusitanica	0	0	0	0	0	0	0	0	3521	0
Discopodium penninervum	0	205	0	0	0	0	0	274	0	0
Dombeya torrida	0	0	0	0	0	34	0	0	0	0
Dovyalis abyssinica.	103	103	102	0	171	137	0	0	137	0
Ekebergia capensis	0	0	0	0	0	34	0	0	0	0
Eucalyptus globulus	0	0	0	0	0	0	0	0	68	0
Erica arbora	1214	0	0	266	205	0	0	0	0	0
Galiniera saxifraga	0	68	0	0	0	34	0	0	0	0
Gnidia glauca	205	0	0	506	171	0	0	0	0	0
Hagenia abyssinica	0	34	8	0	0	0	0	0	0	0
Hypericum revolutum	581	0	0	103	137	0	0	0	0	0
Juniperus procera	2838	1504	667	308	133	167	308	78	581	0
Maesa lanceolata	0	274	0	0	0	34	0	0	0	0
Maytenus addat	0	0	68	0	308	103	786	100	0	0
Maytenus arbutifolia	68	444	188	68	102	103	991	68	103	0
Myrsine africana	3145	650	450	3009	957	0	410	0	0	0
Myrsine melanophleos.	171	2051	691	0	684	991	615	0	0	0
Olea europaea Subsp. cuspidata	342	0	137	34	34	0	103	0	0	0
Olinia rochetiana	103	0	0	171	0	68	68	0	0	0
Osyris quadripartita	308	0	34	618	34	0	0	0	0	0
Phytolacca dodecandra	0	0	0	0	0	0	0	68	0	0
Pittosporum viridiflorum	137	0	0	0	0	0	0	0	0	0
Podocarpus falcutus	103	718	547	34	476	752	102	0	0	0
Rhamnus staddo	34	0	171	0	34	107	410	0	0	0
Rhus glotinosa	547	0	0	581	34	0	0	128	0	0
Rosa abyssinca	103	34	68	376	137	0	0	140	0	0
Rubus steudnerii	0	68	0	85	68	34	0	0	0	0
Schefflera volkensii	0	0	0	0	0	68	34	0	0	0
Vernonia amygdalina	0	68	0	0	0	0	0	0	0	0
Total number of species	**17**	**13**	**12**	**12**	**16**	**12**	**14**	**6**	**5**	**0**

5.2.2 Similarity in species composition of naturally regenerated woody species between different habitats types

The similarity in species composition of the natural regeneration between the habitat types ranged from Sj values of 0.13 (between *Farmland* and *Plantation*) to 0.73 (between *Erica Hypericum* and *Natural Gap*). The second highest similarity in species composition (Sj = 0.70) was recorded between *Erica-Hypericum* and *Fire Gap* (Table 7).

Table 7. Jaccard's Coefficient of Similarity in species composition of naturally regenerated woody species between different habitats types studied at Dodola forest

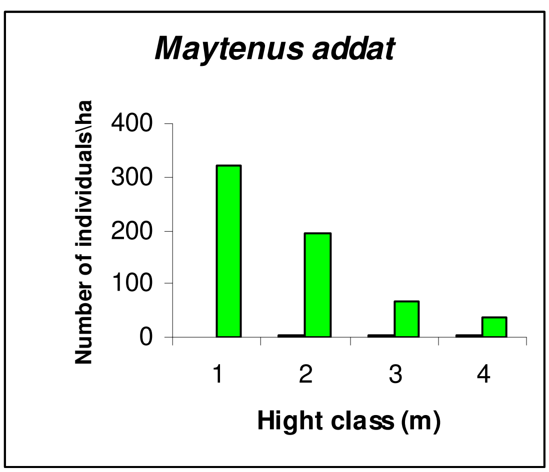
Habitat types	EHY	HJ	JP	FG	NG	RV	FE	FL	PL
EHY	-	0.33	0.52	0.70	0.73	0.29	0.38	0.15	0.16
HJ		-	0.41	0.26	0.40	0.44	0.26	0.28	0.16
JP			-	0.29	0.65	0.37	0.50	0.29	0.21
FG				-	0.65	0.18	0.33	0.20	0.14
NG					-	0.38	0.40	0.22	0.17
RV						-	0.41	0.18	0.19
FE							-	0.20	0.13
FL								-	0.22
PL									-

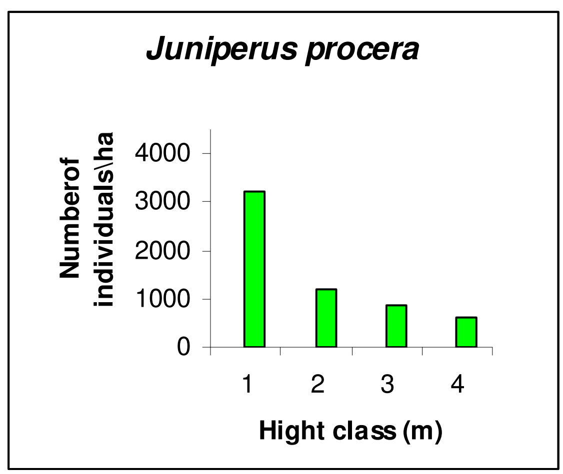
KEY: EHY - *Erica - Hypericum*, **HJ-** ***Hagenia****-Juniperus*, **JP-***Juniperus-Podocarpus*, **NG -** *Natural Gap*, **FG-** *Fire Gap*, **RV-** *Riverine*, **FE -** *Forest Edge*, **FL -***Farmland*, **GL-** ***Grassland***, **PL -** *Plantation*

5.2. 3 Height class distribution of naturally regenerating woody species

Patterns of height class distribution of germinants, seedlings, saplings and mature individuals varied from species to species (Fig.7). Height class distribution of six representative tree species of the Dodola forest was grouped into two categories:

1) Species having the highest proportion of individuals in the lower class and then decrease towards the higher class. Species in this group include *Juniperus procera, Podocarpus falcatus, Maytenus addat, Hypericum revolutum*, and *Myrsine melnophleos*
2) In this category the germinant and seedling groups were missing except mature individuals (Eg. *Hagenia abyssinica*).





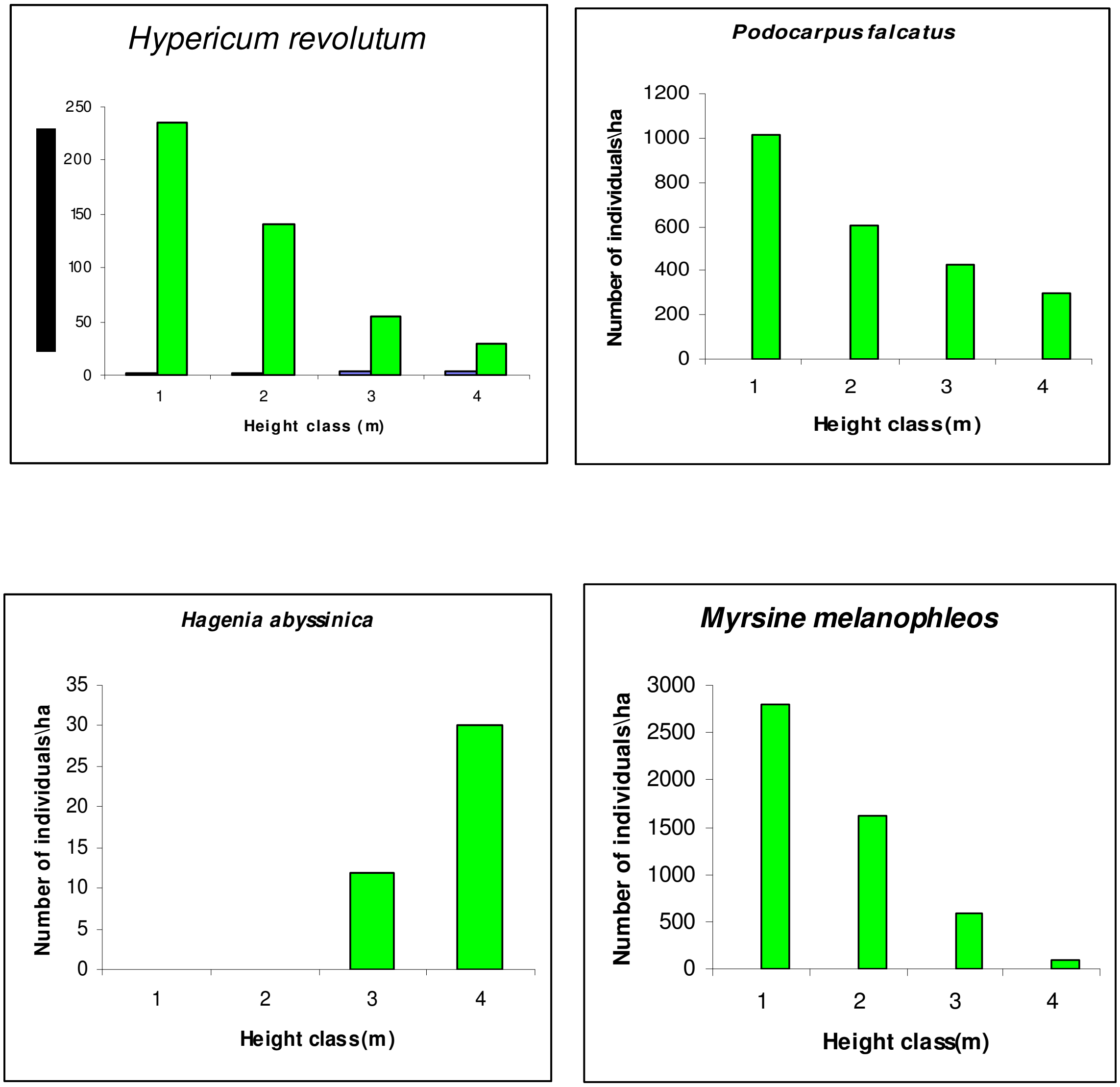


Figure 7: Number of individuals of selected six tree species per hectare in each height class category: (Height class category: 1= <0.1m; 2= 0.1m - 1.5m; 3 = 1.5m - 4m; 4= > 4m)

6. Discussion

6.1 Soil seed bank

The results from the soil seed bank study revealed that there are large quantities of persistent seeds of herbaceous species in the soil. The woody flora in the seed bank is dominated by *Juniperus procera* species. This finding is consistent with those of different authors (Demel Teketay and Granstrom, 1995; Demel Teketay, 1996; Kebrom Tekle and Tesfaye Bekele, 2000; Feyera Senebeta and Demel Teketay, 2001; Tefera Mengistu etal., 2005, Mulugeta Lemenih and Demel Teketay, 2005; Alemayhu Wassie and Demel Teketay, 2006) who reported high accumulation of viable seeds of herbaceous species and low proportion of woody species in the soil seed bank.

Lower proportion of woody species in the soil seed banks is due to the relatively short residence time of most woody species seeds of Afromontane forest in the soil compared with those of herbaceous species except *Podocarpus falctus* and *Juniperus procera*. According to Demel Teketay (1996), most of the tree species in the Afromontane forest germinate within a few days or weeks after dispersal and cannot store large soil seed banks.

The second probable reason for such difference in composition of seed banks is that the seeds of large trees are partly so heavily predated and decompose rapidly. In addition trees need long period of time to give seed to be incorporated to the soil seed bank. Harper (1977) has indicated that the dominance of herbaceous plant species in the soil seed bank is due to delayed reproduction cycle of tree species.

Another explanation for the few seeds of woody plants in the soil seed banks could be that seeds of several woody species are relatively larger in size and fleshy in nature. Fleshy seeds contribute for the rarity of woody species in the soil seed bank since it attract animals like Colobus monkey which may affect germination of fleshy seeds by aborting the fruit before maturation as well as killing the seed in the digestive system; and also seeds which lack apparent adaptation for dispersal may be carried in mud, on the feet of animals and those seed which have adaptation for attachment to animal skin are dispersed to another site. According to Mekuria Argaw *et al.,* (1999) seeds of woody species are affected by pre-dispersal predation.

Their large size also have impact to be easily incorporated to the soil seed bank through cracks if they remain on the surface then they will be affected by surface fire set by the local people to get grazing land and exposed for other impacts. According to the report from soil seed bank study by Mulugeta Lemenih and Demel Teketay (2005) as long as seeds remain on the surface they are either attacked by predators or immediately germinate.

A higher proportion of *Juniperus procera* seeds were recovered from soil sieving and also most of the seeds were viable. In addition the species has high density of naturally regenerating individuals. According to Demel Teketay and Granstrom (1996), higher number of seeds *of Juniperus procera* was recovered from soil seed banks of Afromontane forests of Ethiopia. This result indicates that the species has a potential to regenerate from seeds buried in the soil.

Densities of *Juniperus procera* seeds were higher at *Juniperus-Podocarpus* habitat type where the species was found dominantly in the standing vegetation. In *Riverine* habitat type the highest number of species was recorded from soil seed bank assessment, which could be attributed to the fact that animals that came to the riverside to get water bring a variety of seeds from different area by carrying them either internally or externally. In internal transport, the animals ingest seeds and those that survive digestion may subsequently germinate in the faces. In external dispersal, seeds that lack apparent adaptation for dispersal may be carried in mud on the feet of animals. Alternatively seeds may be adapted for attachment to animal skin and dispersed that way.

For instance, herbaceous species, such as *Achyrantus aspera*, and *Chenopodium schraderianum* possess seeds that stick tightly on animals and become dispersed to the area by birds and other animals. Birds disperse seeds of *Juniperus procera*. Fruits of *Podocarpus falcatus*, *Rosa abyssinica*, and *Solanum* species are eaten and dispersed by birds and other animals. Reports from soil seed bank studies in the highlands of Ethiopia and Northeast Tropical Africa showed that most of the species were dispersed by animals (Friis, 1992).

Flood may also contribute for the high accumulation and diversity of flora in soil seed bank of riverine habitat type since rain-washes small seeds into the riverine habitat type from higher altitudinal gradient. According to Hopkins and Graham (1983), small size seed removal is observed by running waters. Looney *et al.,* (1995), also explained that water washes viable seeds from where they can remain for a long period.

The higher density of seeds in soil seed bank assessment was recorded from *Farmland* and *Grassland* habitat types. The probable reason may be since grasses, sedges and herbaceous plants that produce numerous small persistent seeds in soil seed bank dominated these habitat types.

Low density of viable seeds in soil seed bank was observed in *Hagenia-Juniperus* and *Juniperus-Podocarpus* habitat types. This may be due to the fact that these habitat types have relatively dense canopy closure, which hamper establishment of herbaceous as well as grass species that produce persistent seeds in the soil seeds bank. Demel Teketay (1996) reported that most herbaceous plants colonize disturbed area than areas with closed canopies.

The habitat types exhibited low similarities in species composition of their soil seed banks. This may be due to the variation in intensity and types of disturbances between the habitat types. For instance, disturbance in Fire gap habitat type is caused by fire, in Natural gap and Forest edge it is caused by falling of trees or branches naturally or cut down by human, and in Grass land habitat types domestic animals are the cause for disturbance. The intensity of these different types of disturbance factors that affect the soil seed flora vary from habitat type to habitat type. The findings of other authors (Alemayheu Wassie and Demel Teketay, 2006; and Mulugeta Lemenih and Demel Teketay, 2005) suggest that level of vegetation disturbances have impact on the number of species in soil seed bank. Levassor *et al*., (1990), also explained that the highest species numbers are found at low disturbance intensities while there is a drastic decrease at high disturbance intensity.

Jaccard's coefficient of similarity indicates that the similarity between above ground and soil seed bank flora was very low in all habitat types. This result is consistent with other soil seed bank studies in tropical regions (E.g. Mulugeta Lemenih and Demel Teketay, 2005; Alemayhu Wassie and Demel Teketay, 2006).

One of the main probable reason for the disparity between above ground vegetation and soil seed bank flora is seeds of the woody plant species which are found in the above ground flora germinate immediately with in a few days after dispersal (have transient seeds) therefore they can't store seeds for long period of time in the soil as herbaceous plant. Demel Teketay (1996) explained that many woody species in dry Afromontane forests of Ethiopia germinate within a few days or weeks after dispersal.

The second reason for the disparity is seeds of some species in the glasshouse may die by the temperature of the glasshouse though it is controlled by ventilating the glasshouse. According to Hopkins and Graham (1983), seeds of different species differ greatly in germination requirement and, therefore, glasshouse conditions may not be suitable for the germination of some species.

The vertical distribution of the seed in the soil show that most habitat types have highest seed densities in the upper three centimeters of soil and gradually decreasing densities with increasing depth. This observation is consistent with several pervious studies in Ethiopia (Demel Teketay, 1996; Mekuria Argaw *et al.*, 1999; Kebrom Tekle and Tesfaye Bekele, 2000;

Feyera Senbeta and Demel Teketay, 2001; Tefera Mengistu *et.al*., 2005; and Alemayehu Wassie and Demel Teketay, 2006).

The variations of seed density in three successive layers may indicate differences of species in terms of seed longevity in the soil, mode of seed dispersal and seed predation. It also suggests that if the upper soil layer is degraded by soil erosion or other factors, there may be variation in soil seed bank down to 9 cm.

In *Farmland* and *Grassland* habitat types no seeds of woody species were recovered either by germination trials or through soil sieving. This may be due to animal trampling, and grazing resulted in a complete depletion of seeds of woody species from the soil seed bank. Demel Teketay (1996) , explained that disturbance caused by domestic animals, burning and other farm activities cause exhaustion of native woody species propagules.

From the recovered seeds through sieving 45% were non-viable. This may be due to insect attack, decay and abortion of seeds by wild animals like monkey before maturation. Demel Teketay and Granstrom (1996) explained that decay and predation reduce the number of viable seeds of woody species.

All seeds of *Acacia abyssinica* recovered via sieving were viable. This may be attributed to the fact that seeds of the species have hard seed coat. Demel Teketay and Granstrom (1996), explained that in a four year burial experiment of viability test, seeds of *Acacia abyssinica* remained viable and no evidence of seed deterioration was observed during the four years of storage in the soil.

6.2 Natural regeneration of woody species

Naturally regenerating woody species recorded in the study area was 31, which is lower than that of other Afromontane forest. In Gara Ades and Menagesha forests, which are situated in the same climatic region as Dodola forest, have 40 and 41 species respectively (Demel Teketay, 1997a).

The total density of naturally regenerating individuals at the study area was 46,879 per hectare, which is denser than other forests. For contrast, 16,290 and 32,650 seedlings /hectare were recorded in Gara Ades and Menagesha Afromontane forest respectively (Demel Teketay, 1997a).

The density of under story regenerated woody plants was variable among the various habitat types. Higher density of naturally regenerating plants were recorded in *Erica-Hypericum* habitat type which could be attributed to the fact that since the habitat type is located at a higher altitude above 3100m disturbance by human and domestic animals were lower. Teshome Taddesse (1999), explained that natural vegetation remain with out degradation in areas with difficult access, namely along ridges with steep slopes and on higher elevation.

Farmland and Grassland habitat types have low or no regeneration of woody species recorded. The probable reason for this result may be the disturbance caused by domestic animals. Silvertown (1989), indicated that herbivory is one of the major factor affecting growth and reproductive success of different plant species.

Tewdros Tsegaye (2004), confirmed that the fallow lands in Dodola forest area were used for livestock grazing. Demel Teketay (1996) also reported that deforestation followed by frequent cultivation, weeding, site preparation, stump splitting and animal trampling exhaust native woody species propagules on arable and grazing lands in Ethiopia.

Juniperus procera is the species that have a good regeneration status, higher density and distributed in more than nine habitat types of the forest, which could be attributed to the fact that the species have numerous viable seeds to ensure its perpetuation.

Cupressus lusitanica was represented by relatively high number of naturally regenerating seedlings and viable seeds in soil seed bank under Plantation habitat type. This result suggests that in areas where there is adequate source of seeds or propagules in the above ground flora then their will be high number of naturally regenerating seedlings in the site. Grime (1979) suggested that the reservoir of seedlings and saplings functions in a way that is in some respects analogous to that of a seed bank.

The species *Bersama abyssinica* is found only at forest edge habitat type. This may be due to the fact that the species may be favored by disturbance. According to Tamarat Bekele (1994), at forest edges where human influence is pronounced forest pioneer species such as *Bersama abyssinica* is frequent.

Myrsine africana is a species with the highest density of naturally regenerating woody plants than the remaining woody species. In Gara Ades and Menagesha Afromontane forests also *Myrsine africana* was one of the five species with the highest seedling density (Demel Teketay, 1997a). The probable reason for high density of *Myrsine africana* may be unlike other woody species it resists browsing by wild or domestic animals. Demel Teketay (1996), explained that *Myrsine africana* is one of the species with less valuable woody species for commercial purpose, and also resistant to livestock grazing.

The patterns of height class distribution of *Juniperus procera, Podocarpus falcatus, Maytenus addat, Hypericum revolutum*, and *Myrsine melnophleos* species show higher number of individuals at the germinant stage and a gradual decrease towards seedling, sapling, and mature tree. According to Silvertown (1982), such distribution pattern commonly referred as 'J' shape, which has a good regeneration potential.

From the height class distribution of six common tree species *Hagenia abyssinica* showed improper regeneration. This may be attributed to the fact that matured individuals of *Hagenia abyssinica* were harvested for timber production, which affects the reproductive capacity of the species, which in turn lowers production of viable seeds.

According to Tewdros Tsegaye (2004), between 1986 and 2002 the cutting of *Hagenia abyssinica* was high in Dodola forest for timber production. The other probable reason could be *Hagenia abyssinica* is one of the most useful medicinal plants in Ethiopia. According to Fichtl and Admassu Adi (1994) the female flower parts are used as a remedy for tapeworm infestation, which affects the production of viable seeds to germinate and enhance seedling population.

Hypericum revolutum was expected to have the highest density in *Erica-Hypericum* habitat type but *Juniperus procera* has turned out to be the most regenerating species. The reason may be due to selective cutting of *Hypericum revolutum* species. Tewdros Tsegaye (2003), in its land cover change study explained that *Hypericum revolutum* woody species in Dodola forest was highly used by the local people for construction and fuel wood purposes.

The second probable reason may be since *Hagenia -Junperus* habitat type which is dominated by *Juniperus procera* found proximity to *Erica-Hypericum* habitat type the seeds of *Juniperus procera* may be easily dispersed to *Erica-Hypericum* habitat type by dispersers that use the trees as roosts and transient seeds of *Juniperus procera* may help the species to form seedling banks. According to Demel Teketay and Granstrom (1995), naturally regenerating seedlings can emerge from the vicinity of mature, fruiting trees.

7. Conclusions

Based on the results, it can be concluded that the Dodola Afromontane forest possesses large populations of buried seeds of herb, grasses and sedges. On the other hand trees and shrub species except *Juniperus procera* and *Podocarpus falcatus* have very low viable seeds in the soil.

Juniperus procera and *Podocarpus falcatus* not only accumulate seeds in the soil but also have higher number of naturally regenerating plant populations in more than seven habitat types of Dodola forest. These species also show normal regeneration status. This may imply that the restoration of these two Afromontane tree species may be easy and fast.

The restoration of native forest flora, particularly of woody species on Farmland and Grass land habitat types of the forest may be difficult unless and otherwise artificial seedling plantation is employed.

Hagenia abyssinica species was not represented by either seedling banks or seed banks in the soil except matured trees. This indicates that special attention is required not to loss the species from the study site in the near future.

The study also shows that the different habitat types have variations on seeds buried in the soil and natural regeneration potential. Generally the soil seed bank study of Dodola forest can be characterized by having large populations of buried seeds of herbs, grasses and sedges. On the other hand woody species except the two commercially valuable trees, *Juniperus procera* and *Podocarpus falcatus,* possess low persistent seed in the soil but have relatively high population of naturally regenerating individuals.

8. Recommendations

Based on the results obtained from the study, the following recommendations are forwarded as an implication for conservation and management options:

- The forest management activity, being practiced by the local communities in collaboration with Adaba -Dodola Integrated Forest Management Project (IFMP) is a good alternative to manage the forest. However, the participation of the local people in the area should encompass more households in order to reduce the risks of illegal cutting of trees in the future and also the technique used to manage the forest must be proven to be effective overtime.

- Reduce the continued open grazing system that affects the natural regeneration capacity of different species and the role of soil seed bank by trampling.

- Use the cut and carry method for feeding domestic animals than using free grazing method in the forest to enhance the germination capacity of the seeds in the soil and seedling development of woody species.

- Intervention is crucial to enhance the natural regeneration of poorly represented species through planting seedlings.

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Appendix 1. Above ground flora of the study area

Species	Family	Local Name	Life form
Acacia abyssinica Hochst. ex Benth.	Fabeaceae		Tree
Acanthus sennii Chiov.	Acanthaceae	Qorree	Herb
Achyranthes aspera L.	Amaranthaceae		Herb
Agrocharis melanata Hochst.	Apiaceae		Herb
Anemone thomsonii Oliv.	Ranunculaceae		Herb
Arundinaria alpina K. Schum.	Poaceae		Herb
Asparagus africanus Lam.	Aspargaceae	Sartii	Shrub
Bersama abyssinica Fresen.	Melianthaceae		Shrub
Buddleja polystachya Fresen.	Loganiaceae	Bulchana	Shrub
Carduus chamacephalus (Vatke) Oliv. & Asch.,nom. nud.	Asteraceae	Qorre hare	Herb
Carduus nyassanus (Engl.) Fries	Asteraceae	Qoree	Herb
Cassipourea malosana (Bak.) Alston	Rhizophoraceae	Lelissaa	Herb
Clematis simensis Fressen.	Ranunculaceae	Fiidii	Climber
Commelina benghalensis L.	Commelinaceae		Herb
Conium maculatum L.	Umbelliferae	Bobonqaa	Herb
Convolvulus kilimandischari Engl.	Convolvulaceae	Hooroolaa	Climber
Conyza hypoleuca A. Rich.	Asteraceae		Shrub
Conzya spinosa Sch.Bip. ex Oliv & Hiern.	Asteraceae	Hamaresa	Shrub
Crepis rueppelii Sch. Bip.	Asteraceae	Cenna Guracha	Herb
Crotalaria agatiflora Schweinf.	Fabaceae		Shrub
Crotalaria incana L.	Fabaceae	Ateri binessaa	Herb
Cupressus lusitanica Mill.	Cupressaceae		Tree
Cynoglossum coeruleum Strud. ex DC.	Boraginaceae	Qecheba	Herb
Cyperus alopecuroides Rottb.	Poaceae	Chittaa	Grass
Cyperus nigricans Steud.	Cyperaceae	Qunnii	Herb
Cyperus pauper Hochst. ex DC.	Cyperaceae	Dehlando	Grass
Dichondra repens J.R. & G. Forst	Convolulaceae		Herb
Dierama pendulum (L. fil.) Bak.	Iridiaceae		Herb
Discopodium penninervum Hochst.	Solanaceae	Maraaroo	Shrub
Dombeya torrida (J. F. Gmel) P.Bamps	Tiliaceae	Dannisa	Tree
Dovyalis abyssinica (A. Rich.) Warb.	Flacortiaceae	Dhangagoo	Shrub

Dregea schimperii (Decne) Bullo.	Ascelpidaceae	Hadename	Climber
Echinops angustilobus S.Moore	Asteraceae	Qoree	Herb
Ekebergia capensis Sparm.	Meliaceae	Annoonnuu	Tree
Eleusine floccifolia (forssk.) Spreng.	Poaceae		Grass
Eragrostis tenifolia	Poaceae		Grass
Erica arborea L.	Ericaceae	Satto	Shrub
Eucalyptus globulus Labill.	Myrtaceae		Tree
Festuca abyssinica Hochst. exA.Rich.	Poaceae		Grass
Galiniera saxifraga (Hochst. ex A. Rich.) Bridson	Rubiaceae	Kooralla	Tree
Galium simense Fresen.	Rubiaceae	Maxxannee	Herb
Geranium arabicum Forssk.	Gerianaceae		Herb
Girardinia bullosa (Steud.) Weddel.	Urticaceae	Dobbii-arbo	Herb
Gnidia glauca (Fressen.) Gilg.	Thymelaceae	Diddigsaa	Shrub
Hagenia abyssinica (Bruce) J. Gmel.	Rosaceae	Heexoo	Tree
Halleria lucida L.	Scrophulariaceae	Dahdii	Shrub
Haplocarpha reuppelii (Sch.-Bip) Beauv.	Asteraceae	Canaa	Herb
Helichrysum citrispinum	Asteraceae		Shrub
Helichrysum splendidum (Thunb.) Less.	Asteraceae	Xuqaa	Herb
Hypericum revolutum Vahl	Hypericaceae		Tree
Hypoestes triflora (Forssk.) Roem & Schult.	Acanthaceae		Herb
Isoglossa somalensis Lind.	Acantaceae	Herayee	Herb
Jasminum abyssinicum Hochst. ex DC.	Oleaceae	Dikki	Climber
Juncus effusus L.	Juncaceae		Herb
Juniperus procera L.	Cuppersaceae		Tree
Kalanchoe petitiana A. Rich.	Crassulaceae	Hancuuraa	Herb
Kniphofia foliosa Hochst	Asphodelaceae	Ledhaa	Herb
Maesa lanceolata Forssk.	Myrsinaceae		Tree
Maytenus addat (Loes.) Sebsebe	Celasteraceae		Tree
Maytenus arbutifolia (A.Rich.) Wilczek	Celasteraceae		Shrub
Mentha spicata L.	Lamiaceae	Gogoroo	Herb
Mikanopsis clematoides (A. Rich.) Milne-Redh.	Asteraceae	Qerqora	Climber
Momordica foetida Schumach.	Cucurbitaceae	Horrollaa	Climber
Myrica salicifolia A. Rich.	Myricaceae	Xonna	Tree

Myrsine africana L.	Myrsinaceae		Shrub
Myrsine melanophloes (L.) R Br.	Myrsinaceae	Tulla	Tree
Nuxia congesta R. Br.ex Fresen.	Loganiaceae	Bixxanaa	Tree
Olea europaea subsp. cuspidata (Wall. ex DC.) Ciffer	Oleaceae		Tree
Olinia rochetiana A.Juss.	Oliniaceae	Gunna	Tree
Osyris quadripartita Decn.	Santalaceae	Karro	Shrub
Oxalis radicosa A. Rich.	Oxalidaceae		Herb
Pennisetum clandestinum Hochst. ex Chiov.	Poaceae	Cheqorssa	Grass
Pennisetum humile Hochst. ex A. Rich.	Poaceae	Mujjaa	Grass
Pennisetum villosum (R.Br.) Fresen	Poaceae	Alando	Herb
Phytolacca dodecandra L.	Phytolacaceae	Andoodee	Shrub
Pieperomia abyssinica Miq.	Piperaceae	Raruppee	Epiphyte
Pittosporum viridiflorum Sims.	Pittosporaceae	Aaraa	Tree
Plectranthus orantus Codd.	Lamiaceae		Herb
Poa schimperiana Hochst.ex A.Rich	Poaceae	Fifaa	Grass
Podocarpus falcatus (Thunb.) Mirb.	Podocarpaceae		Tree
Ranunculus multifidus Farssk.	Rananculaceae	Gonde	Herb
Rhamnus prinoides L' Herit.	Rhamnaceae		Shrub
Rhamnus staddo R.Rich.	Rhamnaceae	Qedidaa	Shrub
Rhus glutinosa A.Rich.	Anacardiaceae		Shrub
Rosa abyssinica Lindley	Rosaceae		Shrub
Rubus steudneri Schweinf.	Rosaceae		Shrub
Rumex nepalensis Spreng.	Polygonaceae		Herb
Salvia nilotica Juss. ex Jacq.	Lamiaceae	Butaa	Herb
Satureja paradoxa (Vatke) Engl.	Lamiaceae		Herb
Scabiosa columbaria L.	Dipsacaceae		Herb
Scadoxus multiflorus (Mart.) Raf.	Amaryllidaceae		Herb
Schefflera volkensii (Engl.) Harms	Araliaceae	Ansha	Tree

Senecio lyartus Forssk.	Asteraceae		Herb
Senecio myriocephalum Sch. Bip. ex A. Rich.	Asteraceae	Agedenaa	Herb
Sida schimperiiana Hochst. ex A. Rich.	Malvaceae		Herb
Smilax aspera L.	Smilacaceae		Shrub
Solanum marginatum L.f.	Solanaceae	Galmayoo	Herb
Solanum incanum L.	Solanaceae	Hiddii orom	Shrub
Sonchus asper (L.) Hill	Asteraceae		Herb
Sporobulus africanus (Poir.)Robyns & Tournay.	Poaceae	Merga Kerso	Grass
Stachys alpigena T. C. E. Fries	Lamiaceae		Herb
Stephania abyssinica (Dill. Rich.) Walp.	Menispermaceae		Climber
Thymus schimperi Ronniger	Lamiaceae	Xoshinee	Herb
Trifolium simense Fresen.	Fabaceae		Herb
Trifolium burchellianum Ser.	Fabaceae	Siddisa	Herb
Urtica simensis steudel.	Urticaceae	Doobbii	Herb
Vernonia amygdalina Deli.	Asteraceae		Tree
Vernonia bipontini Vatke.	Asteraceae	Hattaa	Shrub
Zehineria scabra (Linn.f.) Sond.	Cucurbitaceae		Climber

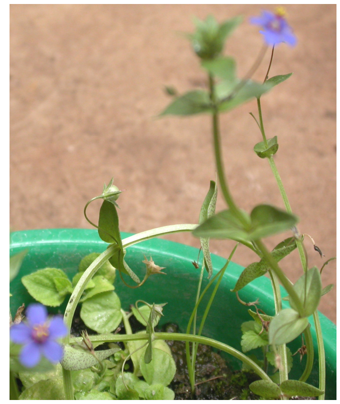
Appendix 2. The total number of viable seeds (germination trials and soil sieving combined) recorded from each of the layers.

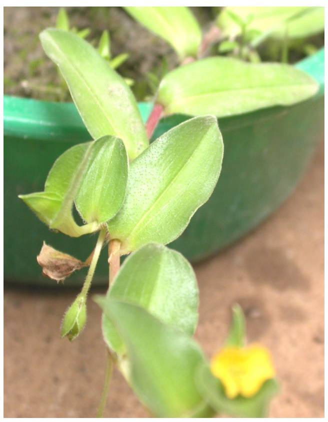
SPECIES	0 - 3 cm	3 - 6cm	6 - 9 cm
Trees			
Acacia abyssinica Hochst. ex Benth	3	1	1
Cupressus lusitanica Mill.	3	46	3
Eucalyptus globulus Labill.	1	0	0
Juniperus procera L.	54	30	21
Podocarpus falcatus (Thunb.) Mirb.	8	9	3
Vernonia amygdlina Del.	4	0	0
Shrubs			
Rosa abyssinica Lindley	0	0	2
Sida schimperiana Hochst. ex A. Rich.	4	0	2
Herbs			
Achyranthes aspera L.	0	1	0
Agrocharis melanatha Hochst.	5	6	1
Alchemilla abyssinica Fresen.	72	98	79
Amaranthus hybridus L.	1	0	1
Anagallis arvensis L.	16	18	9
Cerastium octadrum A.Rich.	23	27	30
Chenopodium schraderianum Schult.	3	2	3
Commolina africana L.	1	0	1
Cotula abyssinica Sch. Bip. ex A. Rich.	8	5	2
Crassula alsinoides (Hook.f.) Engl.	158	83	80
Cripes schimperi (sch. Bip.) Beauv.	1	1	1
Crotalaria agatiflora Schweinf.	7	11	6
Dichondra repens J.R. & G. Forst	42	70	77
Euphorbia schimperiana Scheele.	3	3	4
Galium simense Fresen.	3	2	0
Gallinsoga parviflora Cav.	52	18	15
Geranium arabicum Forssk.	6	7	7
Granphalium unions Sch. Bip.ex Oliv. & Hiern	28	35	14
Haplocarpha rueppelii (Sch.- Bip) Beauv.	0	5	1

Haplocarpha schimperi (Sch.-Bip.) Beauv	4	14	21
Herniaria hirsuta L.	2	5	3
Mentha spicata L.	1	2	1
Oxalis radicosa A. Rich.	286	209	175
Phyllanthus fischeri Pax.	3	2	2
Plectranthus assurgens (Beaker) Morton	6	6	3
Polygonium nepalensis (Meisn.) Miyabe	41	29	29
Rumex nepalensis Spreng.	0	4	0
Sencio lyartus Forssk.	1	0	1
Solanum incanum L.	12	15	11
Solanum marginatum L. f.	10	13	14
Solanum nigrum L.	3	12	14
Sonchus asper (L.) Hill	4	4	8
Spilanthes mauritiana (RIch. ex Pers.) DC	83	50	75
Stellaria media (L.) Vill.	187	134	141
Trifolium rueppellianum Fres.	9	14	25
Trifolium simense Fresen.	2	5	7
Urtica simensis Steudel.	5	5	1
Veronica abyssinica Fresen.	4	5	5
Grass and sedges			
Poa schimperiana Hochst.ex A.Rich	54	19	11
Eleusine floccifolia (Forssk.) Spreng.	44	33	7
Eragrostis tenuifolia (A. Rich.) Steud.	434	268	297
Festuca abyssinica Hochst. ex A.Rich.	153	155	164
Panicum hochstetterii Steud.	10	6	2
Sporoblus africanus (Poir.) Robyns & Tournay.	538	369	404
Cyperus nigricans Steud.	123	70	77
Cyperus pauper Hochst. ex A.Rich.	7	6	2
Climbers			
Convolvulus kilimandischari Engl.	0	2	0
Zehneria scabra (Linn.f.) Sond.	2	4	4
Total	**2534**	**1940**	**1874**

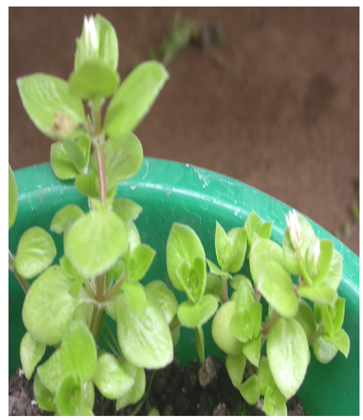

Acacia abyssinica


Alchemilla abyssinica


Anagallis arvensis


Commelina africanus


Cotula abyssinica


Crassula alsinoides

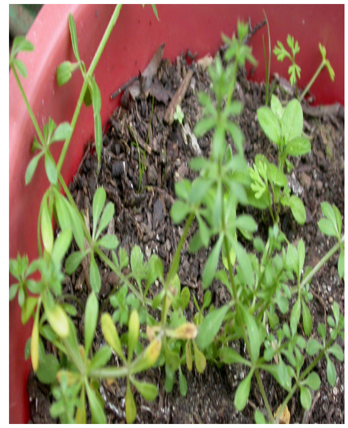

Crotalaria agatiflora


Cuperssus lusitanica


Euphorbia schimperiiana

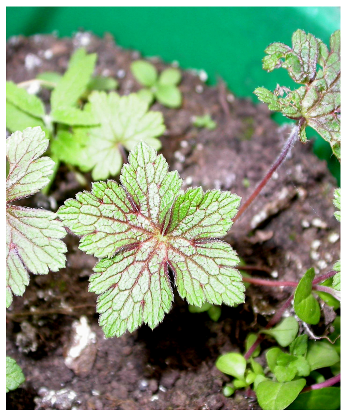
Eucalyptus globulus

Festuca abyssinica



Galium simensis

Gnpahalium unianee



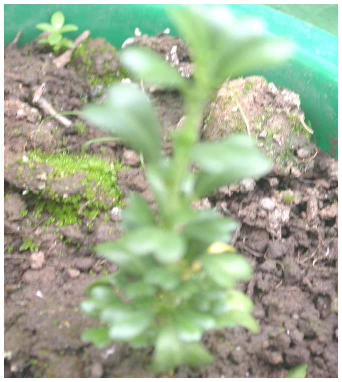
Geranium arabicum

Oxalis radicosa

Podocarpus falcatus

Polygonium nepalensis

Rosa abyssinica



Sida schimperiana

Solanum marginatum

Solanum incanum

Spilanthes mauritiana

Sonchus asper

Trifolium rueppellianum

Trifolium simense

Urtica simensis

Zehneria scabra

Figure 8. Photos of different plant species germinated from soil seed bank In green house

This thesis is my original work and has not been presented for a degree in any other university, and that all sources of materials used for the thesis have been duly acknowledged.

Candidate

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Name Signature

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