Soil Seed Bank Study and Natural Regeneration Status at Entoto Mountain and Along the Addis Ababa - Gohatsion Road

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Abstract

Soil seed banks are an important source of new individuals for many plant populations and contribute to future genetic variability. The objective of this study was to investigate the composition and density of soil seed bank and natural regeneration status at Entoto-mountain and along the Addis Ababa - Gohatsion road. A total of forty-nine quadrats were established in the selected sites. The quadrat size (10 m x 10 m) for trees, shrubs and herb and with seedling (height ≤ 1.0 m), sapling (height between 1 and 3 m) and mature tree/shrub (height >3 m) laid down to examine similarity between standing vegetation and 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 from four soil layers, the litter layer and three successive layers (0-3 cm, 3-6 cm, and 6-9 cm). A total of 98 plant species germinated from all the soil samples collected for the investigation. Herbs dominated the SSB representing nearly 87.8% of the identified species. The distribution of seeds through the profile indicated a sharp decline in abundance with depth. The greatest reserves of seeds were in the surface layer of the soil (0-3 cm). Similarity between standing vegetation and SSB show that there was negligibly low similarity (JCS = 0.204-0.375). However, there was a general tendency of disappearance of native woody species from the SSB as evidenced by the germination of few woody species. This implies that reliance on the SSB for the recovery of native woody species is not worthy. Analysis of natural regeneration of woody species shows that a total of 25 woody species and 8,977 individuals/ha were recorded. The highest seed density of naturally regenerating woody plants and the highest number of species were recorded in Eucalyptus plantation forest. Farmland, pastureland and wetland habitat types show no seedling and/or sapling of woody species. This, in turn, indicates that future existence of the woody flora characteristic of tropical dry evergreen Afromontane areas in Ethiopia depends on the conservation and sustainable utilization of the few remnant natural forests.

Key words/phrases: - Entoto Mountain, *Eucalyptus* plantation, species composition, seed density, soil seed bank, natural regeneration

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ACRONYMS

a.s.l.:	above sea level
AAU	Addis Ababa University
ANOVA:	Analysis Of Variance
EMSA	Ethiopian Meteorological Service Agency
ETH	National Herbarium
FDRE	Federal Democratic Republic of Ethiopia
GPS:	Global Position System
m	meter
S S B:	Soil Seed Bank
SPSS	Statistical Package for Social Science

CHAPTER ONE

1. Introduction

1.1. Background and Justification

The ecosystem diversity in Ethiopia is endowed with immense wealth of biological resources due to its diverse topography, soil and climate. The country has the sixth largest flora in tropical Africa and out of about 6,000 species of higher plants, about 600 taxa plant species are endemic (Ensermu Kelbssa, Pers. Comm.). Its diverse geography has contributed to the development of variety of fauna, which includes about 284 species of mammals and 926 species of birds. Out of these 29 mammalian species, and 21 bird species are endemic in the country (Shimelis Aynalem and Afework Bekele 2008; Tadesse Habtamu & Afework Bekele 2008).

Vegetation types in Ethiopia are highly diverse, varying from Afroalpine to desert vegetation. However, the vegetation resources, including forests, reduction in Ethiopia is mostly attributable to anthropogenic factors. The most prominent ones are deforestation, expansion of agricultural land, overgrazing, unsustainable utilization and invasion of exotic species overexploitation for various purposes such as fire wood, charcoal, construction material and timber, all spurred by rapid human population growth (Teshome Soromessa *et al.,* 2004; Haileab Zegeye *et al*., 2011). Deforestation and land degradation, in the country, led to ecological and socio-economic crises (Haileab Zegeye *et al*., 2011). Due to increasing human pressure, traditional land management practices, such as shifting cultivation, have been replaced by permanent farming systems in most parts of the country. Such continuous cultivations are associated with decline or loss of biodiversity not only through the outright loss of habitat but also through the deterioration of the SSB (Mulugeta Lemenih & Demel Teketay, 2006).

Seed banks, which are the aggregations of viable seeds in the soil potentially capable of replacing adult plants, play a critical role in vegetation maintenance, succession, ecosystem restoration, differential species management and conservation of genetic variability

(Mulugeta Lemenih & Demel Teketay, 2006). Use of SSB in vegetation succession management is acknowledged as a low cost restoration technique since it disposes of many of the problems associated with collecting, storing and sowing seeds as well as transplanting individual seedlings rose in a nursery. SSB exhibits variations in space as well as time and display both horizontal and vertical dispersion, reflecting initial dispersal onto the soil and subsequent movement (Feyera Senbeta & Demel Teketay, 2002). SSB partly reflect history of the vegetation and can play an important role in its regeneration or restoration after disturbances. They have been exploited in two contexts:

i. To manage the composition and structure of existing vegetation, and
ii. To restore or establish native vegetation

Seed bank assessment can illuminate seed inputs from the past that may not presently be apparent in aboveground vegetation because of climatic or competitive factors (Espeland *et al.*, 2010). Seed banks are considered essential constituents of plant communities since they contribute significantly to ecological processes. The recovery-ability of vegetation after disturbance is believed to lie mainly in the buried seed population. The understanding of the dynamics and function of seed banks has become a great challenge to plant community ecologists, as this understanding is necessary to enable determining the role of this community trait in ecosystem functioning and also to improve integrated management of ecosystems (Luzuriaga *et al.*, 2005).

The composition of a seed bank depends on present and former aboveground vegetation and seed rain from adjacent areas. The historical composition of aboveground vegetation has often been identified as a key factor determining seed bank composition (Chaideftou *et al.*, 2009). SSB composition is also influenced by the surrounding vegetation and former successional stages (Godefroid *et al.*, 2006).

In most tropical areas, however, the degraded or completely destroyed forest sites are changed either to other land uses, e.g. establishment of monoculture plantations of fast growing trees (Feyera Senbeta & Demel Teketay, 2001), or permanent arable lands, which is a common practice in the tropics, e.g. in Ethiopia. In these cases, although the seed banks have the potential to initiate re-vegetation of the sites, they are continuously eliminated through weeding practices and ultimately completely exhausted. The other scenario could be the conversion of the destroyed forest sites to permanent arable lands followed by their abandonment. Here, some of the persistent seeds in the soil and the seed rain (if any) may lead to restoration of the vegetation. Plants developing from seeds in the top layer of soil, usually dicotyledonous weeds represent strong competition to the seedlings of grasses, which develop more slowly (Perera, 2005). Therefore, it is necessary to examine whether using their SSB could rehabilitate the disturbed tropical dry evergreen Afromontane forest.

Therefore, studying the formation and variation of the seed bank is of great significance to natural renewal of vegetations, successions of dominant communities, and quick recovery of vegetations. The studies about the seed banks of vegetations can reflect community histories and play an important role in rehabilitating degenerated eco-systems. Thus seed banks are thought as the material basis for natural renewal of vegetations and studies about soil seed banks are part of biodiversity research; and the seeds with long life span in seed banks are of genetic importance and thus are considered the potential supplier of gene diversities in plant communities. Accordingly SSB are, of importance in maintaining ecological diversities of populations and communities and that the problems about soil seed banks are widely concerned in the research about the ecology of plant populations by restorative ecologists at home and abroad.

Plantations in general and *Eucalyptus* plantation in particular can have a catalytic effect on the regeneration of native species and can be used as a management tool for restoration of degraded forest lands (Eshetu Yirdaw, 2002; Feyera Senbeta *et al.*, 2002; Mulugeta Lemenih and Demel Teketay, 2004). Because of the considerable damage of the mountain forests, concern has arisen about the natural regeneration of indigenous species. Regeneration, thus defined as the reassembly of floristic and structural diversity back to self-perpetuating climax states (Fekadu Debushe *et al.*, 2010). In Ethiopia, the uncontrolled removal of trees, land disturbance, specially collecting of firewood, cultivation of lands, grazing, etc severely reducing the density of the species and affecting regeneration (Demel Teketay, 2005).

The natural regeneration of plants is an important subject in both conservation biology and management (Du X *et al.*, 2007). Cost-effective plant regeneration, especially natural regeneration (i.e., regeneration of native plant species), is the keystone of sustainable forestry (Jonasova *et al.*, 2006; Leinonen *et al.*, 2008). Natural regeneration depends on the seed bank (Wang *et al.*, 2009). The seed bank and in particular the long-lived seed species, can buffer against environmental variability because it can provide new seedlings to re-establish the native community after disturbances (Satterthwaite *et al.*, 2007). Also, SSB can be a source of colonizing species that can restore degraded ecosystems or accelerate forest succession (Luzuriaga *et al.*, 2005). The composition of the seed banks mainly depends on seed production and composition of the seed sources, which consist of current and previous vegetation (Godefroid *et al.*, 2006). Therefore the assessment of the regeneration pattern and the role of seed bank in the regeneration of plant species are vital. So far most of the works about seed bank and natural regeneration focuses on forest areas and did not consider the plain land and hill top vegetation like along the road to Gohatsion. This study mainly focuses on the SSB collection from the *Eucalyptus* plantation forest, hill top vegetation and plain land for the investigation of their recovering capacity.

Our work also evaluates to what extent seed bank characteristics such as composition, abundance and vertical distribution of seeds affect the development of the aboveground vegetation. Furthermore, this study brings a contribution not yet sufficiently analyzed, through calibration of the regenerative potential of the seed bank versus the comparing vegetation development in all study sites. We address the following specific questions: (1) Does the SSB have contribution to restoration or rehabilitation of naural forest? (2) Are there any difference and similarity between the *Eucalyptys* plantation forest and the plain land in regeneration status and seed bank potential for recruitment of native species? (3) To what extent the SSB composition and density varies with depth and in different land use types? (4) Does *Eucalyptus* plantation prevent or affect the natural regeneration potential of native woody species? (5) What will be the similarity between SSB and standing vegetation? (6) What will be the current regeneration status of woody species of the study area?

1.2. Objective of the Study

1.2.1. General objective

To study the compostion and density of soil seed banks and natural regeneration status of woody species on Entoto Mountain and along the Addis Ababa - Gohatsion road,

1.2.2. Specific objectives

- To study the seed bank species composition, (as well as the vertical and horizontal distribution and density) in the study area;
- To assess the regeneration pattern and compare the species composition of the seed bank flora and the above ground vegetation;
- To examine the role of seed bank in the natural regeneration status;
- To investigate the seed bank and natural regeneration potential;
- To study the effects of land use type on seed bank and natural regeneration;
- To compare regeneration status and seed banks diversity of the study area; and
- To make recommendations on management options for land management and restoration of the vegetation of the study area.

CHAPTER TWO

2. Literature Review

This section tries to summarize issues related to seed bank and natural regeneration. The parts included are: what is soil seed bank? Characteristics of the soil seed banks, Dynamics of soil seed banks, Dispersal and distribution of seed in seed bank, Seed longevity in the soil, Environmental significance of soil seed bank, The effect of seed bank for regeneration of plant community, Factor affecting soil seed bank composition, Factors affecting seedling emergence from seed banks, sampling method used to study soil seed bank, Methods to determine soil seed bank status, natural regeneration and soil seed bank studies in Ethiopia and *Eucalyptus* plantation and naturally regenerated woody species.

2.1. Soil Seed Bank

2.1.1.What is soil seed bank?

Soil seed bank is defined as the mature viable seeds stock existing in the soil surface, or buried in the soil, duff or litter, in a determinate moment and place (Qiuyan *et al.*, 2011). A soil seed bank is also defined as the total number or density of viable seeds stored in the soil in a given period (Wanga *et al.*, 2005). It represents a living record of the recent vegetation and a new potential seedling emergence pattern of an area in the future. It is a mirror image of the population that persisted in incubation, and it laid the groundwork for the recruitment, regeneration and persistence of a population. Under natural conditions, plant seeds are affected by many ecological factors during the whole process, including dispersal of mature seeds, persistence in soil, germination and, then, growth into seedlings, under optimum condition (Wanga *et al.*, 2005). The soil seed bank plays an important role in the composition of different plant communities and thus in their conservation. Seed bank composition can be used to predict the initial composition of post-recruitment vegetation and yield information on the species composition of previous and new vegetation, the relative abundance of recently recruited species and the potential distribution of each species (Qiuyan *et al.*, 2011). Furthermore, it represents a store of evolutionary memory. Thus, knowledge of the seed bank and an understanding of the population dynamics of buried viable seeds are of practical importance in agriculture, forestry and conservation. The capacity to form persistent seed banks allows species to survive episodes of disturbance and destruction. Many species have this capacity and many do not (Qiuyan *et al.*, 2011). An understanding of persistent seed banks is the key to many aspects of practical management for agriculture and conservation, and to effective conservation of rare species and diverse ecosystems.

Soil seed banks can be either transient, with seeds that germinate within a year of initial dispersal, or persistent, with seeds that remain in the soil more than one year. They exhibit variations in space as well as time and display both horizontal and vertical dispersion, reflecting initial dispersal onto the soil and subsequent movement (Feyera Senbeta & Demel Teketay, 2001). They have been exploited in two contexts:

- To manage the composition and structure of existing vegetation and
- To restore or establish native vegetation

Natural forests in the tropics have been and continue to be subjected to natural and human induced disturbances, which have resulted in their degradation or complete destruction. The fates of these forest sites vary from place to place. In places where the sites are left without further interference, the processes of succession that will ultimately lead to re-vegetation of the sites may be initiated. Here, the soil seed banks serve as one of the major sources of plant re-growth. In most tropical areas, however, the degraded or completely destroyed forest sites are changed either to other land uses, e.g. establishment of monoculture plantations of fast growing trees (Feyera Senbeta & Demel Teketay, 2001), or permanent arable lands, which is a common practice in the tropics, e.g. in Ethiopia (Feyera Senbeta & Demel Teketay, 2002). In these cases, although the soil seed banks have the potential to initiate re-vegetation of the sites, they are continuously eliminated through weeding practices and ultimately completely exhausted (Feyera Senbeta & Demel Teketay, 2002). A third scenario could be the conversion of the destroyed forest sites to permanent arable lands followed by their abandonment. Here, some of the persistent seeds in the soil and the seed rain (if any) may lead to restoration of the vegetation (Demel Teketay, 2005).

2.1.2. Characteristics of the soil seed banks

The characteristics of seed banks, their size and composition, seed distribution in the soil, and seed fate can be highly variable. Land-management practices can affect all of these characteristics. Processes affecting seed-bank dynamics, particularly in crop systems, are complex and vary greatly depending on production practices and timing (Joanne *et al.*, 2006). The ecological framework of soil seed banks and seed persistence has been correlated to seed characteristics, their distribution in soils, land-management practices, and soil/environmental conditions.

The weed species have survived throughout time, because of their ability to resist several adverse climatic conditions, tolerating high and low temperatures, dry and humid environments and variations in oxygen supply. The fundamental point in the success of weed survival is their persistence capacity in certain areas. This capacity is a consequence of a great number of seeds produced, long-term viability, continuous germination, and phenotypic and genetic plasticity (Christoffoleti & Caetano, 1998).

The composition of seed banks is variable, and is classified as temporary or persistent, when modifying the regeneration of the vegetation during different time of the year. Temporary banks are composed of seeds of short life, which do not present dormancy and are dispersed in time for short periods during the year. Persistent seed banks are composed of seeds that have more than one year of age and reserves of seeds remain in the soil year after year, generally buried into the soil (Christoffoleti & Caetano, 1998). The success of a seed bank depends on the seed density ready to germinate, when replacement of a plant is necessary and when the environmental conditions for establishment are favorable. The seed dormancy is another characteristic that affects the seed bank reservoir.

2.1.3. Dynamics of soil seed banks

An understanding of the functions of soil seed bank requires not just knowledge of the number of seeds present at one time but also knowledge of soil seed bank dynamics

(Mulugeta Lemenih & Demel Teketay, 2006): the rates of seed input and the rates at which seeds are lost (Demel Teketay, 2005). In agro-ecosystems, where the soil is disturbed frequently, the soil seed bank acts to stabilize and ensure species survival. The dynamics of a seed bank evolves a series of events and of seeds from the bank, in relation to time (Christoffoleti & Caetano, 1998).

The seed "rain" determines the input. This way of dispersion includes passive forms, mechanical ejection of seeds, fire, wind, water and animals. The result from physiological answer of plants to environmental factors, that induces the germination seed burial or re-dispersion of the seeds and predation of the seeds by insects, pathogens, and other animals. Land preparation and crop rotation are the two primary agricultural practices that generate impacts on soil seed banks. The land preparation practices are used in order to control weeds, break soil surface hardness, and increase aeration; the seed germination is stimulated because of the seed dormancy break by light, alternated temperature, water and nitrate ions. The type of land preparation influences the seed dispersion in the soil profile; the management at same depth favor an uniform distribution of the seeds in the soil profile, finding lower seed populations deeper in the soil (Viswanath *et al.*, 2006), stated that no till and superficial tillage tend to reduce the amount of seeds at the soil surface shed by plants, since there is induction in the germination or loss of viability. The presence of seeds at the superficial layer of the soil and frequent cultivation, are factors that reduce the seed bank rapidly. This situation can facilitate seed predation by exposure of seeds to variations in temperature and humidity, and breaking their dormancy. However, the speed of soil seed bank depletion depends on the seed production of the species (Viswanath *et al.*, 2006).

2.1.4. Dispersal and distribution of seed in soil seed bank

Most of the seeds in the soil seed bank come from the nearby parent plants; while plant communities contribute the remaining seeds a long distance away from the parent plants (Solomon Tefera, 2011). 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 (Eyob Tenkir, 2006). 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. 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 (Wanga *et al.*, 2005). 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; whereas the biotic factors include dispersal by means of different animals including human beings. The effectiveness of seed dispersal agents depends mainly on the number and quality of seeds dispersed (Eyob Tenkir, 2006).

In the seed-maturation season, they drop and are scattered on the ground to form a dispersal map across the habitat of these plants. This process is disturbed by an amalgam of factors, such as wind, predation, standing vegetation and topography of micro-sites in arid ecosystems. The interaction among these factors forms the special spatial and temporal patterns of soil-persistent seed banks. Owing to the growing awareness of the ecological and evolutionary importance of seed banks, many field studies have documented the distribution patterns of soil seed banks and some, in particular, have documented the importance of persistent seed banks in the restoration of plant populations and communities (Wanga *et al.*, 2005). 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 cm of soil and gradually a decrease in densities with increasing depth is also recorded. For tropical rain forests, it is reported that there is a decline in the seed bank density and species with increasing soil depth (Eyob Tenkir, 2006).

2.1.5. Seed longevity in the soil

Seeds in the seed bank can remain stored in the soil for various lengths of time and then later germinate with the return of favorable seasonal conditions. Storage of viable seeds in the soil and the subsequent establishment are functions of the soil. Seedling recruitment from the seed bank is restricted to periods of favorable soil conditions that may control seed survival and germination. One of the most important conditions is soil moisture while other factors include soil pH and light (Solomon Tefera, 2011).

The longevity of seeds represents a major mechanism of survival of certain species, and this leads to a continuous source of emergency. The seed longevity in the soil varies among species, characteristics of the seeds, burial depth, and climatic conditions (Christoffoleti & Caetano, 1998). 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. 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. Longevity of seeds is very variable and depends on many factors and on the conditions through which they pass; for example, some seeds can stay long in the soil if kept in dry atmosphere. In typical soils the longevity of seeds can range from nearly zero (germinating immediately when reaching the soil or even before) to several hundred years (http://en.wikipedia.org/wiki/Soil seed bank).

Depending on internal and external environmental factors as well as species to species the period of seed viability in the soil varies. 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. 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. 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 (Eyob Tenkir, 2006).

The complex relationship between seed longevity and soil moisture makes any prediction of the likely effects of changes in precipitation hazardous. Longevity of dry seeds declines as seed moisture content increases to somewhere between 10% and 15%, although such changes are relevant only to the driest soils (Walck, 2011). Above this threshold, longevity increases as seed moisture content rises, and the seed becomes more metabolically active and able to repair damage to membranes or other metabolic machinery. Increased precipitation may favor fungal pathogens leading to reduced seed persistence in soil (Walck, 2011).

According to Demel Teketay (2005) the inherent properties of seeds such as germination, dormancy and viability, the environmental conditions where seeds land and subsequent changes as well as the presence of seed predators and pathogens determine the length of time which seeds can remain viable in the soil.

2.1.6. Environmental significance of soil seed banks

Soil seed banks play an important role in the natural environment of many ecosystems are also essential in rehabilitation of a degraded For example, the rapid re-vegetation of sites disturbed by wildfire, catastrophic weather, agricultural operations, and timber harvesting is largely due to the soil seed bank. 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. Forest ecosystems and wetlands contain a number of specialized plant species forming persistent soil seed banks. The absence of a soil seed bank impedes the establishment of vegetation during primary succession, while presence of a well-stocked soil seed bank permits rapid development of species-rich ecosystems during secondary succession. In addition their significance in regeneration of lost vegetation, seed banks land

(http://en.wikipedia.org/wiki/Soil_seed_bank).

Soil seed bank is a key element in plant community dynamics. Seed banks enable plant populations to maintain their genetic variability and to withstand periods of adverse conditions and persist over time. It is well own from theoretical and observational studies that the existence of this community component confers an advantage in habitats where environmental conditions are unpredictable and can change dramatically. Seed bank composition and density therefore play a crucial role in vegetation dynamics aboveground after agricultural land is abandoned (Luzuriaga *et al.*, 2005). While it has been suggested that soil seed banks play a major role in community dynamics in determining the composition of aboveground vegetation the species composition of seed banks and aboveground communities does not always resemble each other closely.

2.1.7.The effect of soil seed bank for regeneration of plant community

Plants maintain and expand their populations in time and space by the process of regeneration. Regeneration is a complex ecosystem process involving asexual and sexual reproduction, dispersal and establishment in relation to environmental factors (Haileab Zegeye *et al.*, 2011). It is an ecological process that ensures the development of successive generations of plants. The strategies by which plants regenerate are soil seed banks, seedling banks and vegetative parts. Many plant species possess combinations of regenerative strategies. The existence of multiple forms of regeneration has important roles in the evolutionary and ecological potential of the plant. Possession of several strategies increases the range of circumstances in which regeneration can occur, and this, in turn, widens the ecological range of the plant and confers a greater degree of persistence under fluctuating environmental conditions. Physical factors (e.g. light, temperature, moisture, nutrients and wind), biotic factors (e.g. competition, herbivory and disease) and disturbance regimes strongly influence regeneration processes, and thereby, determine the abundance and status of the plant species (Haileab Zegeye *et al.*, 2011).

Soil seed banks serve as a source of regeneration of plant communities (Demel Teketay, 2005). Seed banks have been exploited to manage the composition and structure of existing vegetation and to restore or establish native vegetation. Knowledge about the dynamics of soil seed banks and seedling populations provides clues about the potential of a plant community to regenerate after disturbance. The seed banks hence reflect the history of the vegetation and have the potential to contribute to its future through regeneration. The contribution of the seed bank to the regeneration process is mainly dependent on the existence, abundance and frequency of appearance of bare soil gaps varying in size and shape (Luzuriaga *et al.*, 2005).

A good understanding of natural regeneration in any plant community requires information on the presence and absence of persistent soil seed banks or seedling banks, quantity and quality of seed rain, longevity of seeds in the soil, losses of seeds to predation and deterioration, triggers for germination of seeds in the soil and sources of regrowth after disturbances. One of the most common methods of reproduction in most plant communities is therefore, regeneration from seeds of the soil seed bank (Demel Teketay, 2005). Soil seed banks play a major role in natural regeneration after disturbances such as fire, logging and overgrazing in humid environments, and determining the composition and density of seed banks is considered as an essential step in artificial restoration of degraded vegetation (Perera, 2005).

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. A 'Safe site' is considered as that zone in which a seed may find itself 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 (Eyob Tenkir, 2006). 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. 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.

2.1.8. Factor affecting soil seed bank composition

The composition of the seed bank depends on the plant communities appearing in a particular area both at the present moment and also in the past, as well as on the biological properties of plants (Perera, 2005). Recruitment by plants of available sites is driven either by soil seed banks or by recently dispersed seed. Since seeds from nearby forest often reach the soil within tens of meters, soil seed banks are often the main determinants of secondary vegetation composition. Composition and density of soil seed banks are influenced by different factors related to human disturbance. Fragmentation of surrounding forest acting as seed sources also reportedly affects seed availability on a given site. Agricultural practices have been shown to strongly affect soil seed banks (Groenendijk, 2005). Several factors, including longevity of viability, seed predation, rate of seed decomposition, seed dissemination, animal manipulation of seed distribution (i.e. caching), and seed germination rates affect seed bank composition. These factors can be divided into two categories: seed bank input and seed bank losses (Duncan, 2008). Dormancy expression has a large influence on the rate of seeds exiting the seed bank. Some seeds may persist in the seed bank for long periods. As new seed is deposited each year, seeds begin to accumulate and thus increase the likelihood of successful regeneration of vegetation after disturbance and possibly increasing site resilience. Other seeds do not exhibit dormancy and therefore do not contribute to the seed bank. A seed bank dominated by seeds lacking dormancy requires annual inputs to maintain site resilience. Under ordinary conditions (i.e. not having been recently disturbed and not experiencing extreme environmental conditions such as drought), the most important input to the seed bank is the level of seed production from mature plants on site. Abundant seed crops are often related to favorable weather conditions (Duncan, 2008). Grazing in particular influences the vegetation and seed bank dynamics in a variety ways. Most importantly, grazing has direct effects on plant community and seed bank by reducing biomass and seed production (Solomon Tefera, 2011).

2.1.9. Factors affecting seedling emergence from soil seed banks

Germination is one of the most critical phases in plant development. Each plant species has a specific range of environmental requirements necessary for germination. Environmental factors such as temperature, light, pH, and soil moisture are known to affect seed germination. The burial depth of seed also affects germination and seedling emergence (Lu P.et al., 2006). Several biotic and abiotic factors affect the establishment, survival and growth of seedlings. Spatial distribution of seedlings is affected by topography through its effect on drainage, moisture and nutrient variation (Mamo Kebede *et al.*, 2012).

Several internal and external factors prevent seeds germination. Among the internal factors, some important are: the presence of a seed coat, which is a barrier to the penetration of water and oxygen; presence of a biochemical inhibitor in the seed; and immature embryo. Among the external factors, the most common are soil water content and temperature (Christoffoleti & Caetano, 1998).

Temperature affects seed germination in several ways. Three cardinal temperatures can be recognized for every species, namely the maximum and minimum temperatures beyond which germination is prevented and the optimum temperature, which allows maximum germination in the shortest time (Cheng *et al.*, 2012).

2.1.10. Sampling methods used to study soil seed banks

In most seed bank studies, the sampling cost, the available resources (time, space, and labor), and the sampling tool have dictated an arbitrarily chosen but reasonable sample size. The optimal sample size (total number of sampling units) required in seed bank studies has been investigated specifically. The general consensus is that a large number of small sampling units are more appropriate than a small number of large sampling units (Benoit, 1989).

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 assess 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 (Mulugeta Lemenih, 2004). When the soil samples are collected the main problems are related to the heterogeneity present in the soil profile (Christoffoleti & Caetano, 1998). 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; (1) and (2) are sometimes difficult to classify. In most literatures the soil block is divided into three or four layers with 3 cm thick particularly on studies made in Ethiopia (Abdella Mekonnen *et al.*, 2007; Feyera Senbeta *et al.*, 2002).

2.1.11. Methods to determine soil seed bank status

The method of emergence of seedlings is simple and has the advantage of the easy identification of the species; however, it requires space in the greenhouse or growth chamber and the results can be influenced by seed dormancy (Christoffoleti & Caetano, 1998). 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 (Mekuria Argaw *et al.*, 1999; Feyera Senbeta and Demel Teketay, 2001). 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 (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.

2.2. Natural Regeneration of Wood Species and Soil Seed Bank Studies in Ethiopia

A good understanding of natural regeneration in any plant community requires information on the presence and absence of persistent soil seed banks or seedling banks, quantity and quality of seed rain, longevity of seeds in the soil, losses of seeds to predation and deterioration, triggers for germination of seeds in the soil and sources of regrowth after disturbances (Demel Teketay, 2005). The Afromontane forests in Ethiopia have experienced severe deforestation, fragmentation, loss of biodiversity, and impoverishment of ecosystems. Few remnants moist Afromontane forests in the central highlands of Ethiopia (Mamo Kebede *et al.*, 2012) is severely threatened by heavy anthropogenic disturbance and has declined from 16% of the catchment land base to 2.8% within the past three decades alone (Mamo Kebede *et al.*, 2012). The frequency and severity of the ongoing disturbance influences the species composition, demography and regenerative processes of a forest stand and when this disturbance become extreme, it leads to species disappearance or heavy fragmentation that limits restoration possibilities (Mulugeta Limenih and Demel Teketay, 2006). Understanding regeneration mechanisms is an important first-step towards a successful implementation of forest rehabilitation as restoration of degraded tropical forestlands rely much on natural regeneration. Seed rain, soil seed bank, seedling bank and coppices are the major sources of natural regeneration (Getachew Tesfaye *et al.*, 2010). While most species depend on persistent seedlings (seedling bank strategy), many others utilize soil seed bank regeneration mechanism. To determine the potential for adequate regeneration the existence of persistent soil seed banks or seedling banks must be known (Demel Teketay, 2005). Several authors have studied regeneration and soil seed banks in Afromontane forests of Ethiopia (Mulugeta Limenih and Demel Teketay, 2006).

In Ethiopia, studies that focused on soil seed banks and natural regeneration of wood species were studied by different scholars including (Mekuria *et al.*, 1999; Feyera Senbeta and Demel Teketay, 2001; Feyera Senbeta & Demel Teketay, 2002; Getachew Tesfaye *et al.*, 2010; Demel Teketay, 2005; Mulugeta Lemenih & Demel Teketay, 2006; Eyob Tenkir, 2006; Abdella Mekonnen *et al.*, 2007; Haileab Zegeye *et al.*, 2011 and Mamo Kebede *et al.*, 2012).

According to Getachew Tesfaye and his coworkers, regeneration is a central component of tropical forest ecosystem dynamics and restoration of degraded forestlands. Sustainable forest utilization is only possible if adequate information on the regeneration dynamics and factors influencing important canopy tree species are available. Tropical forests revealed variation in patterns of regeneration both through differences in their constituent species and the environmental variables in which they grow. They regenerate from one or more pathways: seed rain (recently dispersed seeds), the soil seed bank (dormant seeds in the soil), the seedling bank (established, suppressed seedlings in the understorey), and coppice (root/shoot sprouts of damaged individuals (Getachew Tesfaye *et al.*, 2010).

2.2.1. *Eucalyptus* plantation and naturally regenerated woody species

The presence or absence of understory vegetation in a plantation is a factor of density of the stand, the rainfall regime and management than their origin (Mulugeta Lemenih *et al.*, 2004). *Eucalyptus* plantation forests can host richer species and higher seedling/sapling densities than their adjacent disturbed natural forests (Eshetu Yirdaw, 2002). Even in the native forests of Australia, it is common to find 20 to 30 species of shrubs under *Eucalyptus* plantations, and rather more in the early regeneration stages. *Eucalyptus* has also the potential in enhancing the recruitment, establishment, and successions of native woody species (Feyera Senbeta *et al.*, 2002; Mulugeta Lemenih and Demel Teketay, 2004). Therefore, *Eucalyptus* can act as succession catalysts, facilitating the recolonization of native flora through their influence on understory microclimate and soil fertility, suppression of dominant grasses, and provision of habitats for seed dispersing animals (Feyera Senbeta and Demel Teketay, 2001: Feyera Senbeta *et al.*, 2002; Mulugeta Lemenih *et al.*, 2004).

Studies on the undergrowth of indigenous species, and their diversity in *Eucalyptus* plantations in comparison with the adjecent natural forests were carried out in Ethiopia (Feyera Senbeta and Demel Teketay, 2001; Feyera Senbeta *et al.*, 2002; Mulugeta Lemenih *et al.*, 2004). Studied herbaceous plant richness in plantations of *Eucalyptus* and *Pinus patula* in comparison with the adjacent natural forests and the result indicated that the species richness under plantations was as high as those of natural forests. In the regeneration study of woody species under the canopies of tree plantations (*E. globulus, Pinus patula, P. radiata* and *Juniperus procera*) made by Feyera Senbeta and Demel Teketay (2001), a total of 37 naturally regenerated indigenous woody species were recorded beneath all plantation stands, with densities ranging between 1,630 and 18,270 individuals per hectare. In the study of native woody species regeneration in exotic tree plantations (*E. globulus, E. saligna, Pinus patula* and *Cupruses lustanica*) at Munessa- Shahsemene forest carried out by Feyera Senbeta *et al.*, (2002), a total of 55 naturally regenerated woody species were recorded beneath all plantation stands with densities ranging between 2,300 and 18,650 individuals/ hectare in different stands. The study also revealed that seedling populations were the most abundant components of the regeneration in most of the plantation stands, forming 68% of the total regeneration count in all stands. Eshetu Yirdaw (2002) found greater abundance of naturally regenerated woody species under the exotic *C. lusitanica* than the native *Juniperus procera* stand in Ethiopia. The study also indicated that the density of naturally regenerated woody plants in plantations was over three times the usual planting density in Ethiopia, indicating a high potential of forest plantations for restoring the natural forest ecosystems on degraded lands at a comparatively low cost.

Study on the composition of ground vegetation in plantations of E. *globulus, E. grandis, E. saligna, Pinus patula* and the adjacent natural forest result indicated that there were no differences in the species composition of the ground vegetation of natural forests and plantations. Even the species richness, cover and biomass of their herbaceous flora did not differ (Fekadu Debushe, 2008).

CHAPTER THREE

3. Materials and Method

3.1. Site Description

3.1.1. Geographical Location

The study was conducted in the forest vegetation on Entoto Mountain and along the road to Gohatsion (i.e., Addis Ababa – Gohatsion), on the Central plateau of Ethiopia. It covers an over all distance of about 186 km.

Entoto Mountain is located about 10 km north from the center of Addis Ababa. Entoto is located between latitudes 9° 04' to 9° 06' N and longitudes 38° 42' to 38° 46' E. The altitude range of the area is between 2680 m and 3015 m a.s.l. The next study was conducted along the Addis Ababa to Gohatsion road which covers about 186 km, and is found in northern Shewa, in Oromia Regional State situated at latitude 9^0 01' to 9^0 54' N and longitude 38^0 14' to 38^0 52' E (Figure 1). The altitude range of this study area is between 2400 and 3192 m a.s.l. and located in Shewa plateau, Oromia Region (Figure 1).

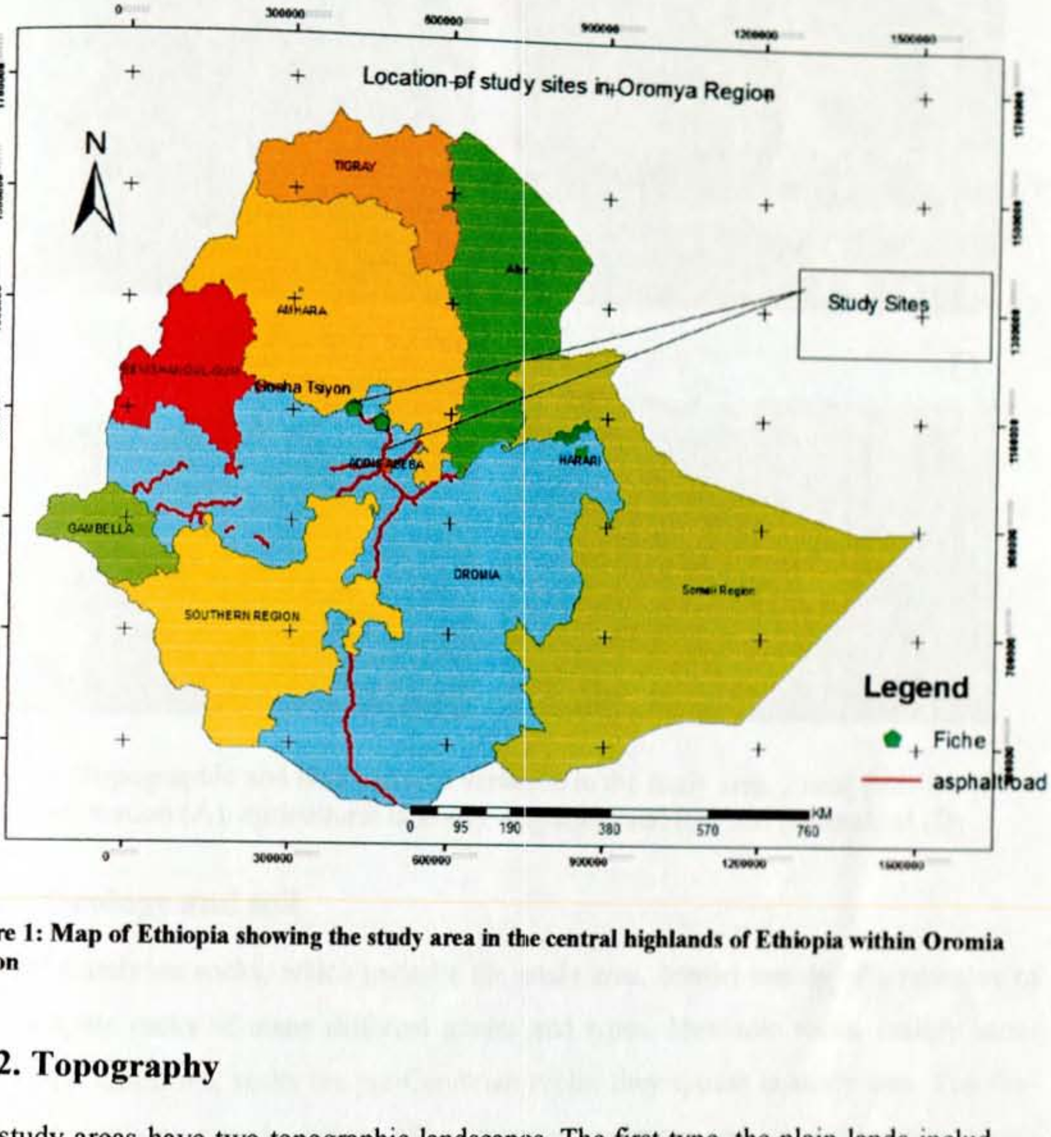


Figure 1: Map of Ethiopia showing the study area in the central highlands of Ethiopia within Oromia Region

3.1.2. Topography

The study areas have two topographic landscapes. The first type, the plain lands including pastureland, agricultural fields and wetland. The second topographical landscape is hill top vegetation. As it was observed the land use is predominantly agricultural land while the rest are hill top vegetation, cultural landscape (church vegetation), *Eucalyptus* plantation, wetland and pastureland (Figure 2).

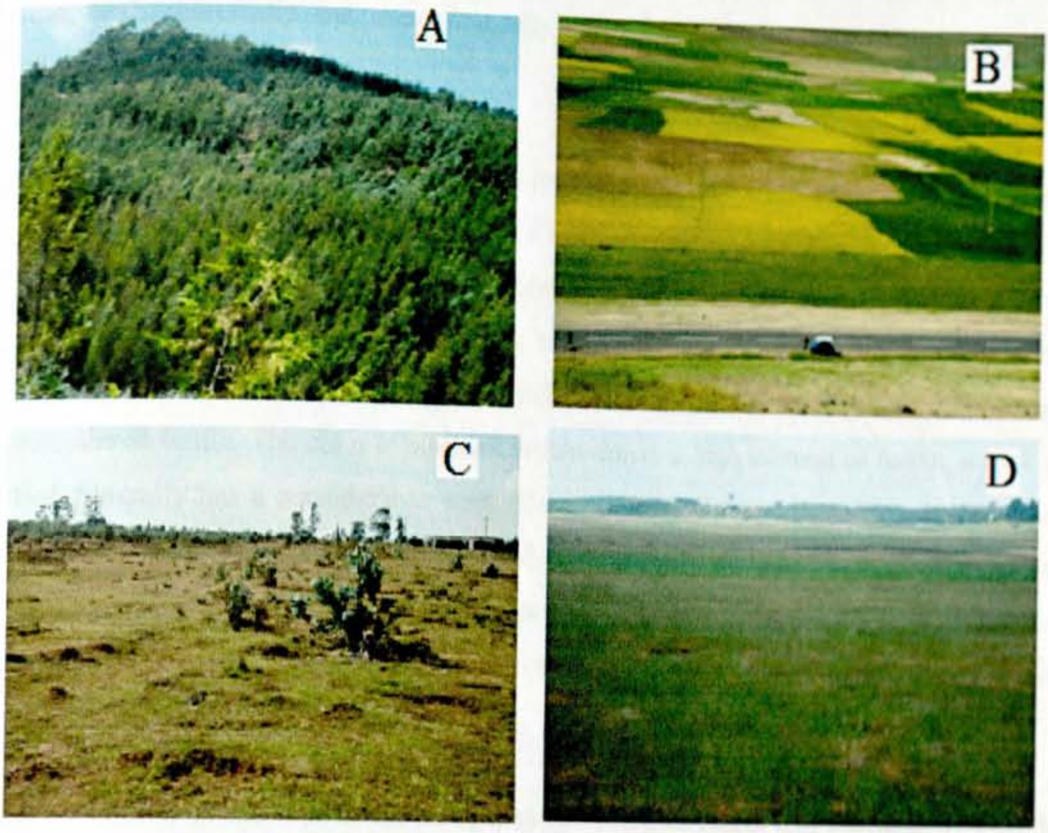


Figure 2: Topographic and land use type variation in the study area: *Eucalyptus* plantation (A), agricultural land (B), degraded land (C), and pastureland (D)

3.1.3. Geology and soil

The pre-Cambrian rocks, which underlie the study area, consist mainly of a complex of metamorphic rocks of many different grades and types. Mesozoic rocks, mainly sand-stones and limestone, cover the pre-Cambrian rocks; they appear in study area. The Pre-cambrian contains a wide variety of sedimentary, volcanic and intrusive rocks, which have been metamorphosed to varying degrees. Igneous rocks also constitute an important proportion of the pre-Cambrian rocks. Volcanic activities during the Tertiary period re-sulted in the extrusion of large quantities of flood lavas which now cover the Mesozoic rocks in most parts of the country. These lava flows occurred in a series of layers to form what is now known as the Trap Series. Various rock types, including rhyolites, trachytes, tuffs, and ignimbrites, compose the Trap Series, while basalts are the components and they constitute the main rock type of the study site. The basalts are uniform in composition, both chemically and mineralogically, over the whole range of the high plateau, (Tamrat Bekele, 1993).

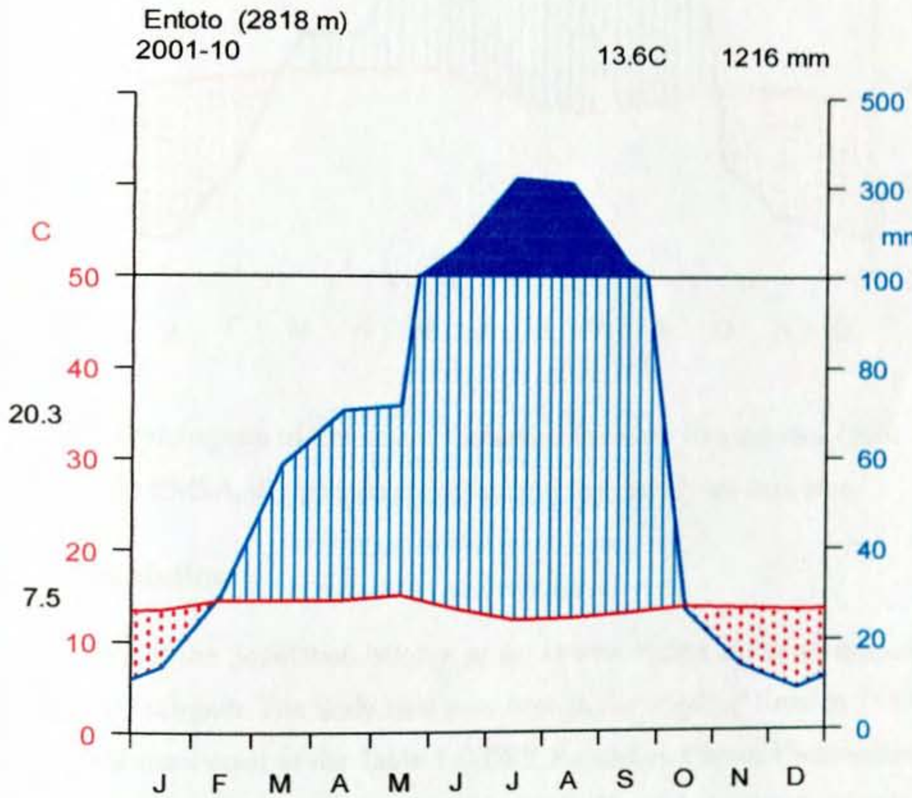
The younger geology of the study sites basically consists of Tertiary volcanic deposits formed from volcanic activity during the Cenozoic era (Fekadu Debushe, 2008). The soil catena (topo-sequence) of Entoto Mountain, for example, includes Nitisols at higher altitude and Cambisols in the middle of the hill. Down the mountain, Vertisols have been formed from the finest erosion material (Fekadu Debushe *et al*., 2010). All these soils are considered fertile. The color is blackish brown due to a high content of basalt, a rock type that generally has a considerable weathering potential. Large areas show severe erosion where the soil has been washed away and the bare bedrock is exposed. Sheep and cattle heavily graze the forest floor and their hoofs destroy the grass roots, which in combination with heavy rain showers during the rain season and dry topsoil the rest of the year, leads to a high risk of increased erosion.

The majority of the soils of the study area are volcanic origin and characterized the lava plateaux by means of two principal soil types originating from the disintegrating volcanic substrates intermingled with sand and limestone: the black and compact clays (Black soil) and reddish-brown and heavy loams (Red soil). The red and brown soils and loams are the most common soils in the study site (Tamrat Bekele, 1994).

3.1.4. Climate

The amount of rainfall varies considerably. Regional variation in rainfall in Ethiopia is mainly determined by two factors, namely the direction of moisture-bearing seasonal air currents and the elevation (Tamrat Bekele, 1993). In addition, variation in topography is another factor that influences the amount of rainfall. Tamrat Bekele recognized 14 rainfall regimes for Ethiopia, which can be grouped into two main types (Tamrat Bekele, 1993). The difference between the two types is determined by the occurrence of rain throughout the year (Type 1) or whether there are two rainy seasons (Type 2). Even though both types are represented in the study areas, Type 2 is specially considered the characteristic of the study area, and receives an average annual rainfall of 1122 to 1216 mm as indicated on Figure 3. The short rainy season extends from November to February, and the long rainy season ranges from June to September. Most of the rain comes in July and August.

Analysis of the ten years meteorological data shows that the mean annual temperature of the study area varies from 13.2 to 19 °C ranging from mean minimum of 7.5 to mean maximum of 25.9 °C temperature ranges as shown in Figure 3. The hottest month is May (mean maximum temperature of 25.9 °C), while the coldest month is December (mean minimum temperature of 7.5 °C).



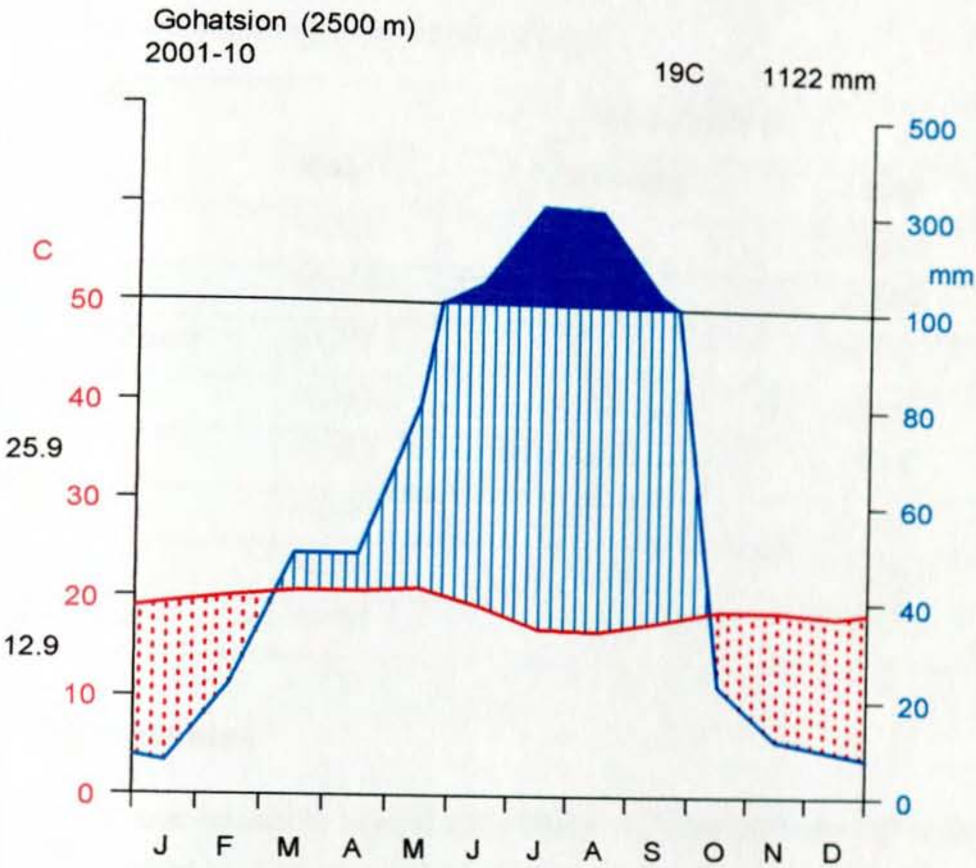


Figure 3: Climadiagram of Entoto and Gohatsion based on 10 years data (2001-2010) from EMSA, dry periods are dotted and wet periods are dark blue.

3.1.5. Population

The majority of the population belongs to the Oromo Nation and predominantly follows the Orthodox religion. The study sites pass through the woredas' listed in Table 1 having a population mentioned in the Table 1 (FDRE Population Census Commission 2010). It can be seen that both sexes are comparable in number and about 21% of the population are living in urban area and 79% are living in the rural area. The Ethnic group distributions in the region are about 84% Oromo and 15% Amhara. The mother tongue language is about 83% Afan Oromo and 17% Amarigna. 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 especially from Entoto-mountain.

Table 1: Northern Shewa Zone population data

Woreda	Population		
	Male	Female	Total
Sululta	64,516	64,484	129,000
Wuchale	49,236	48,293	97,529
Debere Libanos	23,351	21,828	45,179
Girar Jarso	34,467	32,845	67,312
Fiche	12,933	14,560	27,493
Degeme	49,205	49,938	99,143
Kuyu	60,244	60,808	121,052
Were Jarso	70,787	70,639	141,426

3.1.6. Vegetation

The study area belongs to tropical dry evergreen Afromontane forest belt in the central highlands of Ethiopia (Tamrat Bekele, 1993). Formerly, indigenous trees such as *Juniperus procera*, *Olea europaea* subsp. *cuspidata* and *Podocarpus falcautus* were dominantlly-covering most of the area. Similar to other parts of Ethiopia, the natural *Juniperus-Podocarpus-Olea* forest which was once abundant on the study area rapidly vanished due to an over exploitation of the indigenous trees (Fekadu Debushe, 2008). The remnants of *Juniperus procera* and *Olea europaea* subsp. *cuspidata* trees in the area reflect elements of this vegetation. On steep slope areas woodland was composed of *Ekebergia capensis*, *Myrsine africana*, *Acacia abyssinica* and some others, especially around Entoto Mountain (Fekadu Debushe *et al*., 2010).

3.1.7. Farming system and cropping

Subsistence farming that is based on a mixed farming of both livestock and agricultural crop production. Agriculture in study area is dominantly livestock (mostly cattle) production system (Figure 4). Crop cultivation involves plowing the fields with oxen-driven simple plows. Major crops grown in the area are barley, wheat, bean, pea and teff with two harvests per year. Fertilizers used on the farm fields in the area are diammonium phosphate (DAP) in combination with urea.

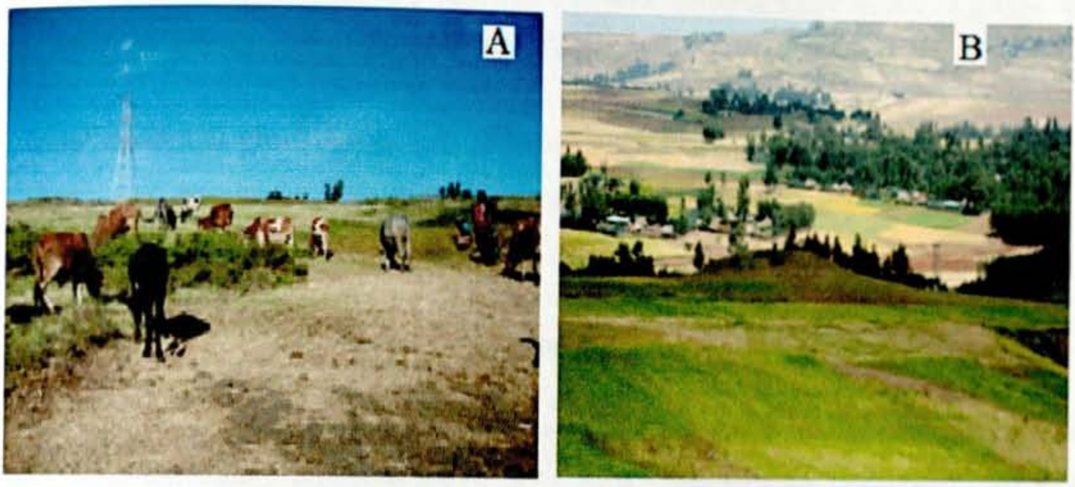


Figure 4: Mixed type of farming system in the study area

3.2. Methods of Data Collection

3.2.1. Sampling design

A reconnaissance survey and data collection were made between September and November 2012. The reconnaissance survey was made to obtain an impression about the variation of the study area. The survey indicated that the study area comprises a mosaic of different land use types. On Entoto Mountain and along the Addis Ababa - Gohatsion road, contains *Eucalyptus* plantation forest, farmland, pastureland, hill top vegetation, cultural landscape (church vegetation) and wetland. The land use types found at different altitudes have different types and levels of disturbances. Therefore, the selected area would give a chance to investigate SSB and natural regeneration potential, and to study the effects of the habitat type on SSB and natural regeneration.

3.2.2. Vegetation data collection and plant identification

Vegetation data was collected to examine similarity between above ground and seed bank floras. A total of 49 quadrats, 28 in Entoto Mountain and 21 along the Addis Ababa - Gohatsion road, were analysed. The quadrat sizes established for all life form were 10 m x 10 m. In each quadrat all trees, shrubs and herbs were identified. The altitude of each quadrat was recorded by using GPS. The collected specimens of each species in the plot were numbered, pressed, and taken to the National Herbarium (ETH), Addis Ababa University, for drying, identification and storage.

Plant specimen identification and verification have been made by comparison with authenticated specimens housed at ETH, consulting experts, and referring to the Flora of Ethiopia and Eritrea.

3.2.3. Sampling for natural regeneration of woody species

In each plot, all of the naturally regenerated woody species were identified and counted. When identification proved difficult in the field, collection and identification of specimens were used following the same procedures mentioned above. Individuals were categorized into three size groups following Feyera Senbeta and Demel Teketay (2001). The plants were categorized as, seedling (height $\leq$ 1.0 m), sapling (height between 1 and 3 m) and tree/shrub (height >3 m). The height (m) of seedlings and saplings within the plot were measured using a meter-marked stick.

3.2.4. Soil Seed Bank Analysis

In order to investigate the composition and density, as well as the vertical distribution, of the SSB in the different land use types, soil samples were collected from sampling plots measuring 15 cm x 15 cm (one at the center and the other four at the corners) and a vertical depth of 9 centimeters in each sample quadrat. The distance between consecutive plots within the seven transect line was 100 m along Entoto mountain spaced 200 m apart from each other. Along the Addis Ababa - Gohatsion road, the sample plots were laid out at about 10 km intervals. Sample plots were laid on each side of the road on different land use types including *Eucalyptus* plantation, agricultural land, wetland, pasturelands and cultural landscape (church vegetation).

From each sample plot four layers consisting of the litter layer and three successively deeper mineral soil layers (each three centimeters thick) were carefully removed with a field knife and a spoon and placed separately (Figure 5 A and B). The rationale for taking the soil samples at the three soil layers were to examine if there was any variation in the depth distribution of seeds. A total of 84 soil samples, including the litter layer, were collected from 28 sites at Entoto. Along the second study route, 63 different soil layers, including litter, were taken from 21 sites. Thus, a total of 147 soil samples were taken from four soil layers, at three successive layers (0-3 cm, 3-6 cm, and 6-9 cm), and the litter layer.

Soil samples from identical layers of the five sub-plots were mixed to form composite samples in order to reduce heterogeneity within the quadrats. Later on, the composite samples were divided into three equal parts out of which one was randomly chosen as the working sample for the study. The soil samples were transferred to cotton bags (Figure 5 C) and transported to the glasshouse of the Department of Plant Biology and Biodiversity Management, Addis Ababa University.

Figure 5: Sample collection process, collecting the samples and keeping separately (A&B), Transfering to the cotton bag (C)

3.2.5. Glasshouse germination

The seedling emergence experiments were performed in a glasshouse at the Department of Plant Biology and Biodiversity Management, Addis Ababa University under average temperature and humidity of 24°C and 57.5%, respectively.

In the glasshouse, each three cm layer soil was spread in a labeled circular plastic tray. Prior to spreading, each sample was thoroughly mixed after removal of all twigs, roots and rhizome fragments. To facilitate proper drainage of water, the pots were perforated at the bottom. Samples were then watered with a misting nozzle every other day to initiate germination and subsequent seedlings were checked twice per day.

The first seedlings in the glasshouse appeared one week after the start of the germination experiment. The emerging seedlings were collected, counted, pressed, dried, checked, and identified at the National Herbarium (ETH), Department of Plant Biology and Biodiversity Management, Addis Ababa University. Identified seedling were recorded and discarded.

As soon as seedlings were identified to the specific level of classification feasible (species) they were removed to reduce the possibility of germination suppression of other seeds due to competition. Some seedlings were left to grow to a certain size for ease of identification. Soil samples were stirred continuously to bring seeds located deeply in the soil samples to the surface thereby stimulating them to germinate. Digital information (Photos) of the seedlings was taken to be included as a pictorial representation. The seedling emergence experiment was terminated after seven months, (November 2012 to May 2013).

3.3. Data analyses

To investigate the effect of habitat types and the potential of SSB and naturally regenerating woody species, in terms of species composition and density of naturally regenerating wood species and SSB flora, the data were analyzed in the following ways. Species composition (number of species germinated per sample) and density of the SSB among the study site and between soil depths were compared using two-way analysis of Variance (ANOVA). Similarities of SSB flora and above ground vegetation were also compared using Jaccard's Coefficient of Similarity (JCS) (Krebs, 1989).

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

Where S_j = Jaccard similarity coeffiecient

a= number ofspecies common to both quadrats/samples

b= number of species in quadrat/sample 1

c= number of species in qudrat/sample 2

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 land use 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 seed bank between habitat types. Total naturally regenerating individuals are expressed as density per hectare. The Shannon-Wiener diversity index (H') and Shannon evenness index (Shanon, 1949) mentioned below were used to measure diversity of naturally regenerated woody species in the different land use types. Similarity index of understory regenerated woody species in the different land use types was calculated using Jaccard's Coefficient of Similarity (JCS) (Krebs 1989).

Shannon-wiener index (H) = $-\sum Pi \log_n Pi$

Where $Pi = \dfrac{Number.of.individual.of.one.species}{Total.number.of.all.individual(one.forest.only)}$

$$\text{Species richness} = \frac{(S-1)}{LogN},$$

Where S= total number of species; N= total number of individual of all species

$$\text{Evenness index} = \frac{H}{LogS}$$

Where H= Shannon Wiener diversity index; S = Total number of species

CHAPTER FOUR

4. Results

4.1. Description of the Habitat Types

Based on visal observation, six major habitat types were identified in study the area. These are acronymed as EPF (*Eucalyptus* plantation forest), HTV (Hill top vegetation), FAL (Farmland), PAL (Pasture land), DEL (Degraded land) and WEL (Wetland).

4.1.2. Species composition of soil seed banks

A total of 98 plant species representing 28 families were recovered from the litter and the top nine cm soil samples from the study area (Appendix 4). A full list of species and their families and seed densities in seed bank at different land use type can be found in Appendix 3. Herbs were dominant and represented by 87 species (88.8%), while, shrubs and tree were represented by 10 species (10.2%) and climber 1 species (1%). The species composition in different land use type ranged from 6 to 76 species; the highest number of species was recovered in the *Eucalyptus* plantation forest and the lowest in wetland (Appendix 3 and Figure 6).

Out of the total number of species recorded 76 were from *Eucalyptus* plantation forest, 34 from hill top vegetation including cultural landscape (church vegetation), 22 from farm land, 15 from pasture land, 15 from degraded land and six species were recovered from wetland. Overall, only a few species of woody (shrub/tree) were recorded from the soil samples collected from *Eucalyptus* plantation and hill top vegetation, i.e. only 10 shrubs/tree were germinated from the collected soil sample. But the rest habitat types had no recovery of woody species at all (Appendix 3).

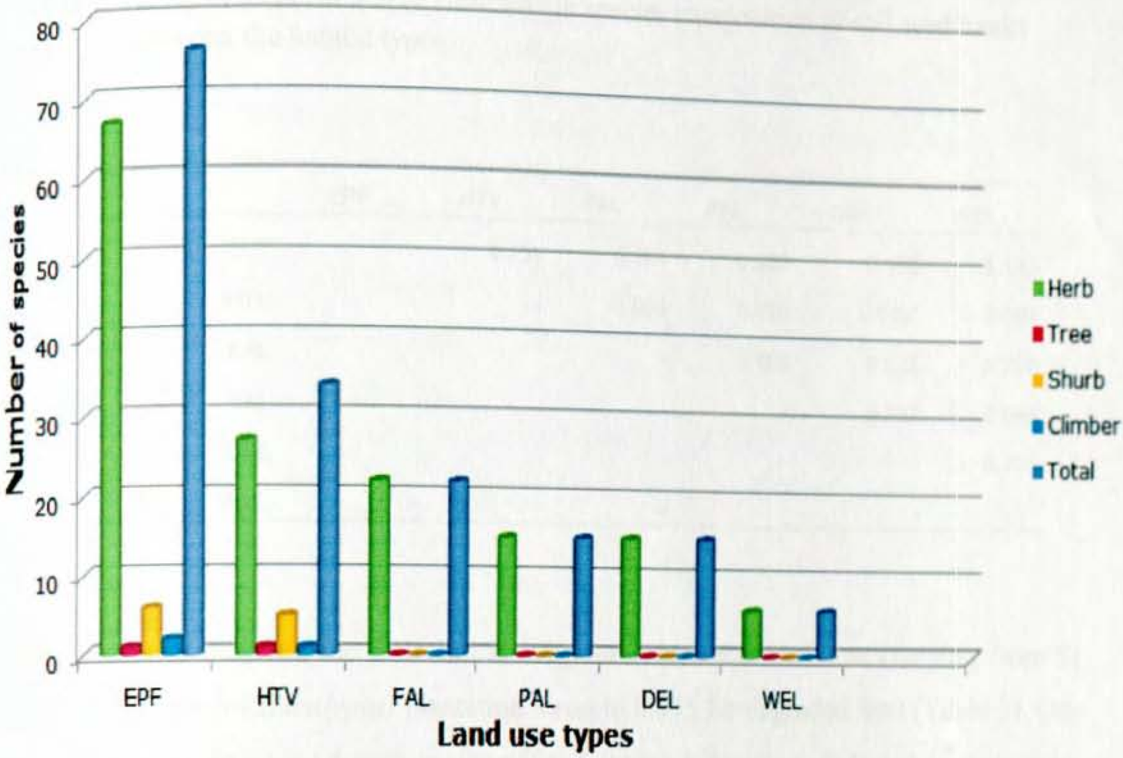


Figure 6: Number of species and their life forms recorded from SSB of the upper 9 cm soil depth collected from six habitat types; KEY: EPF – *Eucalyptus* plantation forest, HTV- Hill top vegetation, FAL - Farmland PAL- Pasture land, DEL- Degraded land and WAL- Wetland.

4.1.3. Similarity in species composition among land use types

The similarity in species composition of the SSB between the six-land use types was generally low and ranged from JCS values of - 0.024 (between hill top vegetation and farmland) to 0.588 (between farmland and degraded land) (Table 2).

Table 2: Jaccarad's coefficient of similarity in species composition of soil seed banks between the habitat types

	EPF	HTV	FAL	PAL	DEL	WEL
EPF	1	0.161	0.186	0.339	0.108	0.133
HTV	-	-	-0.024	0.425	0.149*	0.064
FAL			-	0.166	0.588	0.226
PAL			-	-	0.233	0.085
DEL				-	-	0.236
WEL	-	-	-	-	-	-

The similarity between the SSB and aboveground flora was very low (ranging from Sj values of 0.204 for *Eucalyptus* plantation forest to 0.375 for degraded land (Table 3). Only four woody species (*Acacia melanxylon, Laggera tomentosa, Solanum marginatum, Rubus apetalus* and *Vernonia adoensis*) were represented both in the aboveground vegetation and in SSB. Woody species that are commonly found in the above ground flora, especially in *Eucalyptus* plantation and hill top vegetation were not represented in the seed bank. For example, *Eucalyptus globulus, Juniperus procera, Myrsine africana, Erica arbora, Rosa abyssinica and Dovyalis abyssinica* are abundant species in the above ground flora but absent from the seed bank.

Table 3: Jaccard's coefficient of Similarity between soil seed bank and above ground flora

Habitat types	**Common Species**	**Species exclusively to above ground flora**	**Species exclusively to soil seed bank**	**Jaccard similarity Values**
EPF	19	44	30	0.204
HTV	10	13	13	0.278
FAL	7	10	6	0.304
PAL	4	5	3	0.333
DEL	3	4	1	0.375
WEL	1	1	1	0.333

4.1.4. Seed bank density and habitat types

Seed bank density (number of seedling emerging from seed bank samples) ranged from 3,911-154,844 m^{-2}. All soil layers and land use types exhibited various number of seed bank density. A total of 245,688 m^{-2} seedlings were recorded, of which 154,844 m^{-2} were recorded from *Eucalyptus* plantation forest, 27,333 m^{-2} from hill top vegetation, 19,822 m^{-2} from farmland, 26,044 m^{-2} from pasture land, 13,733 $m^{-2}$from degraded land and 3,911 m^{-2} from wet land (Figure 7).

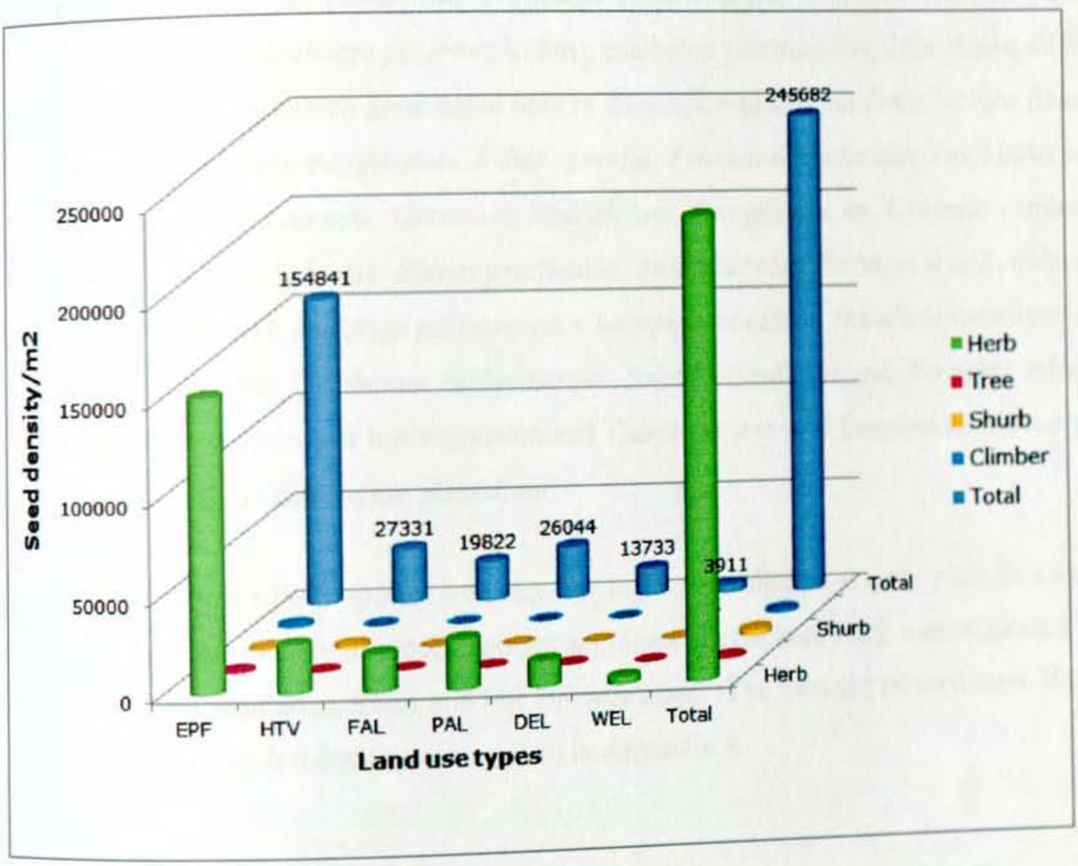


Figure 7: Seed density (seeds/m2) of species and their life form in different land use types; Key: EPF: *Eucalyptus* plantation; HTV: Hill top vegetation; FAL: Farm land; PAL: Pasture land; DEL: Degraded land; WEL: Wetland.

The density was larger in *Eucalyptus* plantation forest and hill top vegetation when compared to the remaining habitat types. The highest total densities of viable seeds among habitat types were recorded in *Eucalyptus* plantation forest (154,841 m^{-2}), while the lowest was recorded in the wetland (3,911m^{-2}). In fact, the contents of seed bank density varied from habitat to habitat (Figure 7).

The sixteen species with the highest soil seed density contributed 67.7% of the total estimated seed banks (Table 4 and Appendix 3). Where the most abundant species are *Oxalis radicosa, Eragrostis schweinfurthii and Campanula edulis* were recovered 58.6% in *Eucalyptus* plantation forest while the remaining 41.4% were contributed from the other habitat types. In all habitat types herbaceous species were dominant (Figure 7 and Appendix 3). *Cyperus pulchellus, Galinsoga quadriradiata, Trifolium pratense, Cotula abyssinica* and *Medicago polymorpha* have exhibeted germinability from almost all habitate types. Those which germinated only in *Eucalyptus* plantation forest include *Sonchus bipontini, Solanum marginatum, Rubus apetalus, Pennistum pentastachyum, Malva verticillata, Galium simensis, Geranium aculeolatum, Cynoglosum* sp. *Crassula alsinoides, Commelina benghalensis, Bidens prestinaria, Anthospermum herbaceum* and *Alchemilla pedata*. Similarly, *Buddleja polystachya, Chenopodium album, Datura stramonium, Kalanchoe petitiana, Raphanus raphanistrum, Solanium indicum* and *Vernonia adoensis* germinated only in hill top vegetation and *Conyza stricta and Laggera tomentosa* were recorded only in *Eucalyptus* plantation.

The density of woody species was very low in the soil collected at study sites. In a similar way, the total density of woody species germinated in the seed bank was originated from *Eucalyptus* plantation forest and hill top vegetation. The total list of seed bank flora by life form for each habitat type was given in Appendix 3.

Table 4: Soil Seed Density (seeds/m2) of some highest seed density species in relation to habitat types

No	Species	EPF	H T V	FAL	PAL	DEL	WEL	Total
1	*Alchemilla abyssinica*	3,689	-	533	-	-	711	4,933
2	*Alloteropsis semialata*	4,755	-	-	-	1,067		5,m822
3	*Campanula edulis*	14,489	-		-	1,867		16,356
4	*Crassula alsinoides*	6,089	-	-	-	-	-	6,089
5	*Cyperus pulchellus*	4,977	578	1,155	1,200	3,333	-	11,243
6	*Eragrostis papposa*	6,667	311	889	3,155	2,667	-	11,289
7	*Eragrostis schweinfurthii*	11,733	1,200	1,511	3,333	1,511	1,289	20,577
8	*Galinsoga quadriradiata*	4,489	4,933	4,444	222	533	-	14,621
9	*Geranium arabicum*	7,289	889	-	-	-	-	8,044
10	*Medicago polymorpha*	800	1,644	355	400	1,911	-	5,110
11	*Oxalis radicosa*	20,978	1,244	-	-	-	-	22,222
12	*Persicaria* sp.	7,333	-	2,622	-	-	-	9,955
13	*Pseudognaphalium luteo-album*	4,311	-	489	-	-	-	4,800
14	*Trifolium pratense*	755	667	2,044	2,489	222	444	6,621
15	*Veronica persica*	6,755	-	-	-	-	-	6,755
16	*Eragrostis* sp.	-	-	3,422	8,489	-	-	11,911

4.1.5. Vertical distribution of seed banks

The density of seeds in the soil showed similar vertical distribution in all land use types. The highest densities of seeds were collected from the upper three centimeters of soil, gradually decreasing with increasing depth (Figure 9 and Appendix 4).

There was variation in the depth distribution pattern of seeds among different plant species. In almost all samples, the litter layers had lower number of species and seed density compared with that in the top three centimeter layer (Figure 8). For instance, seeds of some species were recovered only from the upper three centimeter soil layers, e.g. *Alchemilla pedata, Anthemis tigreensis, Capsella bursa-pastoris, Carduus leptacanthus, Cerastium octandrum, Commelina benghalensis, Cynoglosum* sp, *Geranium aculeolatum, Kalanchoe petitiana, Laggera tomentosa, Malva verticillata, Sonchus asper, Sonchus bipontini, Caylusea abyssinica, Salvia nilotica, Solanum marginatum, Satureja punctata* *pontini, Caylusea abyssinica, Salvia nilotica, Solanum marginatum, Satureja punctata* and *Raphanus raphanistrum*. Likewise *Asterolinon adoense, Trifolium schimperi, Haplocarpha schimperi* and *Vernonia adoensis* had their seeds distributed in the deeper (6-9 cm) soil layers. On the other side *Acacia melanxylon, Alchemilla abyssinica, Alloteropsis semialata, Anagallis arvensis, Campanula edulis, Conyza stricta, Cotula abyssinica, Crassula alsinoides, Crepis rueppellii, Cyperus pulchellus, Delosperma abyssinica, Eragrostis papposa, Eragrostis schweinfurthii, Galinsoga quadriradiata, Medicago polymorpha, Oxalis radicosa, Pseudognaphalium luteo-album, Polygonium nepalensis* and *Persicaria* sp. had almost uniform depth distribution.

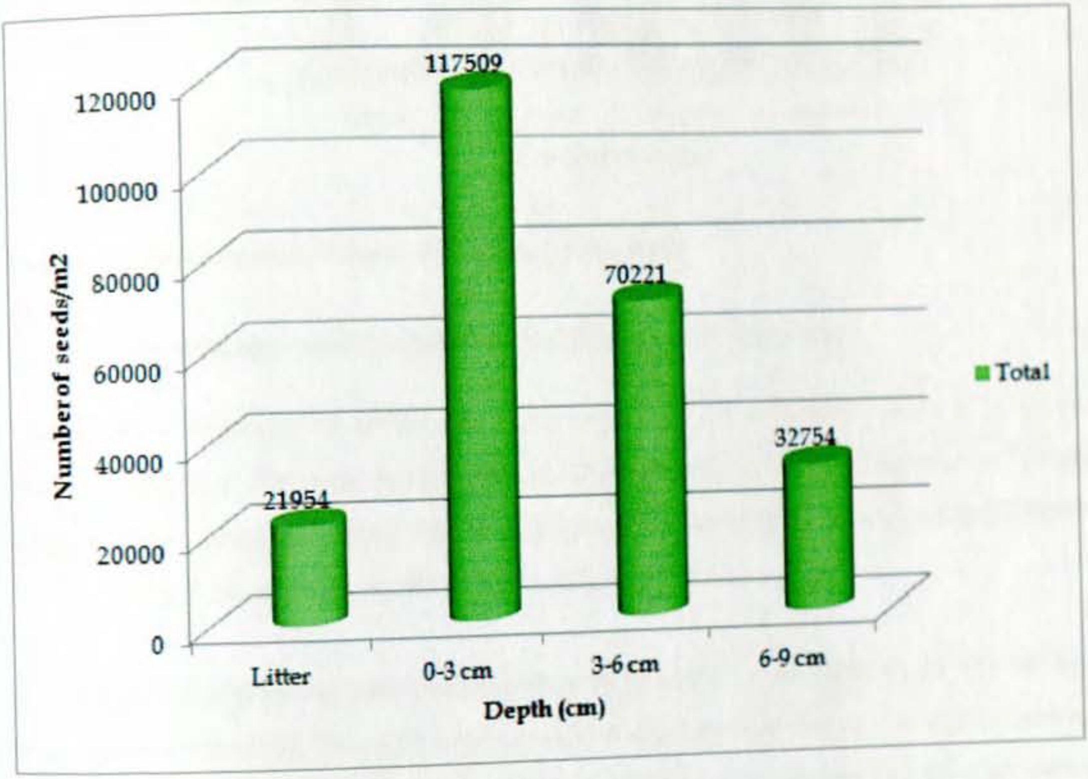


Figure 8: Vertical distribution of seeds

Herbs and grasses have small seeds compared with many woody species, and species with small seeds have a better chance of becoming buried in deeper layers of the soil.

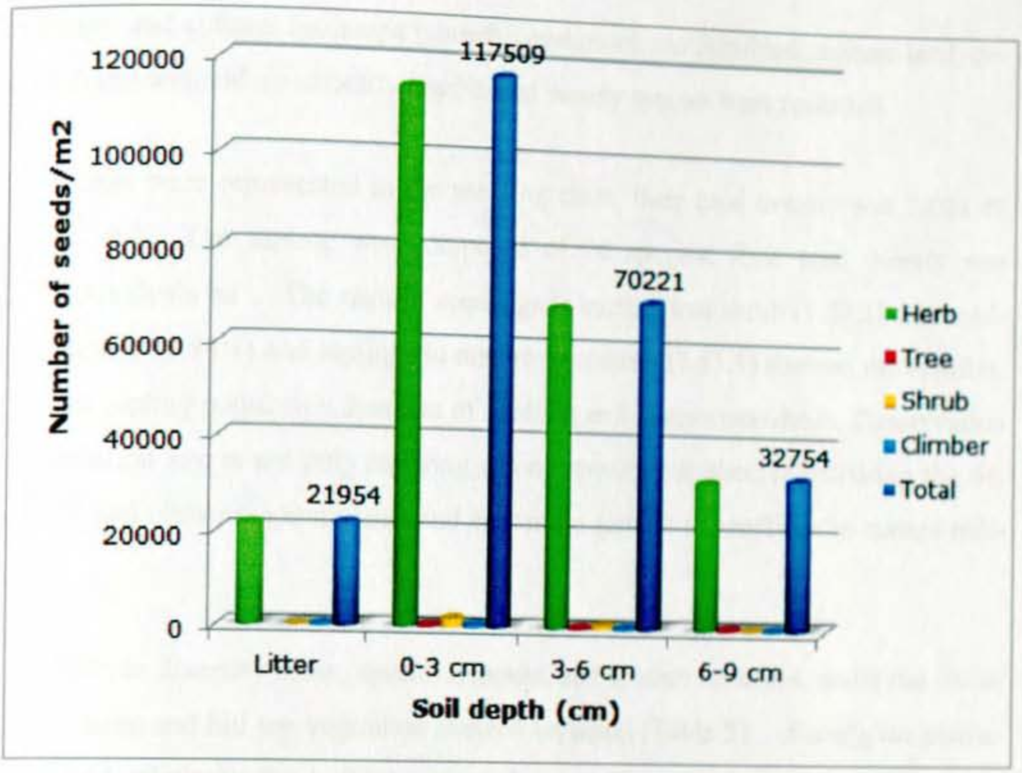


Figure 9: Life form distribution of seed bank with depth

4.2. Compositions and Density of Seedlings and Saplings

The status of regeneration in the study area indicates composition and density of seedlings and saplings. The total number of naturally regenerating species recorded in Entoto Mountain and along the Addis Ababa to Gohatsion road were 25, representing 20 families, of which 52% were trees, 40% shrubs and 8% climbers.

The density of understory regenerated woody species was variable among the various habitat types and species. The four species with the highest densities in *Eucalyptus* plantation were *Rosa abyssinica, Juniperus procera, Myrsine africana and Dovyalis abyssinica*. The species (*Carissa spinarum, Bersama abyssinica, Maytenus arbutifolia, Rosa abyssinica, Maesa lanceolata, Myrsine africana, Juniperus procera, Erica arborea, Rubus apetalus and Dovyalis abyssinica*) were widely distributed in the *Eucalyptus* plantation forest than in hill top vegetation. On the other side *Olea europaea, Prunus africana, Vernonia amygdalina* and *Laggera tomentosa* were also widely distributed in the hill top

top vegetation and cultural landscape (church vegetation). In farmland, pasture land, degraded land and wetland no naturally regenerated woody species were recorded.

The 21 species were represented in the seedling class; their total density was 3,024.49 individuals ha^{-1}. The sapling was composed of 20 species; their total density was 3,587.75 individuals ha^{-1}. The ratio of seedlings to mature tree/shrub (1.29:1) and seedlings to saplings (0.84:1) and saplings to mature tree/shrub (1.53:1) showed the distribution of more sapling population than that of seedling and mature tree/shrub. Conservation of this plantation site is not only restoring woody species but also rehabilitating the degraded land and allowing germination and successful growth of seedlings to mature individuals.

Shannon-Wiener diversity index, species richness, and species evenness, under the *Eucalyptus* plantation and hill top vegetation showed variation (Table 5). *Eucalyptus* plantation exhibited relatively the highest mean values of Shannon species diversity (2.48), species richness (42) and evenness (0.651), while the hill top vegetation exhibited the lowest mean values of Shannon species diversity (2.34), species richness (40) and evenness (0.619). These results indicate that *Eucalptus* plantation harbors larger number of species than the hill top vegetation. For the other habitat types, no seedling or sapling were recorded.

Table 5: Shannon-Wiener diversity index (H'), species richness and species evenness, under Eucalyptus plantation and hill top vegetation

Habitat Type	Shannon index (H)	Species richness (S)	Evenness (E)
EPF	2.48	42	0.651
HTV	2.34	40	0.619

4.2.1. Similarity in species composition of seedling and sapling between different land use types

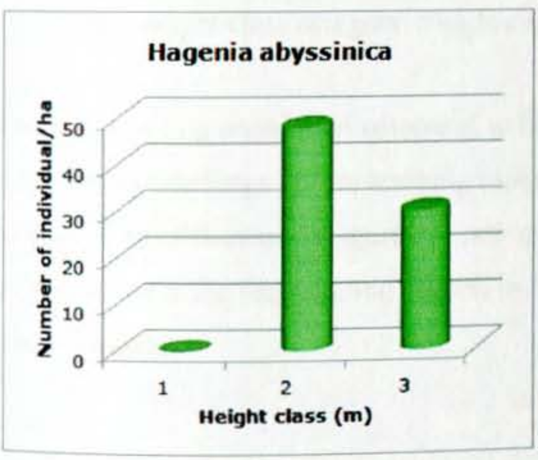
The similarity in species composition of the natural regeneration between the land use types ranged from Sj values of 0 (between Farmland, pastureland, degraded land, wetland and *Eucalyptus* plantation forest, hill top vegetation) to 0.60 (between *Eucalyptus* plantation forest and hill top vegetation).

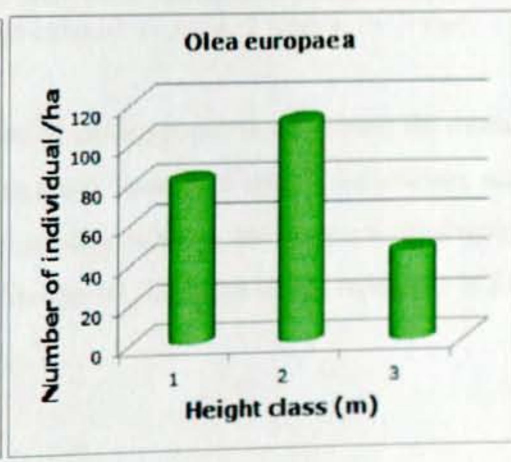
4.2.2. Height class distribution of naturally regenerat ing woody species

Patterns of height class distribution of seedlings, saplings and mature individuals varied from species to species (Figure 10). Height class distribution of five representative species of the study area was grouped into two categories:

1) Species having the lowest proportion of individuals in the lower class while the highest proportion of individuals in the middle class and then decreasing towards the higher class. *Hagenia abyssinica* has missed the seedling group. The other species included in this group are *Olea europaea* and *Prunus africana.*

2) In the second category, the species having the highest proportion of individuals in the lower class and then decreasing towards the higher class. Species in this group include *Juniperus procera* and *Dovyalis abyssinica.*





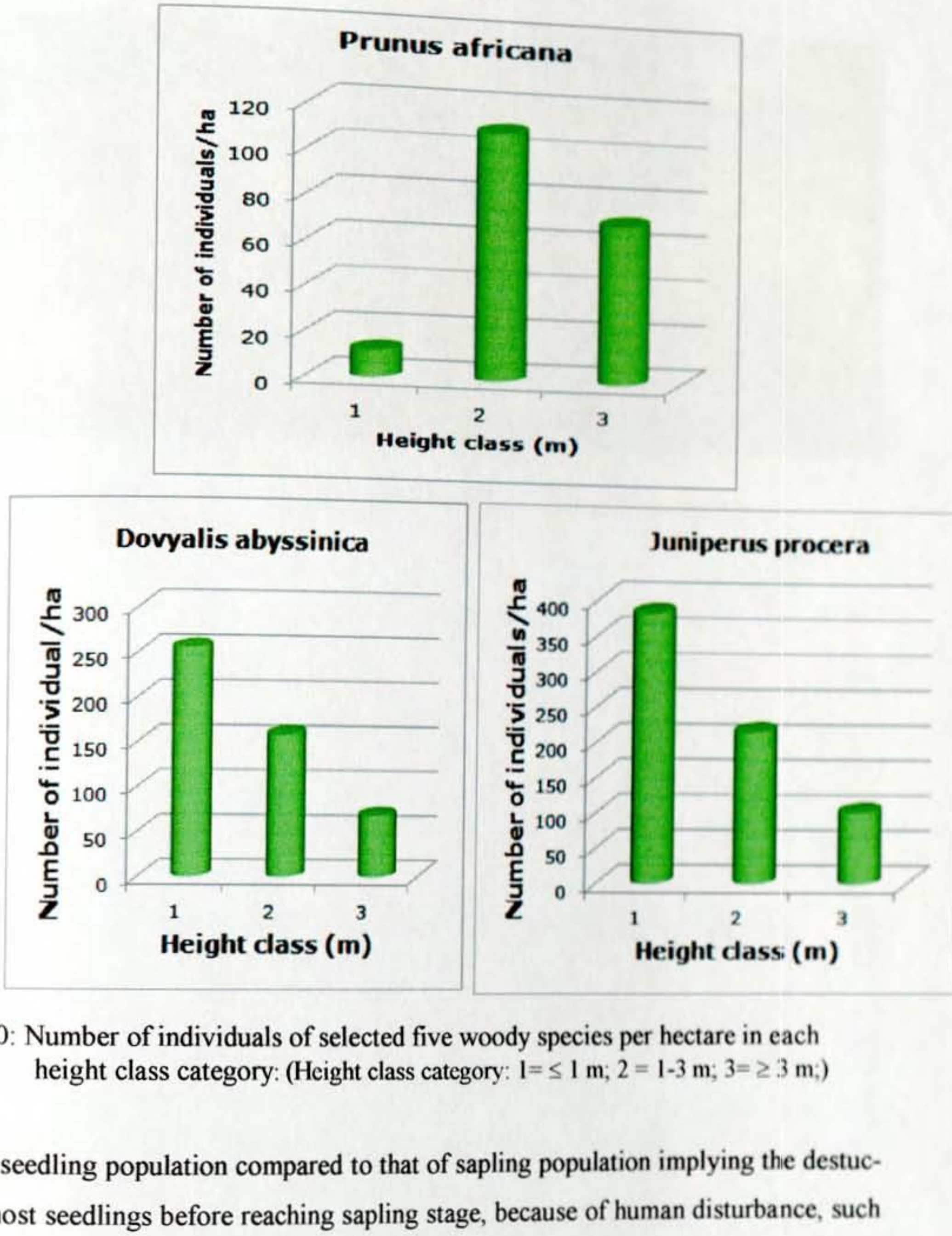


Figure 10: Number of individuals of selected five woody species per hectare in each height class category: (Height class category: 1= ≤ 1 m; 2 = 1-3 m; 3= ≥ 3 m;)

The less seedling population compared to that of sapling population implying the destuction of most seedlings before reaching sapling stage, because of human disturbance, such as collection of firewood (Figure 11), animal grazing, farming, and other activities reduces significantly the regenerating process in *Eucalyptus* plantation forest, especially in Entoto Mountain.

Figure 11: Human disturbance for the regeneration process in the *Eucalyptus* plantation forest

CHAPTER FIVE

5. DISCUSSIONS

5.1. Soil Seed Banks and Natural Regeneration Status

The seed banks were dominated by herbaceous species in the study area, while woody species had very low or no seeds in the soil samples. Most of the seed banks under the different habitat types were characterized by high proportions of herbs (about 87.8%) while woody plants dominated the aboveground flora recorded. Wang *et al*., (2009), stated that the high density of herbaceous seeds in the seed bank may be related to species traits. The similarity between the seed bank and aboveground flora was very low.

Moreover, there are more herbaceous seeds in the upper soil layer than in the lower soil layer. This pattern may be attributed to seed size and the vertical movement of seeds. Several studies have supported the lack of similarity in species composition between the seed in the soil and the aboveground vegetation (Feyera Senbeta & Demel Teketay, 2001; Abdella Mekonnen *et al*., 2007, Mekuria Argaw *et al*., 1999; Kebrom Tekle and Tesfaye Bekele, 2000; Tefera Mengistu *et.al*., 2005; and Alemayehu Wassie and Demel Teketay, 2006). Abundance of species in standing vegetation had predictive value for abundance in the persistence seed bank. At the local scale the present study indicated that the persistant seed bank and standing vegetation have exhibited low compositional similarity.
Also down-slope dispersal promoted by frost heaving in combination with runoff (Entoto Mountain) could be possible factors accounting for poor corroespondence between the density of persistant seed bank and the standing vegetation (Abdella Mekonnen *et al*., 2007).

Alemayehu Wassie, (2007), reported that correlations between aboveground vegetation and the seed bank composition have usually been found to be weak and this is often ascribed to disturbance, with closer relationships found for more stable communities. Nevertheless, even in plant communities with a long history of stable species composition especially in cultural land scape (church vegetation), it is well known that many species present in the aboveground vegetation may be absent from the seed bank as confirmed by Godefroid (2006). Some other species, although present in the aboveground vegetation, lack viable seeds, which are observable after green house experiment. It could be argued that these species may have nonviable seeds in the sampled soil although the soil samples were not subjectd to sieving (Abdella Mekonnen *et al.*, 2007).

Generally, the observed low representation of the standing vegetation by the seed bank could be attributed to conitnious farming, erosion, human disturbance and grazing inducing lack of seed reserve for vegetation to respond following a favorable condition. One of the main probable reason for the disparity between aboveground vegetation and soil seed bank flora, Eyob Tenkir, (2006), explain that 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. So that, many woody species in dry Afromontane forests germinate within a few days or weeks after dispersal. However, composition of seed bank recorded resembled the aboveground vegetation in few cases; for example, *Acacia melanxylon, Rubus apetalus, Achyranthes aspera, Alchemilla abyssinica, Datura stramonium, Galinsoga quadriradiata* and *Solanum marginatum* are an indicator species for the study sites.

In the present study, herbaceous species constituted the most prevalent life forms emerging from various land use types. Their predominance in seed banks can be explained by a combination of several factors. These herbaceous plants generally which are less likely to be predated on, or damaged by microorganisms than large seeds of perennial tree species. Seed size may be another factor responsible for the scarcity of many aboveground species in the seed banks, because seed size and seed longevity are often negatively correlated (Wang *et al.*, 2009).

Herbacious species have survived through time because of their ability to resist several adverse climatic conditions, tolerating high and low temperature, dry and humid environment and variation in oxygen supply (Demel Teketay, 2005). The fundamental point in the success of herbacious species survival is their persistence capacity in certain areas. This capacity is a consequence of a great number of small seeds produced, long term viability, continuous germination, phenotypic and genetic plasticity (Christoffoleti & Caetano 1998). The conclusion from this study was that the seed banks usually contain a high proportion of herbaceous species, which depend on the persistent seed bank as part of their opportunistic strategy.

With continuous farming, along the road to Gohatsion, the proportion of herbaceous forest species declines and the seeds of weedy species such as *Galinsog quadriradiata*, which are favored by continuous cultivation, increase rapidly in the soil. As the cultivation progresses, the composition and density of the seed bank start to change gradually. The change is more pronounced in the woody component of the seed bank as evidenced almost from the absence of woody species in the farmland, pastureland degraded land and wetland. Very few multipurpose trees are left on farms. Since these trees are cleared from time to time, their reproductive capacity is greatly reduced. Even if they produce seeds, which eventually germinate, the seedlings are removed regularly due to continuous farming. Consequently, herbs, including grasses, would dominate the soil seed bank since many herbs grow and reproduce quickly from seeds.

Therefore, the woody species representation in the seed bank or advance regeneration is usually low or totally absent. On the other hand, seeds of the woody species may germinate soon after dispersal or may be affected by pathogens and predation agents and as a result few such species were represented in the seed bank. The residence time seeds of woody species in the soil are relatively short compared with those of herbaceous species, which are capable of maintaining their viability for a long time. Those seeds, which do not germinate are consumed by predators or succumb to attack by microorganisms. Many of them are also capable of re-sprouting from damaged stems or roots. Although there are a few exceptions, most of the woody components of the forest vegetation lack reserves of long-lived seeds in the soil. Seeds of several woody species are large and contain high moisture, indicative of adaptations to immediate germination and seedling establishment and survival under the canopy of forests (Demel Teketay, 2005). Seed bank results also indicated that viable seeds of native woody species are generally rare in some habitat (*Eucalyptus* plantation and hill top vegetation) while it is totally absent in the seed bank of the other habitats.

Therefore, the sources of regrowth of woody species are totally dependent on the presence of the whole or a portion of the forest vegetation with mature individuals, since the probability of long-distance dispersal of most woody species is very low due to the large size of their seeds. In the event of disturbance, herbaceous species can regenerate from both the soil seed bank or from recently dispersed seeds while the woody species regenerate from pre-existing seedlings, coppice shoots or from recently dispersed seeds.

Tropical dry evergreen Afromontane forests accumulate large quantities of persistent seeds of herbaceous species in the soil that is confirmed by this study. Previous research has shown that existence and persistence of seeds in the soils are partially influenced by seed production and intrinsic attributes of seeds (Luzuriaga et al., 2005). The accumulation of seeds in the soil is favored by the dormancy of many of the seeds, which is caused by either the presence of embryo dormancy or impermeable seed coat or both (Alemayehu Wassie, 2007). Dormancy is selected for in most of tropical dry evergreen Afromontane species, which are characterized by long dry seasons and unreliable rainy periods (Demel Teketay, 2005). In non-dormant seeds, dormancy is induced if the seeds are dispersed under dense canopy or buried in the soil.

Natural disturbances and human exploitation, such as careful selective cutting, may promote regeneration of the *Eucalyptus globulus.* However, excessive exploitation of species or clearing and conversion of the forest areas into permanent cultivation will eliminate or reduce the seed reserve and seedling populations. Especially along the Addis Ababa to Gohatstion road (farm land, pasture land, degraded land and wet land habitat types) the seed bank contains no woody species. This may be due to clearing of the forests followed by permanent cultivation, or there was no forest in the past.

The species composition and density of the seed banks in each habitat generally depend on the history of the sites. The factors that are responsible for the disparity in densities of seeds and composition of species within the site might be related to species traits, or environmental factors. In fact it requires further detail investigation.

It was observed that seed bank was concentrated on the upper soil layer (0-3 cm) for most of the species in the study. Overall species and seed numbers were lower in the lower layers than in the upper layer. With increasing soil depth, the seed density and its species compostion declined. This is consistent with what has been found in other studies (Chaideftou *et al.*, 2011; Godefroid *et al.*, 2006; Demel Teketay, 2005; Abdella Mekonnen *et al.*, 2007; Anderson *et al*, 2012; Tessema *et al.*, 2012).

The number of species represented in the seed banks collected from *Eucalyptus* plantation forest and hill top vegetation was relatively high while it is low in the other land use types. Similarly, seed bank densities in the soil samples from Entoto *Eucalyptus* plantation forest were higher than that of the other land use types. In general, our results provide further evidence that consolidates the conclusions of previous studies on SSB in Ethiopia.

Our result imply that the herbaceous flora has a better chance of natural recovery in the event of disturbances owing to the diverse seed banks while the regeneration of woody species, trees and shrubs, would be prevented by removal of mature individuals and their seedlings on the different habitats since most of them lack seed reserves in the soil. The previous research has shown that future existence of the woody flora characteristic of tropical dry evergreen Afromontane areas in Ethiopia depends on the conservation and sustainable utilization of the few remnant natural forests (Feyera Senbeta & Demel Teketay, 2002).

One of the main objectives of this study was to evaluate the potential of natural regeneration status in different land use types. The result showed difference between the floristic composition of the mature stand and the seed bank species. There were seedlings and/or saplings that were not counter represented by mature woody species. The result indicates high density of sapling than seedling. Seedlings are more attacked by environmental hazards and biotic factors especially at the early stages of seedling establishment. According to Demel Teketay, (1997), the main causes of seedling mortality include erosion, shade, drought, human disturbances, and biotic influences such as herbivory, disease and so on.

The composition, distribution and density of seedlings and saplings indicate the future status of the study sites. The absence of seed banks and seedlings, removal of mature trees as well as their stumps and roots coupled with poor long distance dispersal will have severe consequences on the regeneration of the woody vegetation. This implies that the future existence of tropical dry evergreen Afromontane forests depends on the protection and conservation of the remaining patches of forests (Demel Teketay, 2005). Therefore, further studies and continuous monitoring of the natural regeneration and the soil seed bank in the *Eucalyptus* plantation and along the Addis Ababab to Gohatsion road is required.

Previous studies have shown that the presence or absence of understory vegetation in a plantation is a factor of density of the stand, the rainfall regime and management than their origin. *Eucalyptus* plantations have been shown to foster or catalyze regeneration of native species when they are planted close to seed sources and protected from human and animal disturbances, thereby contributing to rehabilitation of degraded lands and increasing biodiversity. Also the less dense stands of *Eucalyptus globulus* harbors more regenerated plant species than the high dense stands of *Eucalyptus globulus*. Infact human disturbance, such as collection of firewood, animal grazing, farming, and other activities reduces significantly the regeneratin process in *Eucalyptus* plantation forest. Therefore, *Eucalyptus* can act as succession catalysts, facilitating the recolonization of native flora through their influence on understory microclimate and soil fertility (Fekadu Debushe, 2008; Fekadu Debushe *et al.*, 2010; Mulugeta Lemenih *et al.*, 2004). This is in agreement with our findings.

The density of understory regenerated woody plants was variable among the various habitat types and species. The heighest number of species and density of seedling and sapling were widely distributed in the *Eucalyptus* plantation forest and in hill top vegetation. A study made by Fekadu Debushe, (2008) clearly demonstrated, provided that there is a seed source in the vicinity, establishment of forest plantations can help not only to provide wood for various purposes, to rehabilitate degraded lands and to conserve soil and water but also to foster or catalyze natural regeneration of native woody species thereby enhancing biodiversity. In agreement with this notion, Mulugeta Lemenih (2004) demonstrated the effect of canopy cover and undersory environment of tree plantations on undergrowth species richness, and concluded that stands of plantation species with open canopies could enhance more native woody recolonization than stands with dense canopies as in Entoto *Eucalyptus* plantation forest. In fact, other site factors such as photosynthetically active radiation (PAR) reaching forest floor could have a substantial impact on ground flora regeneration and recolonization in forest plantations.

Farmland, pastureland, degraded land and wetland habitat types have no regeneration of woody species were recorded. The probable reason for this result may be the disturbance caused by domestic animals, soil erosion, and continuous farming or it might be totally the absence of any forest at the past. Even if there were seeds of woody species such environmental factors as high temperature and direct solar radiation on the bare soils of the habitats that may induce rapid loss of seed viability and consequently reduce woody species composition in the above listed habitats, which are in consistent with (Mulugeta Lemenih & Demel Teketay, 2006). Furthermore, germinating seeds of the woody species on the farm fields either from the SSB and/or newly dispersed seeds are continuously removed during site preparation and successive weeding.

The *Eucalyptus* plantation is characterized by high density of naturally regenerated woody species. Thus, the naturally regenerated woody species are in a good state of regeneration. *Myrsine africana, Juniperus procera* and *Rosa abyssinica* are species with the highest density of naturally regenerating woody plants than the remaining woody species in *Eucalyptus* plantation forests that is also consistent with the reported data (Fekadu Debushe, 2008). The probable reason for high density of *Myrsine africana and Rosa abyssinica* may be due to their resistance to browsing by wild or domestic animals. These species are also of very low household use and these have low commercial demand.

It is very interesting to note that the highest number of naturally regenerated woody species (25 species) was recorded under the *Eucalyptus* plantation rather than from the hill top vegetation including cultural landscape (church vegetation). In addition, the density of naturally regenerated woody species under the *Eucalyptus* plantation was the highest. These findings provide preliminary evidence against the assertion that *Eucalyptus* plantation forest does not allow the regeneration of other plants under its canopy as confirmed by Feyera Senbeta & Demel Teketay (2001). Our result showed that seed banks and natural regeneration status are better indicators for natural regeneration, which can provide important reference for ecological restoration globally as stated by Cheng (2012).

5.2. Conclusion and Recommendations

The seed banks were highly heterogeneous. Species composition of the parent vegetation, the fruiting season and seed dispersal patterns affect the spatial heterogeneity of the SSB. The study showed that different habitat types have variations on seeds buried in the soil and natural regeneration potential. Generally, the seed bank study indicated that from Entoto-mountain and along the Addis Ababa - Gohatsion road possesses large populations of buried seeds of herbaceous species. On the other hand, trees and shrub species have very low viable seeds in the soil. Especially farmland, patureland, degradedland and wetland habitat types have no regeneration of woody species were recorded. The composition and density of SSB in the study site show variation in different land use types. High seed density and composition were recorded in the *Eucalyptus* plantation forest.

Our results showed that clearance of tropical dry evergreen Afromontane natural forest followed by subsequent cropping alters the composition and density of viable seeds in SSB. Deforestation followed by subsequent cultivation resulted in a more or less continuous exhaustion of seeds of woody species from the SSB. This shows that deforestation, driven mainly by the need for more land for permanent agriculture, is a threat to the diversity of the tropical dry Afromontane forest in the highlands of Ethiopia, not only through direct removal of the aboveground forest vegetation but also through gradual exhaustion of viable seed reserves of the woody species in the SSB.

Since fresh dispersal of seeds will be needed for the restoration of native woody species on abandoned agricultural sites in the future, there is a desperate need for urgent interventions, backed by appropriate policy and legislation instruments, which could prevent or reduce deforestation and enhance development, conservation and sustainable utilization of the remnant tropical dry evergreen Afromontane forests. Furthermore, future planning for rapid forest vegetation restoration on degraded abandoned farm fields should be designed based on strategies that include measures other than relying only on SSB. This research result describes full picture of the interaction between *Eucalyptus* plantations and naturally regenerated woody species. Therefore, to conserve naturally regenerated woody species in *Eucalyptus* plantations appropriate management strategy is vital. In situ and ex situ conservation methods have to be employed for the conservation of species having low importance value index and poor regeneration status.

In order to mitigate the shortage of land and prevent farmland expansion, there is a need to introduce modern agroforestry system. It is also necessary to encourage tree planting in homesteads, farmlands and churchyards through supply of seedlings of indigenous and appropriate exotic species or establishment of a nursery in order to reduce the pressure on the natural vegetation. Efforts should be made to provide and encourage the local community to use energy saving stoves to reduce the dependency on the natural vegetation for fuelwood that contributed by in large to human disturbance. To prevent soil erosion and maintain the vegetation, it is important to encourage the maintenance of the terraces through mobilizing the local people and providing appropriate incentives.

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Appendix 1: Data of geographical positions and altitudes of each sample plot

Plot No	Geographical positions	Altitudes (m)
1	09 01.18N; 038 14 .39E	2476
2	09 01.27N; 038 14.46E	2467
3	09 54.52N; 038 20.57E	2605
4	09 49.51N; 038 23.95E	2572
5	09 49.41N; 038 23.84E	2560
6	09 46.40N; 038 27.90E	2625
7	09 48.55N; 038 33.31E	3192
8	09 48.79N; 038 33.57E	3101
9	09 48.79N; 038 36.91E	3118
10	09 48.52N; 038 36.95E	3072
11	09 47.33N; 038 41.21E	3054
12	09 42.72N; 038 50.72E	2405
13	09 42.72N; 038 50.72E	2400
14	09 38.80N; 038 50.64E	2655
15	09 32.73N; 038 52.08E	2682
16	0927.64N; 038 52.78E	2578
17	0937.34N; 038 50.10E	2636
18	09 18.34N; 038 45.10E	2626
19	09 17.13N; 038 46.66E	2730
20	09 16.99N; 038 46.64E	2750
21	09 16.97N; 038 46.63E	2778
22	09 06.32n; 038 42.67E	2765
23	09 06.32N; 038 42.67E	2765
24	09 04.61N; 038 46.43E	2620
25	09 04.66N; 038 46.35E	2880
26	09 04.77N; 038 46.27E	2766
27	09 05.10N; 038 46.29E	2800
28	09 05.35N; 038 46.38E	2852
29	09 05.46N; 038 46.15E	2912

Cont'd...

30	09 05.71N; 038 46.13E	2962
31	09 05.62N; 038 45.93E	2990
32	09 06.20N; 038 43.64E	2746
33	09 05.97N; 038 43.68E	2783
34	09 05.73N; 038 43.82E	2830
35	09 05.47N; 038 43.89E	2870
36	09 05.46N; 038 43.75E	2894
37	09 05.33N; 038 43.71E	2945
38	09 05.69N; 038 43.75 E	2830
39	09 05.46N; 038 43.77E	2880
40	09 05.27N; 038 43.64E	2926
41	09 05.30N; 038 43.96E	2876
42	09 05.26N; 038 44.18E	2936
43	09 05.38N; 038 45.11E	3015
44	09 05.68N; 038 42.85E	2760
45	09 05.64N; 038 42.85E	2788
46	09 05.52N; 038 42.78E	2787
47	09 05.58N; 038 42.73E	2824
48	09 05.40N; 038 42.65E	2854
49	09 05.25N; 038 42.86E	2900

Appendix 2: List of plant species collecccted from the study area

Species name	Family	Local Name	Life form
Acacia abyssinica Hochst. ex Benth.	Fabeaceae		Tree
Acacia melanxylon R. Br.	Fabaceae		Tree
Acanthus pusescens (Oliv.) Engl.	Acanthaceae	Sokoru	Shrub
Achyranthes aspera L.	Amaranthaceae		Herb
Alchemilla abyssinica Fresen.	Rosaceae		Herb
Allophylus abyssinica (Hochst.)Radlkofer	Sapindaceae	Tatesa	Tree
Argemone mexicana L.	Papaveraceae		Herb
Asparagus africanus Lam.	Asparagaceae	Serit	Shrub
Barbeya oleoides Schweinf.	Barbeyaceae		Tree
Bersama abyssinica Fresen	Melianthaceae	Azamir	Tree
Bidens biternata (Lour.) Merr. & Sherft	Asteraceae		Herb
Bidens macroptera (Sch.-Bip.ex Chiov.)	Asteraceae	Kelo	Herb
Capsella bursa-pastoris (L.) Medic.	Brassicaceae		Herb
Carduus leptacanthus Fresen.	Asteraceae		Herb
Carissa spinarum L.	Apocynaceae	Agam	Shrub
Cirsium schimperi (Vatke) Cuf.	Asteraceae		Herb
Clutia lanceolata Forssk.	Euphoribaceae		Shrub
Commelina benghalensis L.	Commelinaceae		Herb
Conyza stricta Willd.	Asteraceae		Herb
Croton macrostachus Del.	Euphorbiaceae	Bekenisa	Tree
Cupressus lustanica Mill.	Cuppressaceae	Tid	Tree
Cyperus dichrostachyus A.Rich.	Cyperaceae		Herb
Datura stramonium L.	Solanaceae	Astenager	Herb
Dovyalis abyssinica (A. Rich.) Warb	Flacourtiaceae	Koshm	Shrub
Dyschoriste multicaulis (A.Rich.) O.Kuntze	*Acanthaceae*	*Sokoru*	*Herb*
Eechinops ellenbeckii D.Hoffm.	Asteraceae	Kosheshla	Herb
Ekebergia Capensis Sparrm.	Meliaceae		Tree
Eleusine floccifolia (Forssk.) Spreng.	Poaceae		Herb
Eragrostis schweinfurthii Chiov	Poaceae		Herb
Erica arborea L.	Ericaceae	Asit	Shrub
Eucalyptus globulus Labill.	Myrtaceae	Nechbahrzaf	Tree
Galinsoga quadriradiata Ruiz & Pavon	Asteraceae		Herb
Hagenia abyssinica (Bruce) J.F. Gmel.	Rosaceae	Kosso	Tree
Hyparrhenia anthistiriodes (Hochst.ex A.Rich.) Stapf	Poaceae	Semebeliet	Herb
Hypoestes forskaolii (Vahl) R.Br.	Acanthaceae		Herb
Inula confertiflora A. Rich.	Asteraceae	Mignore	Herb
Jasminum abyssinicum Hochest. ex Dc.	Oleaceae		Herb
Jasminum abyssinicum Hochest. ex Dc.	Oleaceae		Liana
Juniperus procera Endl	Cuppressaceae	Gatira	Tree
Justicia schimperiana (Hochst. Ex Nees) T.	Acanthaceae		Shrub

Anders.			
Justitia schimperana (Hochst. Ex Nees) T.Anders	Acanthaceae		Herb
Kalanchoe petitiana A. Rich.	Crassulaceae	Endawella	Herb
Kniphofia foliosa Hochst.	Asphodelaceae		Herb
Laggera tomentosa (Sch. Bip. ex A. Rich.) Oliv. & Hiern	Asteraceae		Shrub
Lantana trifolia L.	Verbenaceae	Kese	Shrub
Leontis ocymifolia (Brum. f.) Iwarsson	Lamiacea		Herb
Lippia adoensis Hochst. ex Walp.	Verbenaceae	Koseret	Shrub
Maytenus arbutifolia (A. Rich.) Wilczek	Celasteraceae	Kobelicha	Tree
Measa lanceolata Forssk.	Myrtacaea	Kelewa	Tree
Medicago polymorpha L.,	Fabaceae		Herb
Myrsine africana L.	Myrsinaceae	Kechemo	Shrub
Nuxia congesta R. Br. Ex Fresen	Loganiaceae		Shrub
Ocimum forskolei Benth.	Lamiaceae	Yarogitfes	Herb
Ocimum lamiifolium Hochst. ex Benth.	Lamiaceae	Damakeseh	Herb
Olea europaea L. subsp. cuspidata (Wall. ex G. Don) Cif., L'Olivicoltore	Oleaceae	Ejersa	Tree
Olinia rochetiana A. Juss.	Oliniaceae	Dodie	T/S
Osyris quadripartita Decn.	Santalaceae	Wato	T/S
Pittosporum abyssinicum Del.	Pittosporaceae	Didisa	Tree
Pittosprum viridiflorum Sims.	Pittosporaceae	Asikar	Tree
Plectranthus edulis (Vatke) Agnew,	Lamiaceae		Herb
*Podocarpus falcatus (*Thunb) Mirb.	Podocarpaceae		Tree
Polygonum aviculare L.	Polygonaceae		Herb
Prunus africana (Hook. f.) Kalkm.	Rosaceae	Kobolicha	Tree
Rosa abyssinica Lindley	Rosaceae	Gora	Shrub
Rubus apetalus Poir.	Rosaceae	Enjor	Shrub
Schefflera abyssinica (Hochst. Ex A. Rich.) Harms	Araliaceae	Ariftu	Herb
Sida schimperiana Hochst.ex A.Rich.	Malvaceae	Chefere	Shrub
Smilax aspera L.	Smilacaceae		Climber
Solanium indicum L.,	Solanaceae		Herb
Solanum marginatum L.f.	Solanaceae		Shrub
Sonchus bipontini Asch.	Asteraceae		Herb
Sonchus oleraceus L.	Asteraceae		Herb
Tagetes minuta L.	Asteraceae		Herb
Thymus shimperi Ronniger	Lamiaceae	Tosign	Herb
Trifolium pretense L.	Fabaceae		Herb
Vernonia adoensis Sch. Bip ex Wolp	Asteraceae		Shrub
Vernonia amygdalina Del.	Asteraceae	Grawa	Shrub

Appendix 3: List of species recorded from the soil sample in each of the six habitat types with the total number of seedlings

No	Species Name	Family	Life form	EPF	HTV	FAL	PAL	DEL	WEL
1	*Abutilon logicuspe* Hochst.ex A.Rich.	Malvaceae	Shrub	-	3	-	-	-	-
2	Acacia *melanxylon* R. Br.	Fabaceae	Tree	21	-	-	-	-	-
3	*Achyranthes aspera* L.	Amaranthaceae	Herb	11	1	-	-	-	-
4	*Acmella caulirhiza* Del.	Asteraceae	Herb	8	16	-	-	-	-
5	*Alchemilla abyssinica* Fresen.	Rosaceae	Herb	83	-	12	-	-	16
6	*Alchemilla padata* A.Rich.	Rosaceae	Herb	8	-	-	-	10	-
7	*Alloteropsis semialata* (R.Br.) Hitch	Poaceae	Herb	107	-	-	-	24	
8	*Alopecurus baptarrhenius* S. M. hillips	Poaceae	Herb	-	-	-	34	-	-
9	*Amaranthus caudatus* L	Amaranthaceae	Herb	1	-	-	-	-	-
10	*Anagallis arvensis* L.	Primulaceae	Herb	61	-	15	-	-	-
11	*Anthemis tigreensis* J.Gay ex A.Rich.	Asteraceae	Herb	1	-	1	-	-	-
12	*Anthospermum herbaceum* L.f.	Rubiaceae	Herb	9	-	-	-	-	-
13	*Arthraxon micans* (Nees) Hochst.	Poaceae	Herb	14	16	-	-	4	-
14	*Asterolinon adoense* Kunze	Primulaceae	Herb	-	2	-	-	-	-
15	*Bidens pachyloma* (oliv. &Hiern) Cuf.	Asteraceae	Herb	8	-	-	-	-	-
16	*Bidens prestinaria* (Sch. Bip.) Fiori.	Asteraceae	Herb	9	-	-	-	-	-
17	*Buddleja polystachya* Fresen.	Loganiaceae	Shrub	-	29	-	-	-	-
18	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	Tree	-	1	-	-	-	-
19	*Campanula edulis* Forssk.	Campanulaceae	Herb	326	-	-	-	42	-
20	*Capsella bursa-pastoris* (L.) Medic.	Brassicaceae	Herb	5	-	-	-	-	-
21	*Cardamine hirsute* L.	Brassicaceae	Herb	6	-	-	-	-	-
22	*Carduus leptacanthus* Fresen.	Asteraceae	Herb	5	-	-	-	-	-
23	*Caylusea abyssinica* (Fresen.) Fisch. & Mey.	Resedaceae	Herb	-	-	1	-	-	-
24	*Cerastium octandrum* A.Rich.	Caryophyllaceae	Herb	61	-	-	-	-	-
25	*Chenopodium album* L.	Chenopodiaceae	Herb	-	45	-	-	-	-
26	*Cirsium vulgare* (Savi.) Ten.	Asteraceae	Herb	3	-	-	-	-	-

27	*Colpodium hedbergii* (Meld.) Tzvel.	Poaceae	Herb	-	15	-	-	-	-
28	*Commelina benghalensis* L.	Commelinaceae	Herb	3	-	-	-	-	-
29	*Conyza stricta* Willd.	Asteraceae	Herb	46	-	-	-	-	-
30	*Cotula abyssinica* Sch.-Bip.ex A.Rich.	Asteraceae	Herb	65	-	-	6	5	-
31	*Crassula alsinoides* (Hook.f.) Engl.	Crassulaceae	Herb	137	-	-	-	-	-
32	*Crepis rueppellii* Sch.-Bip.	Asteraceae	Herb	38	3	-	-	4	-
33	*Cynoglosum* sp.	Boraginaceae	Herb	3	-	-	-	-	-
34	*Cyperus pulchellus* R.Br.	Cyperaceae	Herb	112	13	26	27	75	-
35	*Datura stramonium* L.	Solanaceae	Herb	-	27	-	-	-	-
36	*Delosperma abyssinica* (Regel) Schwantes	Aizoaceae	Herb	50	-	45	-	-	-
37	*Dichondra repens* J.R. & G. Forst.	Convolvulaceae	Herb	18	20	-	-	-	17
38	*Dichrocephala integrifolia* (L.f.) O.Kuntze	Asteraceae	Herb	5	-	-	-	-	-
39	*Digitaria velutina* (Forssk.) P.Beauv.	Poaceae	Herb	94	-	-	-	-	-
40	*Eleusine floccifolia* (Forssk.) Spreng.	Poaceae	Herb	-	7	20	-	-	-
41	*Eragrostis papposa* (Roem. & Schult.) Steud.	Poaceae	Herb	150	7	20	71	6	-
42	*Eragrostis schweinfurthii* Chiov.	Poaceae	Herb	264	27	34	75	34	29
43	*Eragrostis* sp.	Poaceae	Herb	-	-	77	191	-	-
44	*Erucastrum* sp.	Brassicaceae	Herb	-	5	-	-	-	-
45	*Farsetia stenoptera* Hochst.	Brassicaceae	Herb	5	-	-	-	-	-
46	*Festuca abyssinica* Hochst.ex A. Rich.	Poaceae	Herb	23	-	5	-	-	6
47	*Galinsoga quadriradiata* Ruiz & Pavon	Asteraceae	Herb	166	111	100	15	12	-
48	*Galium simensis* Fresen.	Rubiaceae	Herb	7	-	-	-	-	-
49	*Geranium aculeolatum* Oliv.	Geraniaceae	Herb	6	-	-	-	-	-
50	*Geranium arabicum* Forssk.	Geraniaceae	Herb	161	20	-	-	-	-
51	*Gypsophila elegans* M.Bieb.	Caryophyllaceae	Herb	0	-	6	-	-	-
52	*Haplocarpha schimperi* (sch.Bip.) Beauv.	Asteraceae	Herb	7	-	-	-	-	-
53	*Helichyrsum* sp.	Asteraceae	Shrub	-	6	-	-	-	-
54	*Kalanchoe petitiana* A. Rich.	Crassulaceae	Herb	-	8	-	-	-	-
55	*Lactuca serriola L.*	Asteraceae	Herb	-	-	6	-	-	-
56	*Laggera crispata* (Vahl) Hepper & Wood	Asteraceae	Herb	19	8	-	-	-	-
57	*Laggera tomentosa* (Sch. Bip. ex A. Rich.) Oliv. &	Asteraceae	Shrub	3	-	-	-	-	-

	Hiern								
58	*Launea rueppellii* (Oliv.& Hiern) Amin ex Boulos	Asteraceae	Herb	-	-	2	-	-	-
59	*Malva verticillata* L.	Malvaceae	Shrub	7	-	-	-	-	-
60	*Medicago polymorpha* L.,	Fabaceae	Herb	18	37	8	9	43	-
61	*Oxalis corniculata* L.	Oxalidaceae	Herb	27	-	-	-	-	-
62	*Oxalis radicosa* A. Rich.	Oxalidaceae	Herb	472	28	-	-	-	-
63	*Panicum subalbidum* Kunth.	Poaceae	Herb	-	-	-	34	-	-
64	*Pennisetum riparium* Hochst. ex A.Rich.	Poaceae	Herb	38	-	-	23	-	-
65	*Pennistum pentastachyum* A.Rich.	Poaceae	Herb	13	-	-	-	-	-
66	*Persicaria* sp.	Polygonaceae	Herb	158	-	59	-	-	-
67	*Plantago lanceolata* L.	Plantagnaceae	Herb	1	-	2	-	2	-
68	*Plantago palmata Hook*.f.	Plantagnaceae	Herb	3	-	-	-	-	-
69	*Plectranthus edulis* (Vatke) Agnew,	Lamiaceae	Herb	8	-	-	-	-	-
70	*Poa anna* L.	Poaceae	Herb	72	4	-	-	5	-
71	*Polygonium nepalensis* Meisn.	Polygonaceae	Herb	51	16	5	3	-	-
72	*Polygonum aviculare* L.,	Polygonaceae	Herb	-	-	-	3	-	-
73	*Pseudognaphalium luteo-album* (L.) Hilliard & *Burtt*	Asteraceae	Herb	97	-	11	-	-	-
74	*Raphanus raphanistrum* L.	Brassicaceae	Herb	-	4	-	-	-	-
75	*Rubus apetalus* Poir.	Rosaceae	Shrub	3	-	-	-	-	-
76	*Rumex nepalensis* Spreng.	Polygonaceae	Herb	2	2	-	-	-	-
77	*Salvia nilotica* Jacq.	Lamiaceae	Herb	-	-	-	-	-	-
78	*Satureja paradoxa* (Vatke) Engl.ex A.Seybold	Lamiaceae	Herb	58	-	-	-	-	-
79	*Satureja punctata* (Benth.) Briq.	Lamiaceae	Herb	12	-	-	-	-	-
80	*Solanium indicum* L.	Solanaceae	Herb	-	3	-	-	-	-
81	*Solanum americanum* Miller,	Solanaceae	Herb	44	14	-	3	-	-
82	*Solanum marginatum* L.f.	Solanaceae	Shrub	1	-	-	-	-	-
83	*Solanum nigrum* L.	Solanaceae	Herb	5	38	-	-	-	-
84	*Sonchus asper* (L.) Hill	Asteraceae	Herb	6	-	-	-	-	-
85	*Sonchus bipontini* Asch.	Asteraceae	Herb	12	-	-	-	-	-
86	*Sonchus oleracus* L.	Asteraceae	Herb	-	5	-	-	-	-
87	*Spergularia rubra* (L.) J. & C. Presl.	Caryophllaceae	Herb	52	-	36	-	-	-
88	*Tagetes minuta* L.	Asteraceae	Herb	-	-	1	-	-	-
89	*Trifolium bilineatum* Fresen.	Fabaceae	Herb	-	-	-	-	8	-
90	*Trifolium decorum* Chiov.	Fabaceae	Herb	11	-	-	10	-	-
91	*Trifolium multinerve* A.Rich.	Fabaceae	Herb	18	-	-	25	-	-
92	*Trifolium pratense* L.	Fabaceae	Herb	17	15	46	56	5	10
93	*Trifolium rueppellianum*	Fabaceae	Herb	10	-	-	-	-	-

	Fresen								
94	*Trifolium schimperi* A.Rich.	Fabaceae	Herb	-	-	-	-	-	10
95	*Uebelinia abyssinica* Hochst.	Caryophllaceae	Herb	4	-	-	-	-	-
96	*Vernonia adoensis* Sch. Bip ex Wolp	Asteraceae	Shrub	-	3	-	-	-	-
97	*Veronica persica* Chiov.	Scrophulariacea	Herb	152	-	-	-	-	-
98	*Vicia sativa* L.	Fabaceae	Climbe	24	4	-	-	-	-

Appendix 4: List of species recorded from the soil seed bank with the total number

No	Species Name	Litter	0 - 3 cm	3 – 6 cm	6 - 9 cm
1	*Abutilon logicuspe* Hochst.ex A.Rich.		3	3	
2	*Acacia melanxylon* R. Br.		8	8	5
3	*Achyranthes aspera* L.	7	1	2	
4	*Acmella caulirhiza* Del.		9	15	
5	*Alchemilla abyssinica* Fresen.		64	26	12
6	*Alchemilla padata* A.Rich.		18		
7	*Alloteropsis semialata* (R.Br.) Hitch		95	51	45
8	*Alopecurus baptarrhenius* S. M. Phillips		18	5	
9	*Amaranthus caudatus* L			1	
10	*Anagallis arvensis* L.	15	31	2	22
11	*Anthemis tigreensis* J.Gay ex A.Rich.		3		
12	*Anthospermum herbaceum* L.f.		5	4	
13	*Arthraxon micans* (Nees) Hochst.	17	11	5	2
14	*Asterolinon adoense* Kunze				1
15	*Bidens pachyloma* (oliv. &Hiern) Cuf.			5	3
16	*Bidens prestinaria* (Sch. Bip.) Fiori.		4	5	
17	*Buddleja polystachya* Fresen.		21	8	
18	*Calpurnia aurea* (Ait.)Benth.			1	
19	*Campanula edulis* Forssk.	57	141	139	31
20	*Capsella bursa-pastoris* (L.) Medic.		5		
21	*Cardamine hirsuta* L.		6		
22	*Carduus leptacanthus* Fresen.		4		
23	*Caylusea abyssinica* (Fresen.) Fisch. & Mey.		1		
24	*Cerastium octandrum* A.Rich.		6		
25	*Chenopodium album* L.		30	18	
26	*Cirsium vulgare* (Savi.) Ten.		2		1
27	*Colpodium hedbergii* (Meld.) Tzvel.		15		
28	*Commelina benghalensis* L.		3		
29	*Conyza stricta* Willd.		20	11	15
30	*Cotula abyssinica* Sch.-Bip.ex A.Rich.		33	15	7
31	*Crassula alsinoides* (Hook.f.) Engl.		80	31	26
32	*Crepis rueppellii* Sch.-Bip.	9	8	17	15
33	*Cynoglosum* Sp.		2		
34	*Cyperus pulchellus* R.Br.	54	93	56	7
35	*Datura stramonium* L.		17	9	1
36	*Delosperma abyssinica* (Regel) Schwantes		40	45	26
37	*Dichondra repens* J.R. & G. Forst.			51	
38	*Dichrocephala integrifolia* (L.f.) O.Kuntze	4			1
39	*Digitaria velutina* (Forssk.) P.Beauv.	15	29	38	12

40	*Eleusine floccifolia* (Forssk.) Spreng.		12	15	
41	*Eragrostis papposa* (Roem. & Schult.) Steud.	20	145	62	27
42	*Eragrostis schweinfurthii* Chiov.	15	228	178	51
43	*Eragrostis* sp.		168	87	13
44	*Erucastrum* sp.		2		3
45	*Farsetia stenoptera Hochst.*		5		
46	*Festuca abyssinica* Hochst.ex A. Rich.		31	3	
47	*Galinsoga quadriradiata* Ruiz & Pavon	25	144	141	44
48	*Galium simensis* Fresen.	7			
49	*Geranium aculeolatum* Oliv.		6		
50	*Geranium arabicum* Forssk.	49	88	44	
51	*Gypsophila elegans* M.Bieb.			6	
52	*Haplocarpha schimperi* (Sch.Bip.) Beauv.				9
53	*Helichyrsum* sp.		6	9	
54	*Kalanchoe petitiana* A. Rich.		8		
55	*Lactuca serriola L.*		2		4
56	*Laggera crispata* (Vahl) Hepper & Wood	4	16	7	
57	*Laggera tomentosa* (Sch. Bip. ex A. Rich.) Oliv. & Hiern		3		
58	*Launea rueppellii* (Oliv. & Hiern) Amin ex Boulos		2		
59	*Malva verticillata* L.		7		
60	*Medicago polymorpha* L.,		75	18	33
61	*Oxalis corniculata* L.	21	6		
62	*Oxalis radicosa* A. Rich.	77	208	96	106
63	*Panicum subalbidum* Kunth.		34		
64	*Pennisetum riparium* Hochst. ex A.Rich.		10	20	
65	*Pennistum pentastachyum* A.Rich.		13		
66	*Persicaria* sp.		98	71	39
67	*Plantago lanceolata* L.,		3	2	
68	*Plantago palmata Hook.*f.		3		
69	*Plectranthus edulis* (Vatke) Agnew		1	1	
70	*Poa annua* L.	8	34	23	6
71	*Polygonium nepalensis* Meisn.	9	26	15	18
72	*Polygonum aviculare* L.,			3	
73	*Pseudognaphalium luteo-album* (L.) Hil-liard & *Burtt*	13	35	57	40
74	*Raphanus raphanistrum* L.	3	1		
75	*Rubus apetalus* Poir.			3	
76	*Rumex nepalensis* Spreng.			4	
77	*Salvia nilotica* Jacq.		2		
78	*Satureja paradoxa* (Vatke) Engl.ex A.Seybold	14	46	12	

79	*Satureja punctata* (Benth.) Briq.		12		
80	*Solanium indicum* L.	2		1	
81	*Solanum americanum* Miller,	14	35	14	3
82	*Solanum marginatum* L.f.		1		
83	*Solanum nigrum* L.	20	8	9	4
84	*Sonchus asper* (L.) Hill	4	2		
85	*Sonchus bipontini* Asch.	7	5		
86	*Sonchus oleracus* L.	4		1	
87	*Spergularia rubra* (L.) J. & C. Presl.		52	19	17
88	*Tagetes minuta* L.			1	
89	*Trifolium bilineatum* Fresen.			8	8
90	*Trifolium decorum* Chiov.		5	7	9
91	*Trifolium multinerve* A.Rich		30	6	4
92	*Trifolium pratense* L.		53	43	34
93	*Trifolium rueppellianum* Fresen.		7		3
94	*Trifolium schimperi* A.Rich.				6
95	*Uebelinia abyssinica* Hochst.		3		
96	*Vernonia adoensis* Sch. Bip ex Wolp				3
97	*Veronica persica* Chiov.		118	23	11
98	*Vicia sativa* L.		13	7	4


Greenhouse Germination


Sonchus asper


Geranium arabicum


Oxalis radicosa

Cynoglosum sp

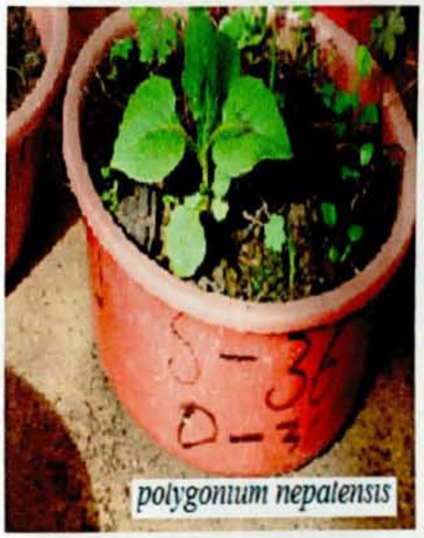
Solanum marginatum

Acacia melanxylon

Laggera tomentosa

Abutilon logicuspe

Kalanchoe petitiana



polygonium nepalensis

Acmella caulirhiza

Datura stramonium