Soil Seed Bank Study at Gera Moist Evergreen Afromontane Forest, Jimma Zone of Oromia Regional State, Southwest Ethiopia

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This is to certify that the thesis prepared by Yohannis Teklu Ayele, entitled: *Soil Seed Bank Study at Gera Moist Evergreen Afromontane Forest, Jimma Zone of Oromia Regional State, Ethiopia* and submitted in partial fulfillment of the requirements for the degree of master of science (Biology: Botanical science) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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I, the undersigned declare that, this thesis is my original work and it has not been presented in other universities, colleges and institutes for degree or other purpose. All sources of the material used in the thesis have been duly acknowledged.

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The work has been done under our supervision.

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Prof. Ensermu Kelbessa ------------------ Signature: --------------- Date: ----------------

Abstract

Soil Seed Bank Study at Gera Moist Evergreen Afromontane Forest, Jimma Zone of Oromia Regional State, Southwest Ethiopia

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Soil seed banks are important sources 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 Gera moist afromontane forest. A total of fifty quadrats were established in the selected sites. The quadrat size (30m × 30 m) for trees, shrubs and herbs 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 66 plant species germinated from all the soil samples collected for the investigation. Herbs dominated the soil seed bank representing nearly 65.7% 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). Between the standing vegetation and the soil seed bank there was very low similarity (JCS = 0.08-0.28). However, there was a general tendency of appearance of native woody species from the soil seed bank as evidenced by the germination of few woody species. This implies that reliance on the soil seed bank for the recovery of native woody species is worthy for Gera moist afromontane forest.

Key words/phrases: - Gera Forest, Seed density, Soil seed bank, Species composition

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ACRONYMS

AAU	Addis Ababa University
a.s.l.	Above sea level
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
SW	Southwest

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 are endemic (Ensermu Kelbssa and Sebsebe Demissew, pers. comm.). Its diverse geography has contributed to the development of variety of fauna, which includes about 284 species of mammals and 861 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 and 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 firewood, 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, have led to ecological and socio-economic crises (Haileab Zegeye *et al*., 2011). Due to increasing human pressure, traditional land management practices, including 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 soil seed bank (Mulugeta Lemenih and 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 and Demel Teketay, 2006). Use of soil seed bank 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 raised in a nursery. Soil seed bank exhibits variations in space as well as time and displays both horizontal and vertical dispersion, reflecting initial dispersal onto the soil and subsequent movement (Feyera Senbeta and Demel Teketay, 2002). Soil seed bank partly reflects 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 recoveryability 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). Soil seed bank composition is also influenced by the surrounding vegetation and former successional stages (Godefroid *et al*., 2006).

In most tropical areas, the degraded or completely destroyed forest sites are changed either to other land uses, establishment of monoculture plantations of fast growing trees (Feyera Senbeta and Demel Teketay, 2001), or permanent arable lands, which is a common practice in the tropics, 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 soil seed bank could rehabilitate the disturbed tropical moist Afromontane forest. Studying the formation and variation of the seed bank is great significance to natural renewal of vegetation, succession of dominant communities, and quick recovery of vegetation. The studies about the seed banks of vegetation types can reflect community histories and play an important role in rehabilitating degenerated ecosystems. 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, soil seed bank are 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. Because of the considerable damage of the mountain forests, concern has arisen about the natural regeneration of indigenous species. Regeneration is 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, soil seed bank 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. This study mainly focuses on the soil seed bank collection from the Wild Coffee Forest, Non-coffee Forest, Modern Coffee Plantation Forest, Ridge and Valley habitat types of the forest for the investigation of their recovering capacity.

The study 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 comparing vegetation development in all study sites. The following specific questionswill be addressed:

- Does the soil seed bank have contribution to restoration or rehabilitation of natural forest?
- Are there any differences and similarities between the Modern Coffee Plantation Forest and the Non-coffee Forest in regeneration status and seed bank potential for species diversity?
- To what extent does the soil seed bank composition and density varies with depth and in different land use types?
- Does Modern Coffee plantation affect the natural regeneration potential of other native woody species?
- What will be the similarity between soil seed bank and standing vegetation?
- What will be the current regeneration status of woody species of the study area?

1.2. Objectives of the Study

1.2.1. General objective

The main objectiveis:
To study the composition and density of soil seed bankand regeneration status of plant species in Gera Moist Montane Forest as input for land and vegetation management.

1.2.2. Specific objectives

The specific objectives of the study are:

- ❖ 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 with the aboveground vegetation;
- ❖ To examine the role of seed bank regeneration status;
- ❖ To investigate the seed bank regeneration potential;
- ❖ To study the effects of land use type on seed bank;
- ❖ To compare regeneration status and seed banks diversity of the study area; and
- ❖ To describe plausible options for management of the land and vegetation of the study area.

CHAPTER TWO

2. Literature Review

This section tries to summarize issues related to seed bank regeneration. The parts included are: definition of 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 and regeneration and soil seed bank studies in Ethiopia and coffee plantation and 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 some species 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 and 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 and Demel Teketay, 2001), or permanent arable lands, which is a common practice in the tropics, e.g. in Ethiopia (Feyera Senbeta and 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 and 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 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 seedbank dynamics, particularly in crop systems, are complex and vary greatly depending on production practices and timing (Joanne, 2006). The ecological framework of soil seed banks and seed persistence has been correlated to seed characteristics, their distribution in soils, landmanagement 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 and 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 and 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 and 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 and 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 response of plants to environmental factors, that induces the germination seed burial or redispersion 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 (EyobTenkir, 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 seedmaturation 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 and 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 (2005a) 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 revegetation 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 wellstocked soil seed bank permits rapid development of species rich ecosystems during secondary succession. In addition their significance in regeneration of lost vegetation, seedbanks land 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 known 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 impact of climate change on soil seed bank regeneration

Increased soil temperatures could reduce the proportion of viable seeds within the seed bank by producing temperatures that are lethal to seeds.Soil seed banks play a critical role in the vegetation dynamics of many plant communities (Leishman *et al*. 2000). A reserve of dormant seeds in the soil can stabilize population dynamics in response to short term environmental flactuations and disturbances determine future successional trajectories (Buisson *et al*. 2006); in contrast, a depleted seed bank limits the potential for community regeneration. Despite the important role played by seed banks in varying environments, the potential effects of climate change on this key process have barely been considered (Bekker *et al*. 1998; Leishman et al. 2000b), particularly via experiments with climatic manipulation. Akinola *et al*. (1998a, b) found that soil seed banks tend to exhibit considerable inertia, but some annuals may display relatively rapid response to climate treatments. Another approach to evaluating potential effects of climate change involves the estimation of seed bank dynamics under current conditions of climatic variability (Bekker *et al*. 1998). For example, in Mediterranean ecosystems, some studies have reported that seed bank richness was higher in wetter years than in drier ones (Pugnaire and La zaro 2000). The response of soil seed banks to climate change is characterized, however, by inertia in the face of short term environmental fluctuations, and this creates a need for studies in which new climatic conditions remain constant for several years.

Greater richness and density are found under vegetated areas (Moro *et al*. 1997; Guo *et al*. 1998), where seed input is high (Mull and MacMahon 1996; Lloret *et al*. 2005). Thus, seed accumulation tends to be higher under vegetation patches and decreases with greater distance from the canopy cover (Guo *et al*. 1998).

Temperature is the main factor controlling dormancy in arid zone short lived species, particularly those with physical (also known as 'hardseeded') and physiological dormancy mechanisms (Baskin and Baskin, 1998; Bell, 1999). Both dormancy and germination mechanisms can contribute to the maintenance of long lived seed banks by ensuring that germination is either delayed until the onset of favorable conditions, or that the seed bank does not germinate all at once (Baskin and Baskin, 1998; Fenner and Thompson, 2005). Studying plant traits that are directly influenced by temperature, such as seed dormancy and germination, can therefore give insights into the effects of increased temperatures caused by climate change. For example, physically dormant species have an impermeable seed coat which can be broken by high temperatures, often with increasing treatment temperatures alleviating dormancy in increasing proportions of any seed lot (Martin *et al*., 1975). Similarly, many physiologically dormant species require either stratification or periods of dry after-ripening at specific temperatures to overcome dormancy.

Temperature may also directly influence seed survival, and soil temperatures that increase as a result of global warming may approach thresholds for seed death in those ecosystems where high temperatures are already apparent.Dispersal capability varies widely among plant species and for many it is likely that migration will not enable persistence in the face of rapid climate change (Neilson *et al*., 2005). Many species will therefore have to either evolve, or maintain traits enabling them to persist through rapid change (Skelly *et al*., 2007). Assessing the ability of plants to cope with temperature regimes that are warmer than those that they currently experience is the key to understanding the potential threat that climate change poses in these ecosystems (Westoby and Burgman, 2006).

Forecast higher air temperatures may affect the seed bank via two main mechanisms. First, seedling mortality could increase due to increased evaporation of soil moisture, with subsequent recruitment failure producing a net loss of seeds from the seed bank. For example, in Mediterranean shrub land in Spain, Lloret *et al*. (2004) found that warming and drought conditions related to climate change reduced seedling survival and related species richness. They concluded that species producing fewer seedlings were most susceptible to local extinction and that the different responses between species could result in altered community diversity and structure. Second, increased air temperatures would change maternal environment conditions.

The association between higher air temperatures experienced by the parent plant and the production of less dormant seeds (Fenner, 1991), particularly when physiological dormancy is the controlling mechanism, means that seeds may be less discerning about when to emerge.

2.1.8. 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, 2005a). 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 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 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.

2.1.9. 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 of ways. Most importantly, grazing has direct effects on plant community and seed bank by reducing biomass and seed production (Solomon Tefera, 2011).

2.1.10. 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 once 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 and 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).

2.1.11. 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 and 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).

2.1.12. 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 and 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. 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 forest lands 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 carried out by different scholars including (Mekuria Argaw *et al*., 1999; Feyera Senbeta and Demel Teketay, 2001; Feyera Senbeta and Demel Teketay, 2002; Getachew Tesfaye *et al*., 2010; Demel Teketay, 2005; Mulugeta Lemenih and 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 colleagues, 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).

2.3. Herbs and shrubs in Coffee Forest of Gera Forest

The forested area in southwest Ethiopia is under considerably high human threat. There are some major driving forces that increase pressure on the coffee forest in SW-Ethiopia. The most important are the rising population pressure causing deforestation for new settlements and agricultural land, as well as general over exploitation of the remaining forest. The others are road construction, making the forests more accessible, a poor policy and legislation with almost no control on illegal deforestation and the rising demand for coffee worldwide (Gove *et al.*, 2008; ICO, 2011).

Wild coffee, *Coffea arabica* L., is native to Ethiopia and grows as an understorey shrub species in Afromontane rainforests between 1000 and 2000m above sea level (Vavilov 1951). The local communities in Ethiopia have developed a long tradition of managing the forest for coffee production which is nowadays the main export product of Ethiopia (FAO and WFP 2009). This traditional management has only minor effects on the structure and biodiversity of the forest. Even today an important part of Ethiopian coffee beans (c. 35%) is produced in traditional

Coffee production forests. But with the rising demand for coffee, and its higher prices (ICO, 2011), the management intensifies, aiming for higher yields (Aerts *et al.,* 2011).

Coffee yields are much higher in semi-plantation coffee systems (SPC) and semi-forest coffee systems (SFC) than in forest coffee systems (FC) because of forest management (Schmitt *et al.* 2009). Therefore, in forests in SW Ethiopia that are cultivated for coffee, the undergrowth is removed at least once a year to avoid competition with non-coffee shrubs. New coffee seedlings are planted whereas older shrubs are pruned to increase growth efficiency (Aerts *et al.,* 2011). The tree layer is managed as well: both tree species that are less efficient in shading and slow growing species are cut, resulting in 30% less canopy trees in SFC (Schmitt *et al.,* 2009). Even the trees that are used as shade trees are managed, often for wood extraction. These modifications to the forest have led to a uniform, species poor tree canopy and a single-species (Coffee) shrub layer (Figure 1) (Schmitt *et al.,* 2009; Aerts *et al.,* 2011). In more intensely managed coffee forests, there is no intermediate layer anymore. In the long term, this will have serious implications for the regeneration of the forest when the mature trees reach a post-productive stadium (Aerts *et al.,* 2011).

Figure 1 Modern Coffee plantation system with an open, species poor canopy and a uniform coffee shrub layer.

Some of the forest relicts, for example on more steep slopes, have been conversed to coffee forests. These relicts, which can vary greatly in size, are situated in an agricultural landscape matrix (Figure 2). Depending on the quality of the surrounding matrix, it can be expected that these processes of fragmentation and intensified management have caused significant changes in abundance and diversity of forest plant species. Management inthe tree layer consists of thinning the canopy to create optimal shading conditions for the coffee shrubs.

Managing the shrub layer is done by the removal of competing shrubs (Figure 2) and old or unproductive coffee. Thinning of the canopy has resulted in the disappearance of almost all emergent trees (e.g. the climax species *Pouteria adolfi-friederici*) because the shade of these species is too deep for maximum coffee growth, and because the wood is of high economic value (Tadesse Woldemariam *et al.*, 2003). The trees that currently dominate in this forest type are pioneer or secondary species such as *Albizia gummifera* and *Macaranga capensis*, which are typical for secondary or disturbed forest because they have a relative high growth rate in gaps, created by coffee management (Chapman *et al.*, 2002).

Figure 2 Active removal of shrubs, other than coffee, in plantation forests.

CHAPTER THREE

3. MATERIAL AND METHODS

3.1 Description of the Study Area

3.1.1 Location

The study was conducted in Gera District, Jimma Zone of Oromia Regional State, Ethiopia. The Forest is located at about 380 km southwest of Addis Ababa and covers a total area of 80,830.4 ha. The altitudinal range of the study area is from1300 to 2400 m a.s.l.Gera District is bordered on the south by Gojeb River which separates it from the Southern Nations, Nationalities and Peoples Region, on the northwest by Sigmo, on the north by Setema, on the northeast by Gomma, and on the east by Seka Chekorsa districts. The administrative center of Gera district is Chira town. Cheriko and Dusta are also the other towns which include in Gera District (Figure 3).

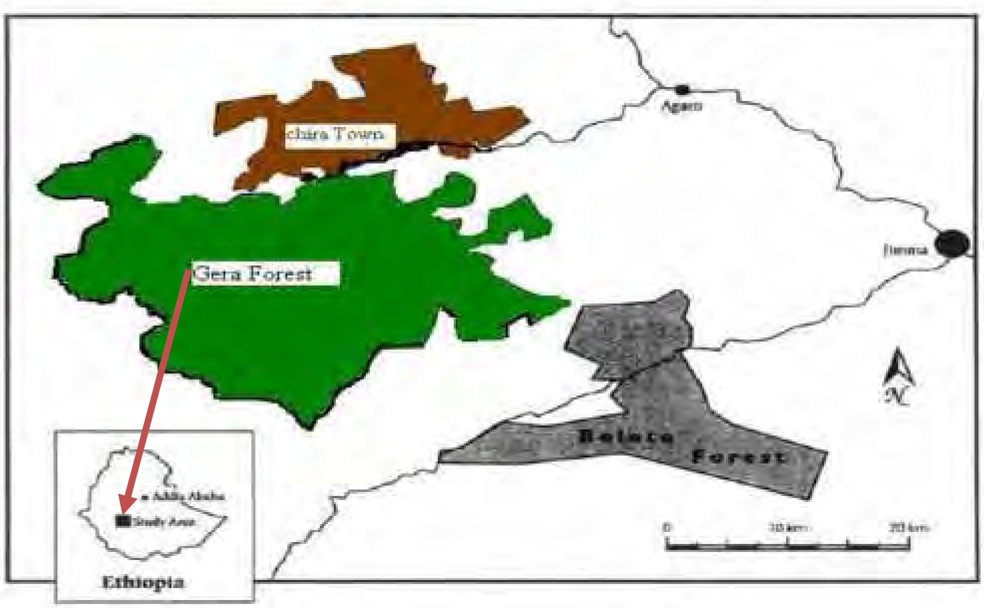

Figure 3 Map of Ethiopia and Jima Zone showing the study area, Gera Forest

1.2. Topography

Gera District is characterized by mountains (Waka, Kimbibit and Timba), plateaus (Chewra and Kella), plains (Walla, Kecho, Tuta and Tuam Mayi) and valleys (Naso and Gojeb) (figure 4). Gera Forest is situated at the intermediate altitudinal range between 1300-2400 m a.s.l.

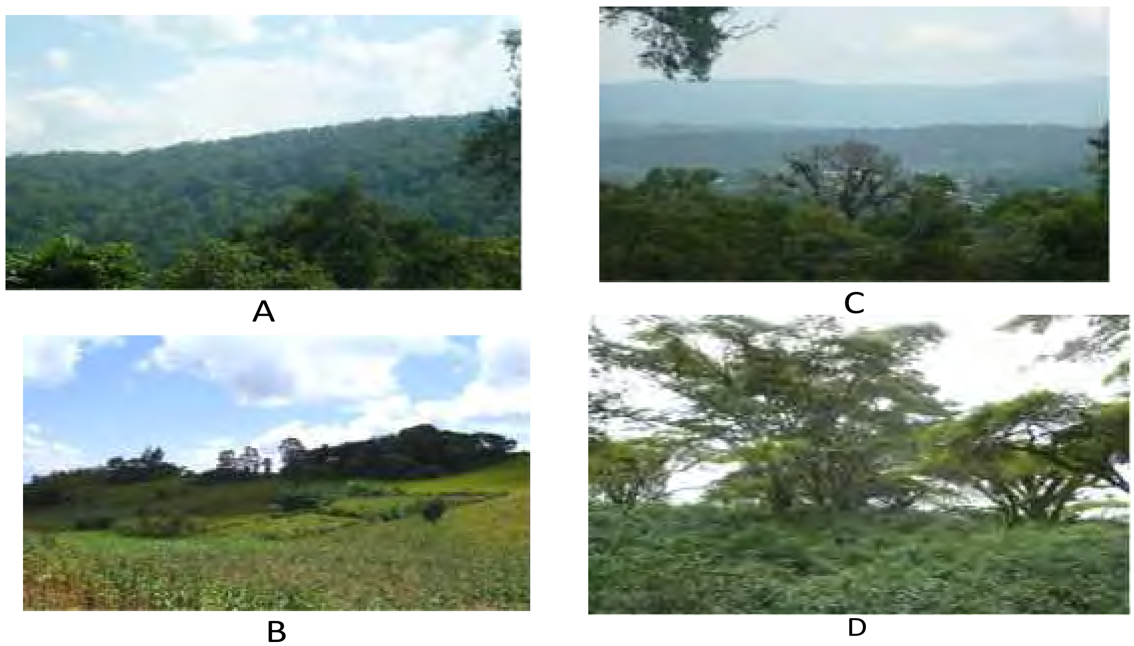

Figure 4: Topographic and land use type variation in the study area: Non-coffee Forest (A) Agricultural land (B), Cira Town area (C), *Coffea* plantation (D)

3.1.3. Geology and Soil

The study area has a drastic nitosol soil type, which is deep, clay red soil. The soil is porous and has good potential for agriculture, good physical properties, stable structure, deep rooting volume, and high moisture storage volume. Orthic acrisol and drastic nitosol are the major soil types found in Gera District (G.D.A.R.D.O., 2012).

3.1.4. Demographics

The 2007 National Census reported a total population of 112,395 for this District, of which 56,488 were men and 55,907 women. About 4,746 or 4.22% of its population were urban dwellers and the rest live in rural areas. The three largest ethnic groups in Gera District are Oromo (86.08%), Amhara (8.27%), and Kafficho (4.16%); all other ethnic groups made up

1.49% of the population. Afan oromo is spoken as a first language by 86.02%, while 9.71% speak Amharic, and 3.48% speak Kafa; the remaining 1.52% speak other languages rather than the stated once. The majority of the inhabitants are Muslims, 85.64% while 11.9% of the population where followers of Ethiopian Orthodox Christianity, and 2.36% were Protestant.

3.1.5. Climate and agroclimatic zones

The rainfall and temperature data for the study area were collected from National Meteorological Service Agency (NMA, 2012). The mean annual temperature is about 18.4^0C and the mean minimum and maximum temperatures are 11.7 and 26.5^0 C respectively. The hottest months are from January to May with a maximum temperature record of 26^0 C and the coldest months range from June to October with a minimum temperature of 12.2^0 C. The mean annual rainfall of the study area is 1805 mm. The rainfall pattern is unimodal, with little or no rainfall in January and February, and gradually increasing to a peak period between June and September and decreasing in November and December (Figure 5). Gera is classified into Dega (5%), Woinadega (75%) and Kolla (20%) agro climatic zones (G.D.A.R.D.O, 2012).

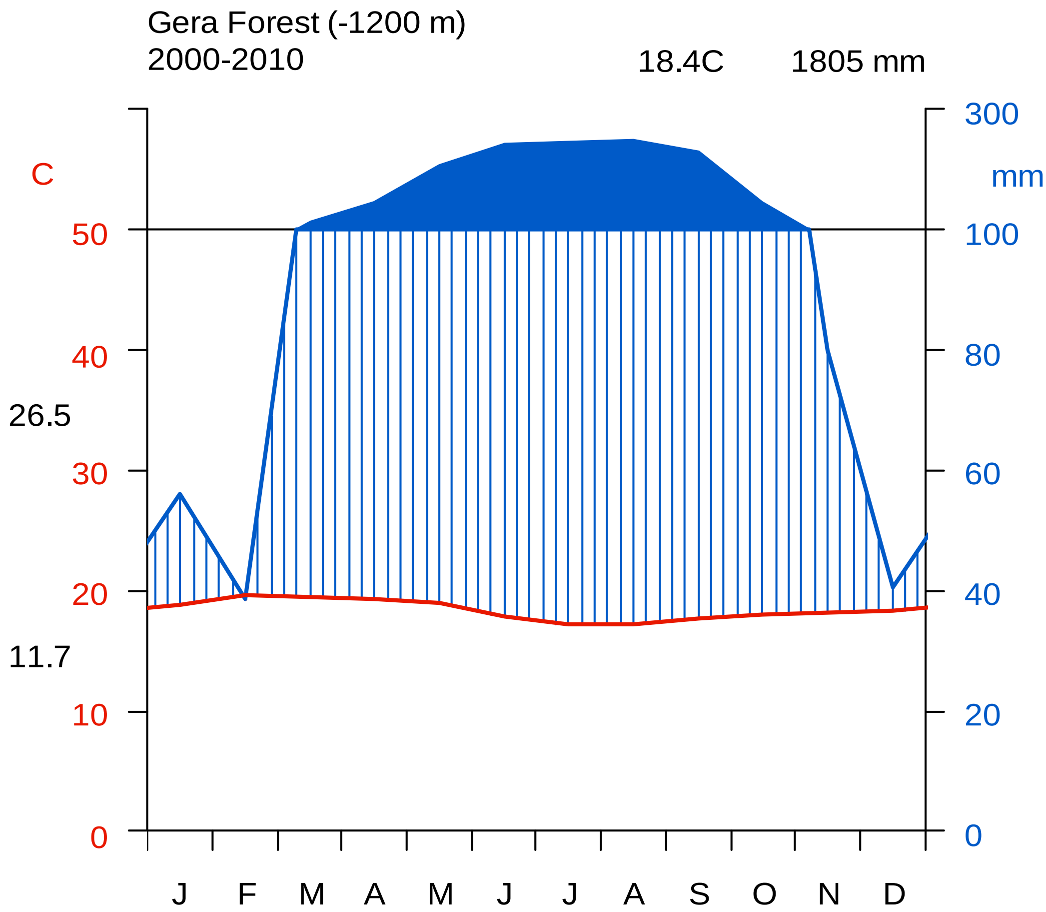

Figure 5 Climate diagram of the study area (Data source EMA)

3.1.6. Land use and agriculture

The proportion of arable, grazing and forest lands in Gera District is 15.47%**,** 5.6%and 56% respectively (G.D.A.R.D.O., 2012). The remaining land area is either degraded, houses has built-up or serves for other purpose (Table 1). High forest, woodland and plantation forests are available in the District. The majority of the natural forest patches are under the government protection**.** Gera District has 226,754 cattle, 54,801 sheep, 30,532 horses, 21, 205 poultry 14,473 goats, 7,041 mules and 1,934 donkeys. There are some retail traders, small shops, and open markets, in the District. Teff, maize, wheat, sorghum, barely, faba bean, field pea, peppers, fruits, spices, and coffee are important cash crops in the District. Honey production is also practiced in the Forest area.

Table 1 Land use pattern of Gera District (Source: G.D.A.R.D.O., 2012)

No.	Land use Type	Area in hectare	%
1	Potential arable land	22,323.00	15.47
2	Grazing land	8089.22	5.6.00
3	Forest	80,830.40	56.00
4	Cultivable land	3,148.00	2.18
5	Uncultivable land	5,901.76	4.09
6	Construction	9002.62	6.24
7	Others	15,045.00	10.42
	Total	**144,340.00**	**100.00**

3.1.7. Wildlife

The forest vegetation of Gera District hosts various species of wild animals including mammals, birds, reptiles and amphibians. Commonly mammals found in the Forest are buffalos, lions, Colobus monkeys, Gelada baboons, Vervet monkeys, tigers, warthogs, pigs, civet cats and antelopes. However, the populations of these animals are under severe threat due to deforestation and habitat fragmentation mainly because of human encroachment.

3.1.8. Drainage

Gera District is characterized by a wide topographic land forms. It is endowed with numerous streams and rivers. Several perennial rivers such as Naso and Gojeb, and intermittent streams (Atta, Naniya, Sisay, Koka, Dacho, etc.) are flowing through the District. Locally protected springs, rivers, developed springs and wells are the major sources of drinking water in Gera (figure 6).

Figure 6 Picture showing partial view of Gera Moist Montane Forest

3.1.9. Vegetation

The forest vegetation is stratified into four different layers, namely, upper canopy, sub-canopy, shrub layer and the ground layer. The upper canopy is composed of the spectacular emergent trees of *Pouteria adolfi-friederici*. *Podocarpus falcatus* is important in the mixed broad-leaved forests of the Gera Mountains, although conifers are generally less important in moist forests of Ethiopia. Other characteristic species in the canopy include *Olea welwitschii* and *O.capensis* subssp *macrocarpa*, *Prunus africana*, *Albizia schimperiana*, *Millettia ferruginea* and *Celtis africana*. Others such as *Polyscias fulva*, *Schefflera volkensii*, *Trilepisium madagascariense*, *Schefflera abyssinica*, *Bersama abyssinica* and *Mimusops kummel* are also associated to it. Sub-canopy species include: *Croton macrostachyus*, *Cordia africana*, *Dracaena steudneri*, *Syzygium giuneense* subsp. *afromontanum*, *Sapium ellipticum*, *Ilex mitis*, *Erythrina brucei* and *Rothmannia urcelliformis*. The shrub layer consists of species including *Coffea arabica*, *Galiniera saxifraga*, *Teclea nobilis*, *Ocotea kenyensis*, *Clausena anisata*, *Maesa lanceolata* and *Maytenus* spp. The woody climbers are *Urera hypselodendron*, *Landolphia buchananii*, *Embelia schimperi* and *Jasminum* spp. The ground vegetation is mainly composed of herbaceous plants include species of *Acanthus*, *Justicia*, *Piperoma*, *Galinsoga*, *Impatiens*, *Urtica* and several grass species. (Yohannes Mulugeta, 2013)

3.2. Methods of Data Collection

3.2.1. Sampling design

Reconnaissance survey and data collections 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. Gera Forest contains modern coffee plantation forest, non-coffee forest, wild coffee forest, ridge and valley. 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 soil seed bank regeneration potential, and to study the effects of the habitat type on potential ofsoil seed bank regeneration.

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

- **a) RI** (ridge),
- **b) VA** (valley),
- **c) WCOF** (Wild Coffee forest),
- **d) NCOF** (Non-coffee forest) and
- **e) MCOFP** (Modern Coffee plantation)

3.2.2. Vegetation data collection and plant identification

Vegetation data were collected to examine the similarity between above ground and seed bank floras. A total of 50 quadrats were analysed. The quadrat sizes established for all growthform were 30 m x 30 m (900m^2). In each quadrat all trees, shrubs and herbs were identified. Thealtitude 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 referring to the Flora of Ethiopia and Eritrea comparison with authenticated specimens housed at ETH and consulting experts.

3.2.4. Soil Seed Bank Analysis

In order to investigate the composition and density, as well as the vertical distribution of the soil seed bank 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 nine centimeters in each sample quadrat. The Sampling method employed was systematic.

A line transect was laid along an altitudinal gradient between 1650 to 2350 m a.s.l. Along three transect lines, 1st from Chira Town to Anfalo District, 2nd Weastern part of Chira Town to non-coffeeforest, and 3rd from Chira Town to Agaro town. 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 7). The reason for taking the soil samples at the three soil layers were to examine if there was any variation in the depth distribution of seeds within and amongthe Gera Wild Coffee Forest, Non-coffee forest, Modern Coffee Plantation, Ridge and Valley Forest in the soil.

A total of 200 soil samples, including the litter layer, were collected from 50 quadrats at Gera Forest. At Chira Town-Anfalo site, a total of 16 soil samples composed of 64 different soil layers and including litter were taken. On the second study site, around Chira Town Non-Coffee area, a total of 21 soil samples composed of 84 different soil layers and including litter were taken. On thethird study site, Chira to Agaro, a total of 13 soil samples composed of 52 different soil layers and including litter were taken (Table 2).

Table 2 summary of site, quadrats and soil sample

Site	**Number of quadrats**	**Number of soil sample**
Chira Town to Anfalo	16	64
Western part of Chira Town Non-coffee forest	21	84
Chira Town to Agaro	13	52
Total	**50**	**200**

For such investigation from three study sites, a total of 200 soil samples were taken from four soil layers, the litter layer and three successive layers (0-3 cm, 3-6 cm, and 6-9 cm). Soil samples from identical layers of the five subplots 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 and transported to the greenhouse of the Department of Plant Biology and Biodiversity Management, Addis Ababa University.

Figure 7 Picture of seed bank sample collection from Gera Wild Coffee Forest

3.2.5. Greenhouse germination

The seedling emergence experiments were performed in a green house at the Department of Plant Biology and Biodiversity Management, Addis Ababa University under average temperature and humidity of 24^{o}C and 57.5%, respectively. In the greenhouse, each three centimeter 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 greenhouse appeared two weeks after the start of the germination experiment. Because of shade tolerant species the sample pots were placed under the table to control direct sun light. The emerging seedlings were collected, counted, pressed, dried, checked, and cross checked with the seedeling that we collect from the study site for further identification plant species at seedling stage and identified at the National Herbarium (ETH), Department of Plant Biology and Biodiversity Management, Addis Ababa University. Identified seedlings were recorded and discarded.

Seedlings that were identified at the species level were counted and removed to reduce the possibility of germination suppression of other seeds due to competition. Seedlings that could not be identified were individually transplanted to pots and grown, where necessary, until flowering. After three months, germination in most trays ceased, partly due to colonization of the trays by mosses and liverworts. By that time, the soil samples were stirred in order to expose seeds to the light that resided in lower sections of the soil layer within the trays, which might have hampered germination. Stirring was done every three months. After 12 months (November 2012 to November 2013), few additional seeds were germinating even immediately after stirring the soil, and the experiment was concluded.

Digital information (photo) of the seedlings was taken to be included as a pictorial representation.

3.3. Data analyses

To investigate the effect of habitat types and the potential of soil seed bankflora, in terms of species composition of soil seed bank flora, the data were analyzed in the following ways. Species composition (number of species germinated per sample) and density of the soil seed bank among the study sites and between soil depths were compared using two-way analysis of Variance.

Similarities of soil seed bank 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 of species common to both quadrats/samples

b= number of species in quadrat/sample 1

c= number of species in quadrat/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 through the use of Minitabversion16was used to assess the differences in density of seed bank between habitat types. Total regenerating individuals are expressed as density per hectare. Similarity index of soil seed bank regenerated species in the different land use types was calculated using Jaccard's Coefficient of Similarity (JCS) (Krebs 1989).

CHAPTER FOUR

4. Results

4.1. Description of the Habitat Types

Based on visual observation, five major habitat types were identified in the study area. These are acronymed as RI (Ridge), VA (Valley), WCOF (Wild Coffee Forest), NCOF (Non-coffee Forest) and MCOFP (Modern Coffee Plantation).

4.1.2. Species composition of soil seed banks

A total of 66 plant species representing 34 families were recovered from the litter and the 0-9cm 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 44 species (66.7%), while shrubs and trees were represented by 21 species (31.8%) and climber 1 species (1.67%). The species composition in different land use types ranged from 29 to 62 species; the highest number of species was recovered in the Non-coffee forest habitat types and the lowest in the Modern Coffee plantation (Figure 8, Appendix 3).

Out of the total number of species recorded, 62 were from Non-coffee Forest, 60 from Valley habitats, 51 from Ridges, 41from Wild Coffee Forest and 29 species were recovered from Modern Coffee Plantation. Overall, only a few species of woody (shrub/tree) were recorded from the soil samples collected from Modern coffee plantation, i.e. only 7 shrubs/ trees germinated from the collected soil samples. However, all the other habitat types had more recovery of woody species (figure 9, Appendix 3).

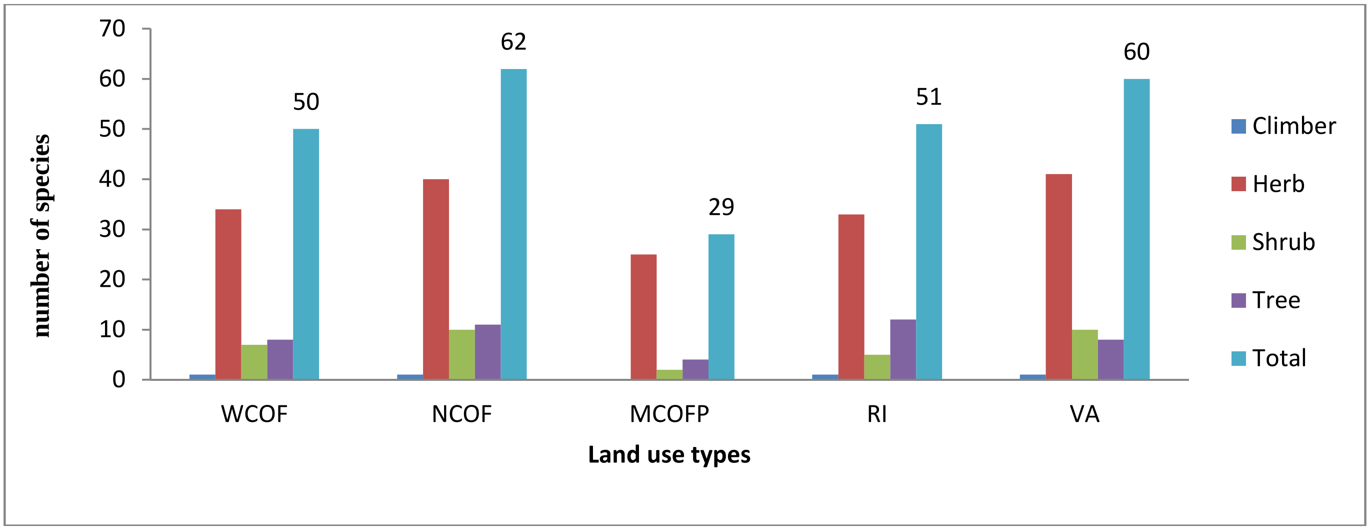

Figure 8: Number of species and their growth forms recorded from SSB of the upper 9 cm soil depth collected from five habitat types; KEY: RI (Ridge), VA (alley), WCOF (Wild Coffee Forest), NCOF (Non-Coffee Forest) and MCOFP (Modern Coffee Plantation).

4.1.3. Similarity in species composition among land use types

The similarity in species composition of the soil seed bank between the five-land use types was generally high and ranged from JCS values of 0.414 (between Non-Coffee Forest and Modern Coffee Plantation forest habitat types) to 0.737 (between Ridge and Valley habitat types). The second highest similarity in species composition (*Sj* = 0.721) was recorded between Non-coffee Forest andValley habitat types (Table 3).

Table 3: Jaccarad's coefficient of similarity in species composition of soil seed banks between the habitat types, (* the lowest similarity, ** the highest similarity)

	WCOF	**NCOF**	**MCOFP**	**RI**	**VA**
WCOF	-	0.6	0.643	0.586	0.685
NCOF		-	0.414*	0.689	0.721
MCOFP			-	0.431	0.509
RI				-	0.737**
VA	-	-	-	-	-

The similarity between the soil seed bank and aboveground flora was very low (ranging from Sj values of 0.08 for Modern Coffee Plantation Forest to 0.28 for Non-coffee forest (Table 4).

Only seventeen woody species out of 66 species (*Vernonia hochstetteri, Vernonia auriculifera, Vernonia amygdalina, Syzygium guineense, Rubus niveus, Podocarpus falcatus, Olea welwitschii, Millettia ferruginea, Maesa lanceolata, Macaranga capensis, Ehretia cymosa, Ficus sur, Erythrina brucei, Coffea arabica, Cordia africana, Croton macrostachyus* and *Allophylus abyssinicus*) were represented both in the aboveground vegetation and in the soil seed bank. Some woody species that are commonly found in the aboveground flora, especially in Wild Coffee Forest and Non-Coffee Forest, were not represented in the seed bank. For example, *Albizia gummifera, Brucea antidysenterica, Ekebergia capensis, Teclea nobilis, Schefflera abyssinica, Rhamnus prinoides, Ricinus communis, Prunus africana, Olea capensis* and *Pouteria adolfi-friederici* are abundant species in the aboveground flora but absentfrom the seed bank.

Table 4: Jaccard's coefficient of Similarity between soil seed bank and aboveground flora

Habitat Types	Common Species	Species exclusive to aboveground flora	Species exclusive to soil seed bank	Jaccard similarity Values
WCOF	4	22	6	0.125
NCOF	10	16	10	0.28**
MCOFP	5	21	10	0.08*
RI	6	20	4	0.2
VA	3	4	19	0.115

4.1.4. Seed bank density and habitat types

Seed bank density (number of seedlings emerging from seed bank samples) ranged from 10,333 - 93,293 m^{-2}. All soil layers and land use types exhibited various number of seed bank density. A total of 257,404 m^{-2} seedlings were recorded, of which 93,293 m^{-2} were recorded from Non-Coffee Forest, 39,954 m^{-2} from Wild Coffee Forest, 65,866 m^{-2} from Valley habitat type, 44,310 m^{-2} from Ridge habitat type of the forest and 10,333 m^{-2} from Modern Coffee Plantation Forest (Figure9).

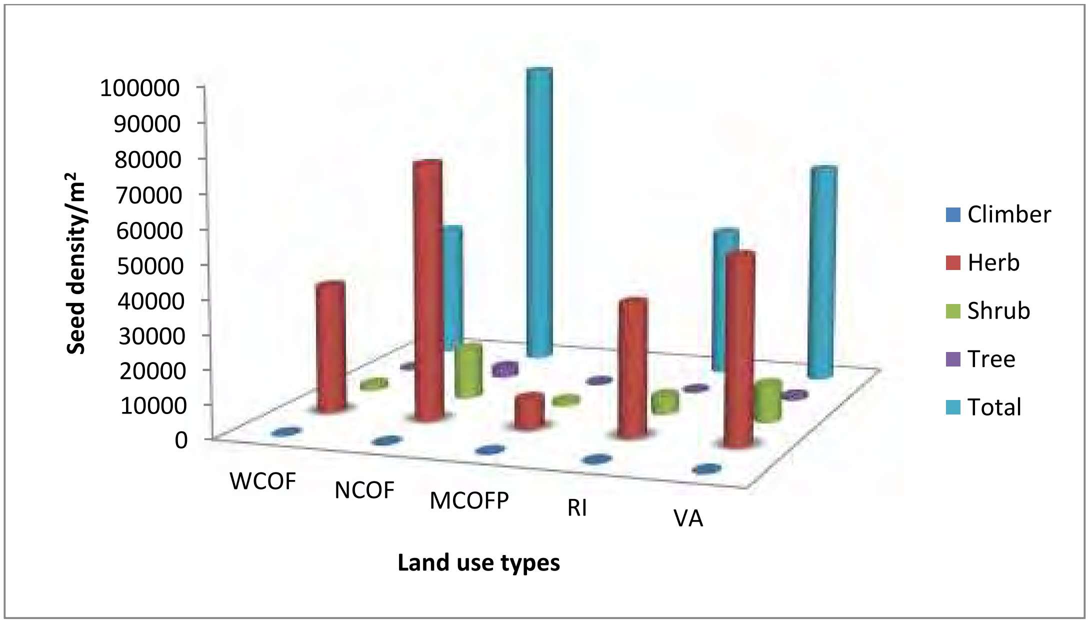

Figure 9: Seed density (seeds/m^2) of species and their growth form in different land use types; Key: RI (Ridge), VA (Valley), WCOF (Wild Coffee Forest), NCOF (Non-coffee Forest) and MCOFP (Modern Coffee Plantation).

The density was larger in Valley and Non-coffee Forest when compared to the remaining habitat types. The highest total densities of viable seeds among habitat types were recorded in Non-coffee Forest habitat type of the forest (93,293 m^{-2}), while the lowest was recorded in the Modern Coffee Plantation (10,333m^{-2}). In fact, the contents of seed bank density varied from habitat to habitat.

Thirteen species with the highest soil seed density contributed 66% of the total estimated seed banks (Table 5, Appendix 4). Accordingly, the most abundant species are; *Scoparia dulcis, Oxalis radicosa*, *Dichondra repens* and *Vernonia amygdalina* were recovered 61% in Non-Coffee Forest while the remaining 39% were contributed from the other habitat types. In all habitat types, herbaceous species were dominant (Figure10, Appendix3). *Vernonia amygdalina, V. auriculifera, Stellaria media, Oxalis radicosa, Kalanchoe petitiana, Impatiens hochstetteri, I. ethiopica, Hypericum peplidifolium, Bidens pilosa, Commelina benghalensis, Crassula alsinoides, Cyperus pulchellus, Dichondra repens, Dichrocephala integrifolia, Galinsoga quadriradiata, Oplismenus hirtellus* and *Scoparia dulcis* have exhibited germinability from almost all habitat types. Those which germinated only in Valley habitat type of the forest include *Olea welwitschii* and *Podocarpus falcatus*. Similarly, *Physalis peruviana, Dissotis rotundifolia* and *Abutilon logicuspe* germinated only in Non-coffee Forest and *Hibiscus vitifolius, Ehretia cymosa* and *Conyza stricta* were recorded only in Ridge habitat type of the forest.

The density of climber species was very low in the soil collected from thestudy sites. The total density of climber species germinated in the seed bank that originated from Non-coffee Forest only. The total list of seed bank flora by growth form for each habitat type is given in Appendix 3.

Table 5: Soil Seed Density (seeds/m^2) of some highest seed density species in relation to habitat types

No	Species	WCOF	NCOF	MCOFP	RI	VA	Total
1	*Oxalis radicosa*	5467	9111	1778	2578	7556	**26490**
2	*Galinsoga quadriradiata*	3600	4400	3556	3689	4711	**19911**
3	*Dichondra repens*	1200	8578	889	4311	4578	**19556**
4	*Ardisiandra wettsteinii*	2222	2667	578	3111	5778	**14356**
5	*Impatiens hochstetteri*	2444	3333	2000	2978	3156	**14044**
6	*Scoparia dulcis*	2044	9356	711	2933	3556	**13200**
7	*Impatiens ethiopica*	2222	2400	1778	2444	2667	**11111**
8	*Vernonia amygdalina*	889	6667	444	711	2222	**10933**
9	*Vernonia auriculifera*	889	1778	889	2222	2889	**8667**
10	*Crassula alsinoides*	2400	2578	667	889	2000	**8533**
11	*Droguetia iners*	1867	3511	89	800	2133	**8400**
12	*Cyperus pulchellus*	1556	4578	222	533	889	**7600**
13	*Stellaria media*	2000	2889	444	889	933	**7156**
Total		**28,800**	**61,846**	**14,045**	**28,088**	**43,068**	**169957**

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 seed bank density was recorded in the first sampling layer (= 0-3 cm depth) for all habitat types (Figure.10). Although the general anticipation is a gradual decrease in the density of seed bank along increasing depth gradient, higher number of seed bank was recorded for soil layer 0-3 cm than 3-6 cm and 6-9 cm e.g.Valley (Figure 10, Appendix 4).

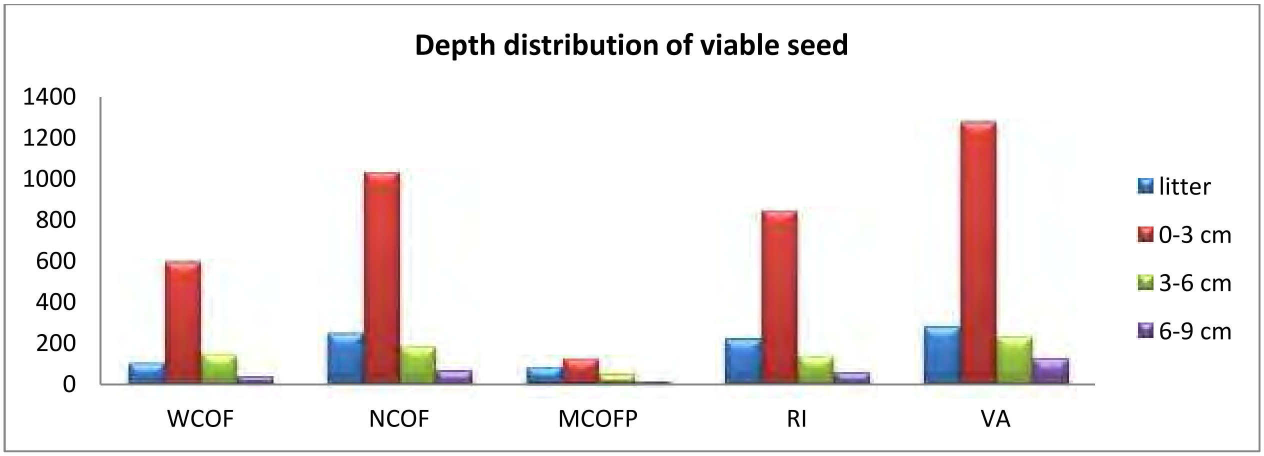

Figure 10: Depth distribution of viable seeds for all habitat types

There was variation in the depth distribution pattern of seeds among different plant species. In almost all samples, the 6-9 layers had lower number of species and seed density compared with that in the top three centimeter layer (Figure 11). For instance, seeds of some species were recovered only from the upper three centimeter soil layers, e.g. *Coffea arabica*, *Carduus leptacanthus*, *Commelina benghalensis*, *Cynoglosum amplifolium*, *Kalanchoe petitiana*, *Laggera crispata*, *Sonchus asper* and *Salvia nilotica*. Likewise, *Podocarpus falcatus* and *Caesalpinea* had their seeds distributed in the deeper (6-9 cm) soil layers. On the other hand, *Alchemilla abyssinica*, *Conyza stricta*, *Crassula alsinoides*, *Cyperus pulchellus*, *Galinsoga quadriradiata*, *Medicago polymorpha* and *Oxalis radicosa* had almost uniform depth distribution.

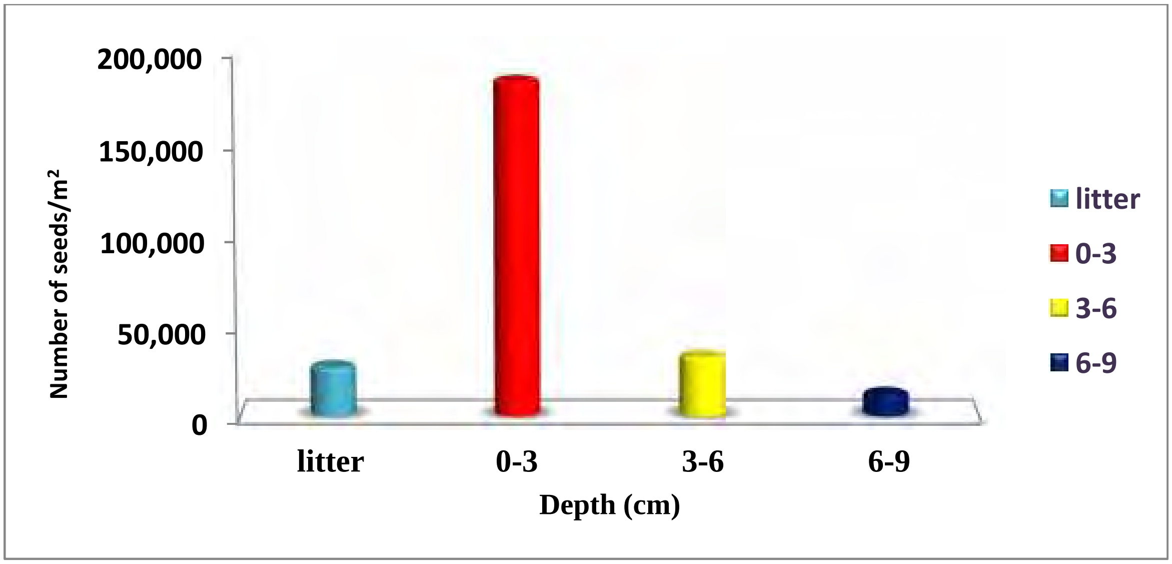

Figure 11: Vertical distribution of seeds

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.For instance, herbaceous species, such as *Achyrantus aspera* and *Oxalis radicosa* possess seeds that stick tightly on animals and become dispersed to the area by birds and other animals.

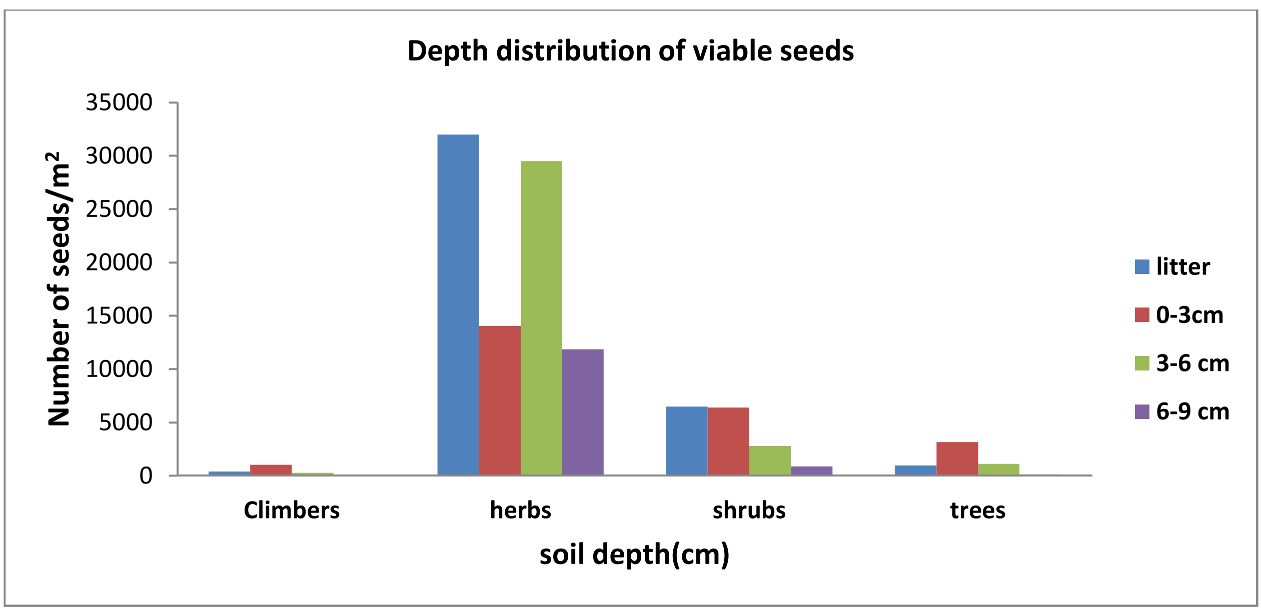

Figure 12: Growth form distribution of species in the seed bank with depth

4.2. Compositions and Density of Seedlings and Saplings in Gera Forest

Seedlings of 24 different woody species were encountered during the current study. The aggregate density of these seedlings was 4,208 individuals /hectare. *Millettia ferruginea* was found to have the highest seedling density (741individuals/hectare). While *Grewia ferruginea* had the second highest seedling density (740 individuals/hectare) in the natural gaps study conducted at Gera forest. On the other hand some species exhibited to have the smallest seedling density (individuals/ hectare) in the forest. Twenty seven woody species were recorded inside the sampled plots. The aggregate density of saplings was 630individuals/hectare.

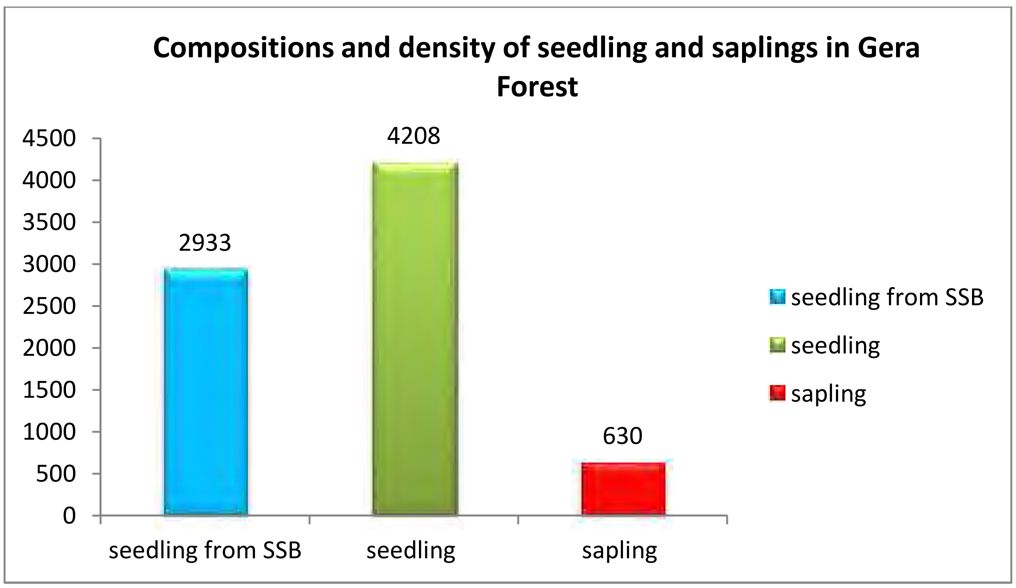

Figure 13: composition and density of seedlings from soil seed bank (SSB), seedlings and saplings in Gera Forest

CHAPTER FIVE

5. DISCUSSIONS

5.1. Discussion

5.1.1. Soil Seed Banks

The seed bank in Gera Forest contains many species (66) as determined from germinated seedlings. This goes and line with earlier findings that showed vegetation maintains and increases its populations through the process of regeneration involving soil seed banks and vegetative sprouts (Garwood, 1989). In this study, it was observed that several species employ soil seed bank strategies to maintain their population structure. The mean sapling was higher and seedling density was lower than in other similar montane forests. For instance, Mamo Kebede (2012) recorded a density of $1331.1h^{-1}$ seedling and $917h^{-1}$ sapling in Wondo Genet moist montane forest. This difference is probably due to selective logging of Wondo Genet seed trees leaving several species with little or no offspring.

The seed banks were dominated by herbaceous species in the study area, while woody species were fewer in number. Most of the seed banks under the different habitat types were characterized by high proportions of herbs (about 65.7%) 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 seed sizes of most herbs are small and easily dispersed by different mechanisms and get the opportunity to find with high density in the soil seed bank. The similarity between the seed bank and aboveground flora was low. All seeds in the soil (from the standing vegetation or dispersed from far distances) were not likely to germinate, their loss can be one of the probable reasons for the weak association between the seed bank and standing vegetation. Several studies have supported the lack of similarity in species composition between the seed in the soil and the aboveground vegetation (Mekuria Argaw *et al.*, 1999; Kebrom Tekle and Tesfaye Bekele, 2000; Feyera Senbeta and Demel Teketay, 2001; Tefera Mengistu *et.al*., 2005 and Abdella Mekonnen *et al*., 2007). 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 persistent seed bank and standing vegetation have exhibited low compositional similarity, which agrees with the result obtained by

Abdella Mekonnen *et al*., (2007). Seeds can be buried or lost by being washed down, especially in coarse textured soils, transported into deep parts of the soil by ants and worms or may die from genetically controlled physiological responses to environmental factors (Kebrom Tekle and Tesfaye Bekele, 2000).

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. The smallest seed size has high potential to bury in the soil and can get much transportation opportunity to travel to the soil.

Some other species, although present in the aboveground vegetation, lacked viable seeds, which were observed 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 subjected to sieving (Abdella Mekonnen *et al*., 2007).Before identification has been made many species were dead at seedling stage and the growth of seedlings was very slow in the green house.

Generally, the observed low representation of the standing vegetation by the seed bank could be attributed to coffee cultivation and human disturbance, inducing lack of seed reserve for vegetation to respond following a favorable condition. One of the main probable reasons for the disparity between aboveground vegetation and soil seed bank flora, as explained by Eyob Tenkir (2006), explain that seeds of the woody plant species which are found in the aboveground flora germinate immediately within a few days after dispersal (have transient seeds) therefore they can't store seeds for a long period of time in the soil as herbaceous plants. Thus many woody species in forests germinate within a few days or weeks after dispersal. However, composition of the seed bank recorded resembled the aboveground vegetation in few cases; for example, *Coffea arabica, Rubus niveus, Achyranthes aspera, Alchemilla abyssinica, Galinsoga quadriradiata* and *Solanum nigrum*are indicator species for the study sites.

In the present study, herbaceous species constituted the most prevalent growth form emerging from various land use types. Their predominance in seed banks can be explained by a combination of several factors. These herbaceous plants are generally 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).

Herbaceous 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 herbaceous 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 and 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 coffee plantation, along Chira Town to Agaro, the proportion of herbaceous forest species declines and the seeds of weedy species such as *Galinsoga quadriradiata*, *Acyranthes aspera and Bidens* specieswhich 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 dominance only by a few of the woody species in the Coffee Plantation and Wild Coffee Forest. Selective trees like *Albizia gummifera* and *Pouteria adolfi-friederici* trees have been left because the shade of these species is too deep for maximum coffee growth, and because the wood is of high economic value. 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 clearing for coffee plantation. 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 woody species generally decreased in some habitat (Modern Coffee Plantation and Wild Coffee Forest) in the seed bank than the other habitats. Because of clearing of trees with left of only few of tree species like *Albizia gummifera* for coffee shade. Overgrazing is highly experienced in the forest and it also can affect the density of soil seed bank.

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 moist 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, 2005b). In non-dormant seeds, dormancy is induced if the seeds are dispersed under dense canopy or buried in the soil. 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 (Demel Teketay, 2005; Godefroid *et al*., 2006; Abdella Mekonnen *et al*., 2007;Chaideftou *et al*., 2011;Anderson *et al*, 2012; Tessema *et al*., 2012).

The number of species represented in the seed banks collected from Non-coffee Forest and Valleyhabitat types of the Forest was relatively high while it is low in the other land use types. In general, our results provide further evidence that consolidates the conclusions of previous studies on soil seed bank in Ethiopia.

Our result implies 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 main objective of this study was to evaluate the potential of natural regeneration status in different land use types. The results 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 results indicate higher density of seedlings than saplings. Seedlings in the Gera forest is high because they get more shade and can easily survive. But the saplings are removed regularly at least twise in a year. Our result is contrast with the density of seedlings and sapling in other area. 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. Our results showed that seed bank regeneration status is a better indicator for natural regeneration, which can provide important reference for ecological restoration globally as stated by Cheng (2012).

5.2. Conclusion

The seed banks can not be homogenous. Species composition of the parent vegetation, the fruiting season and seed dispersal patterns affect the spatial heterogeneity of the soil seed bank. 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 Gera Forest possesses large populations of buried seeds of herbaceous species. On the other hand, trees and climber species have very low viable seeds in the soil. Especially in Modern Coffee Plantation

Forest and Wild Coffee Forest habitat types have low regeneration of woody species were recorded. The composition and density of soil seed bank in the study site show variation in different land use types. High seed density and composition were recorded in the Non-coffee Forest.

Our results showed that human disturbance of the natural forest followed by subsequent Coffee plantation alters the composition and density of viable seeds in soil seed bank. Selective cut of Woody species followed by subsequent coffee plantation resulted in a more or less continuous exhaustion of seeds of woody species from the soil seed bank. This shows that plantation of coffee in wider manner, driven mainly by the need for more land of the forest for large coffee plantation based investment, is a threat to the diversity of the tropical Moist Afromontane forest in 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 soil seed bank.

Gera Forest is one of the remaining forests harboring a unique gene reserve of wild coffee and several associated economic plant species. This Forest is ecologically, socially and economically very important for the inhabitants residing nearby who are mostly dependent on forest products to make their living. Loss of such a forest and the various threatened species would have great implications for the environment, biodiversity and socio-economic setup of the communities.
The concerned bodies have to take due consideration for conservation and sustainable utilization of this Forest resource.

5.3. Recommendation

For effective management and monitoring of Gera Forest on a sustainable basis, the following points are forwarded as recommendations:

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

- The management strategy should focus on multiple-use conservation approach. For example, undisturbed areas of the Forest can be designated for strict conservation so that they may act as repositories of biodiversity and possibly as a source of forest genetic resources while the peripheral areas could be utilized on a sustainable basis,

- More basic and applied researches should be encouraged to assist the planning and management of the Forest.
- Some trees and shrubs in the forest margins are being cleared for Modern coffee plantation this will create its own problem in species richness and abundance so education must be given to the society about the diversity.
- Greenhouse experiment of such research should be available at Gera forest.

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

Transect	Plot (Quadrat)	Altitude (m a.s.l)	Latitude	Longitude
1	1	2100	07^{0} 43.02' N	036^{0} 15.91' E
1	2	2050	07^{0} 43.152' N	036^{0} 15.045' E
1	3	1880	07^{0} 43.16' N	036^{0} 15.98' E
1	4	1920	07^{0} 41.28' N	036^{0} 15.21' E
1	5	2000	07^{0} 41.10' N	036^{0} 15.29' E
1	6	2030	07^{0} 42.7' N	036^{0} 15.3' E
1	7	2030	07^{0} 41.9' N	036^{0} 15.2' E
1	8	2950	07^{0} 42.73' N	036^{0} 15.30' E
1	9	2060	07^{0} 42.81' N	036^{0} 15.433' E
1	10	2040	07^{0}42.98' N	036^{0}15.480' E
1	11	2050	07043.04' N	036^{0}15.480' E
1	12	1650	07^{0}36.79' N	036^{0} 12.18' E
1	13	1700	07^{0} 36.74' N	036^{0} 11.95' E
1	14	1700	07^{0} 36.79' N	036^{0} 12.05' E
1	15	1720	07^{0} 36.87' N	036^{0} 12.37' E
1	16	1700	07^{0} 36.92' N	036^{0} 12.95' E
2	17	2320	07^{0}46.19' N	036^{0} 14.21' E
2	18	2320	07^{0}46.10' N	036^{0} 14.21' E
2	19	2300	07^{0}46.21' N	036^{0} 14.21' E
2	20	2315	07^{0}45.93' N	036^{0} 14.21' E
2	21	2300	07^{0}45.93' N	036^{0} 14.22' E
2	22	2290	07^{0}45.96' N	036^{0} 14.26' E
2	23	2300	07^{0}45.93' N	036^{0} 14.15' E
2	24	2300	07^{0}45.86' N	036^{0} 14.24' E
2	25	2200	07^{0}45.88' N	036^{0} 14.33' E
2	26	2200	07^{0}45.63' N	036^{0} 14.35' E
2	27	2200	07^{0}45.69' N	036^{0} 14.35' E
2	28	2150	07^{0}45.50' N	036^{0} 14.38' E
2	29	2150	07^{0}45.55' N	036^{0} 14.40' E
2	30	2150	07^{0}45.37’N	036^{0}14.44' E
2	31	1800	07^{0}39.51’N	036^{0}14.88' E
2	32	1800	07^{0}39.51’N	036^{0}14.88' E
2	33	1977	07^{0}39.81' N	036^{0}14.74' E
2	34	1977	07^{0}39.81' N	036^{0}14.74' E
2	35	1988	07^{0} 40.25' N	036^{0}14.58' E
2	36	1988	07^{0} 40.25' N	036^{0}14.58' E
2	37	1990	07^{0}40.43' N	036^{0}14.56' E

3	38	2030	07^{0}40.81' N	036^{0}14.450' E
3	39	2110	07^{0}45.46' N	036^{0}15.355' E
3	40	2160	07^{0}45.82' N	036^{0}15.23' E
3	41	2000	07^{0}46.087' N	036^{0}17.387' E
3	42	1970	07^{0}46.232' N	036^{0}17.381' E
3	43	1980	07^{0}46 .381' N	036^{0}17.299' E
3	44	1945	07^{0} 46.096' N	036^{0}18.052' E
3 3	45 48	1945 2140	07^{0} 46.096' N 07^{0}45.563' N	036^{0}18.044' E 036^{0}14.499' E
3	49	2200	07^{0}45.605' N	036^{0}14.464' E
3	50	2190	07^{0} 45.638' N	036^{0}14.403' E

Appendix 2 List of plant species collected from Gera forest. Key: T=tree, S=shrub, H=herb, C=climber

No.	Scientific Name	Family	Vernacular Name	Habit	Coll. No
1	*Acanthus eminens* C.B. Clarke	Acanthaceae	Balawarantii	S	YM 001
2	*Achyranthes aspera* L.	Amaranthaceae	Tebe dima	H	YM 035
3	*Achyrospermum schimperi* Hochst.ex Briq.	Lamiaceae	Bala dalecha	H	YM 038
4	*Adenostemma mauritianum* DC.	Asteraceae	Maxxanee	H	YM 099
**5	*Aframomum corrorima* (Braun) Jansen	Zingiberaceae	Ogiyo	H	YM 090
6	*Aframomum zambesiacum* (Baker) K.Schum.	Zingiberaceae	Ogiyo-deljessa	H	YM 117
7	*Ageratum conyzoides* L.	Asteraceae		H	YM 047
**8	*Albizia gummifera* (J.F.Gmel.) C.A.Sim.	Fabaceae	Sasa	T	YM 014
9	*Allophylus abyssinicus* (Hochst.) Radlkofer	Sapindaceae	Se'o	T	YM 070
**10	*Apodytes dimidiata* E. Mey. ex Arm.	Icacinaceae	Wendebo	T	YM 089
11	*Arthropteris monocarpa* (Cordem.) C.Chr.	Oleandraceae		H	YM 131
12	*Asparagus racemosus* Willd.	Asparagaceae	Sariitii	S	YM 031
13	*Bersama abyssinica* Fresen.	Melianthaceae	Lolchiisaa	S	YM 015
14	*Brucea antidysenterica* J.F.Mill.	Simaroubaceae	Boqo/Qomonyo	S	YM 009
15	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	Ceekaa	S	YM 005
16	*Canthium oligocarpum* Hiern	Rubiaceae	Barsadi	S/T	YM 048
**17	*Celtis africana* Burm.f.	Ulmaceae	Qawo	T	YM 054
18	*Chamaecrista mimosoides* (L.) Greene	Fabaceae	Harengema	S	YM 125
19	*Clausena anisata* (Willd.) Benth.	Rutaceae	Ulumaayyii	S	YM 012

20	*Clerodendrum myricoides* (Hochst.) Vatke	Lamiaceae	Marachissa	S	YM 121
**21	*Coffea arabica* L.	Rubiaceae	Bunaa	S/T	YM 069
22	*Combretum paniculatum* Vent.	Combretaceae	Begge	C	YM 113
23	*Commelina benghalensis* L.	Commelinaceae	Laalunxyee	H	YM 091
24	*Coniogramme africana* Hieron.	Hemionitidaceae	Gitto	H	YM 096
**25	*Cordia africana* Lam.	Boraginaceae	Waddessaa	T	YM 067
26	*Crassocephalum crepidioides* (Benth.)S. Moore.	Asteraceae		H	YM 040
27	*Crotalaria incana* L.	Fabaceae	Atokemelle	H	YM 046
28	*Crota1aria mildbraedii* Bak.f.	Fabaceae		S	YM 092
**29	*Croton macrostachyus* Del.	Euphorbiaceae	Bakanisaa	T	YM 055
30	*Culcasia falcifolia* Engl.	Araceae	Emberiko	C	YM 080
31	*Cyathea manniana* Hook.	Cyatheaceae	Sesno	S/T	YM 085
32	*Cymbopogon caesius* (Hook, &Am.) Stapf.	Poaceae	Kello	H	YM 118
33	*Cynoglossum amplifolium* Hochst. ex A.DC.	Boraginaceae	Chaqo	H	YM 097
34	*Cynoglossum coeruleum* Hochst. ex A.DC.	Boraginaceae	Matane-chati	H	YM 115
35	*Deinbollia kilimandscharica* Taub	Sapindaceae	Qomenno	T	YM 075
36	*Desmodium repandum* (Vahl) DC.	Fabaceae	Matane	H	YM 036
37	*Dracaena afromontana* Mildbr.	Dracaenaceae	Algae	S	YM 002
38	*Dracaena steudneri* Engl.	Dracaenaceae	Lankuso/Yudo	T	YM 082
39	*Drynaria volkensii* (Hieron)	Polypodiaceae		H	YM 122
40	*Ehretia cymosa* Thonn.	Boraginaceae	Ulaagaa	S	YM 066
**41	*Ekebergia capensis* Sparrm.	Meliaceae	Sombo	T	YM 024
42	*Englerina woodfordioides* (Schweinf.) M.Gilbert	Loranthaceae	Harmuko	S	YM 119
*43	*Erythrina brucei* Schweinf.	Fabaceae		T	YM 109
44	*Euphorbia ampliphylla* Pax	Euphorbiaceae		T	YM 027
45	*Euphorbia schimperiana* Scheele	Euphorbiaceae	Anneno	H	YM 087
46	*Euphorbia* sp.	Euphorbiaceae		H	YM 119
47	*Ficus lutea* Vahl	Moraceae	Harbu	T	YM 059
48	*Ficus sur* Forssk.	Moraceae	Harbu	T	YM 023
49	*Ficus thonningii* Blume	Moraceae	Dambii	S	YM 103
50	*Flacourtia indica* (Burm.f.) Merr.	Flacourtiaceae	Akuukkuu	T	YM 084
51	*Galiniera saxifraga* (Hochst.) Bridson	Rubiaceae	Simararu	T	YM 063
52	*Geranium arabicum* Forssk.	Geraniaceae		H	YM 050
53	*Girardinia diversifolia* (Link) Friis	Urticaceae		H	YM 095
54	*Gouania* longispicata Engl.	Rhamnaceae	Homechesa	C	YM 007

55	*Grewia ferruginea* Hochst. ex A.Rich.	Tiliaceae	Bururi	S	YM 064
56	*Halleria lucida* L.	Scrophulariaceae	Mukafoni	S/T	YM 053
57	*Hibiscus cannabinus* L.	Malvaceae	Kunche gajo	H	YM 025
58	*Hibiscus macranthus* Hochst. ex A. Rich.	Malvaceae	Keraba	H	YM 073
59	*Hibiscus vitifolius* L.	Malvaceae		H	YM 037
60	*Hippocratea africana* (Willd.) Loes.	Celastraceae	Hida -galle	C	YM 116
61	*Huperzia ophioglossoides* (Lam.) Hayata	Lycopodiaceae		H	YM 123
62	*Hypoestes forskaolii* (Vahl) R.Br.	Acanthaceae	Togo	H	YM 003
63	*Ilex mitis* (L.) Radlk.	Aquifoliaceae	Qetto	T	YM 033
64	*Impatiens hochstetteri* Warb.	Balsaminaceae	Kichu	H	YM 044
65	*Jasminum abyssinicum* Hochst. ex DC.	Oleaceae	Elchime	C	YM 021
* 66	*Justicia diclipteroides* Lindau subsp.aethiopica Hedren	Acanthaceae		H	YM 104
67	*Justicia schimperiana* (Hochst. ex Nees) T. Anders	Acanthaceae	Dumuga	S	YM 071
68	*Landolphia buchananii* (Hall.f.) Stapf.	Apocynaceae	Qeyo	C	YM 106
69	*Lantana viburnoides* (Forssk.) Vahl.	Verbenaceae	Kusaye	S	YM 039
70	*Lepidotrichila volkensii* (Gurke) Leroy	Meliaceae	Sa'o/Hororo	T	YM 052
71	*Lepisorus excavatus* (Bory ex Willd.) Ching	Polypodiaceae		H	YM 132
72	*Loxogramme abyssinica* (Baker) M.G.Price	Polypodiaceae		H	YM 130
73	*Lycopodium clavatum* L.	Lycopodiaceae		H	YM 056
74	*Macaranga capensis* (Baill.) Sim.	Euphorbiaceae	Wongo	T	YM 004
75	*Maesa lanceolata* Forssk.	Myrsinaceae	Abbayyii	T	YM 018
76	*Margaritaria discoidea* (Baill.) Webster	Euphorbiaceae	Qetto	S	YM 114
77	*Mariscus sieberianus* Nees	Cypraceae		H	YM 124
78	*Maytenus arbutifolia* (A .Rich.) Wilczek	Celastraceae	Kombolcha	S	YM 022
79	*Maytenus undata* (Thunb.) Blakelock	Celastraceae	Kombolcha	S/T	YM 100
80	*Medicago polymorpha* L.	Fabaceae	Siddisa	H	YM 074
81	*Millettia ferruginea* (Hochst.) Bak.	Fabaceae	Sotollo/Askra	T	YM 016
82	*Momordica foetida* Schumach.	Cucurbitaceae	Minan bofa	C	YM 028

83	*Olea capensis* L.	Oleaceae	Gaagama	T	YM 057
84	*Olea welwitschii* (Knobl.) Gilg & Schellenb	Oleaceae	Baya	T	YM 058
85	*Olyra latifolia* L.	Poaceae	Gaawa	H	YM 030
86	*Oplismenus hirtellus* (L.) P. Beauv.	Poaceae	Salamey	H	YM 049
87	*Passiflora edulis* Sims	Passifloraceae		C	YM 013
88	*Pavonia schimperiana* Hochst. ex A. Rich.	Malvaceae		H	YM 021
89	*Pavonia urens* Cav.	Malvaceae	Hiniccinni	H	YM 101
90	*Pentas lanceolata* (Forssk.) Deflers	Rubiaceae		H	YM 053
91	*Peperomia molleri* C. DC.	Piperaceae		H	YM 129
92	*Peperomia tetraphylla* (Forster) Hook.	Piperaceae		H	YM 077
93	*Phoenix reclinata* Jacq.	Arecaceae	Mexxii	T	YM 065
94	*Physalis peruviana* L.	Solanaceae		H	YM 043
95	*Piper capense* L.f.	Piperaceae	Tunjo	H	YM 076
96	*Pittosporum viridiflorum* Sims.	Pittosporaceae	Sole	T	YM 006
97	*Plectranthus lanunginosus* Hochst. ex Bent.	Lamiaceae	Dama kesse	H	YM 062
98	*Podocarpus falcatus* (Thunb.) R. B. ex Mirb	Podocarpaceae	Birbirsaa	T	YM 020
100	*Polyscias fulva* (Hiern) Harms	Araliaceae	Kariyo	T	YM 008
**101	*Pouteria adolfi-friederici* Rob. & Gilg	Sapotaceae	Qararoo	T	YM 017
102	*Premna schimperi* Engl.	Lamiaceae	Urgessa	S	YM 032
103	*Prunus africana* (Hook.f.) Kalkm	Rosaceae	Oomoo	T	YM 107
104	*Psychotria orophila* Petit	Rubiaceae	Xumanee	S	YM 079
105	*Pycnostachys eminii* Gurke	Lamiaceae	Qoricha qemele	H	YM 026
106	*Rhamnus prinoides* L'Herit.	Rhamnaceae	Gesho	S	YM 110
107	*Ricinus communis* L.	Euphorbiaceae	Qobbo	S	YM 111
108	*Rubusniveus* Thunb.	Rosaceae		S	YM 045
109	*Rytigynia neglecta* (Heirn) Robyns.	Rubiaceae	Mixoo	S	YM 051
110	*Sapium ellipticum* (Krauss) Pax	Euphorbiaceae	Bosoqa	S	YM 086
*111	*Satureja paradoxa* (Vatke) Engl.	Lamiaceae	Nado	H	YM 093
112	*Schefflera abyssinica* (Hochst. ex A. Rich.) Harms	Araliaceae	Botto/Gatamaa	T	YM 010
113	*Senna septemtrionaiis* (Viv.) Irwin & Barney	Fabaceae		S	YM 041

114	*Sida rhombifolia* L.	Malvaceae	Karrabaa	H	YM 029
115	*Solanecio angulatus* (Vahl) C. Jeffrey	Asteraceae		H	YM 088
*116	*Solanecio gigas* (Vatke) C.Jeffrey	Asteraceae	Simbiriko	S	YM 034
117	*Sparmannia ricinocarpa* (Eckl. & Zeyh.) O.Ktze	Tiliaceae		S	YM 072
118	*Stephania abyssinica* (Dillon & A. Rich.) Walp.	Menispermaceae		C	YM 083
**119	*Syzygium guineense* (Willd.) DC. subsp. *afromontanum* F. White	Myrtaceae	Bedessa	T	YM 019
120	*Teclea nobilis* Del.	Rutaceae	Hadheessa	T	YM 011
121	*Tectaria gemmifera* (FÀe) Alston	Tectariaceae	Gitto	H	YM 098
122	*Thunbergia alata* Boj. ex Sims	Acanthaceae		C	YM 042
123	*Trema orientalis* (L) Bl.	Ulmaceae	Debbo	T	YM 060
124	*Tristemma mauritianum* J.F. Gmel.	Melastomataceae	Teyb	H	YM 110
125	*Urera hypselodendron* (A.Rich.) Wedd.	Urticaceae	Emo	C	YM 078
*126	*Vepris dainellii* (Pichi-serm.) Kokwaro.	Rutaceae	Hadheessa	T	YM 094
127	*Vernonia adoensis* Sch. Rip. ex Walp	Asteraceae	Solle	S	YM 102
128	*Vernonia amygdalina* Del.	Asteraceae	Ebbichaa	T	YM 061
129	*Vernonia auriculifera* Hiern	Asteraceae	Reejjii	S	YM 081
130	*Vernoniahochstetteri* Sch. Bip. ex Walp.	Asteraceae	Eilbu	S	YM 112

* Endemicspecies recorded from Gera Forest
** Commercially importance plant species in Gera Forest

Appendix 3: List of species recorded from the soil seed bank with the total number

No	Species Name	Litter	0–3 cm	3– 6 cm	6–9cm	Total	Seeds/m^2
1	*Abutilon logicuspe* Hochst.ex A.Rich.	0	17	3	1	**21**	**933**
2	*Achyranthes aspera* L.	0	41	6	3	**50**	**2,222**
3	*Alchemilla abyssinica* Fresen.	9	10	5	1	**25**	**111**
4	*Allphylus abyssinicus* (Hochst)Radlkor	0	5	1	0	**6**	**267**
5	*Ardisiandra wettsteinii* R. Wagner	48	185	66	24	**323**	**14,356**
6	*Bidens pilosa* L.	5	35	12	0	**62**	**2,756**
7	*Bidens prestinaria* (Sch. Bip.) Fiori.	2	4	5	0	**11**	**489**
8	*Cardamine africana*	0	28	11	2	**41**	**1,822**
9	*Carduus leptacanthus* Fresen.	0	13	1	0	**14**	**622**
10	*Caesalpinia decapetala*	0	7	2	0	**9**	**400**
11	*Commelina benghalensis* L.	0	12	1	0	**13**	**578**

12	*Cordia africana* Lam.	0	7	3	1	**11**	**489**
13	*Croton macrostachyus* Del.	5	3	2	0	**10**	**444**
14	*Conyza stricta* Willd.	0	2	1	0	**3**	**133**
15	*Coffea arabica* L	13	15	0	0	**29**	**1,289**
16	*Crassocephalum crepidioides*	5	16	9	4	**34**	**1,511**
17	*Crassula alsinoides* (Hook.f.) Engl.	5	143	31	13	**192**	**8,533**
18	*Cynoglosum amblifolium*Hochst.ex A.DC.	10	2	1	2	**15**	**667**
19	*Cyperus pulchellus* R.Br.	23	132	9	7	**171**	**7,600**
20	*Dichondra repens* J.R. & G. Forst.	52	311	55	22	**440**	**19,556**
21	*Dichrocephala integrifolia* (L.f.) O.Kuntze	11	113	5	4	**133**	**5,911**
22	*Dissotis rotundifolia*(Sm.)	0	14	3	1	**18**	**800**
23	*Drynaria cordata*(L) Schultes	6	10	2	1	**19**	**844**
24	*Droguetia iners*	25	146	17	1	**189**	**8,400**
25	*Erythrina brucei* Schwenf	4	2	0	0	**6**	**267**
26	*Ficus sur* Forssk	5	9	1	0	**15**	**667**
27	*Galinsoga quadriradiata* Ruiz & Pavon	24	301	108	15	**448**	**19,911**
28	*Geranium arabicum* Forssk.	13	28	10	7	**58**	**2,578**
29	*Scoparia dulcis*	40	235	14	8	**297**	**13,200**
30	*Hibiscus vitifolius* L.	14	16	12	4	**46**	**2,044**
31	*Ehretia cymosa* Thonn	0	19	1	0	**20**	**889**
32	*Hypericum peplidifolium*A. Rich	0	99	6	2	**107**	**4,756**
33	*Impatience ethiopica*	23	173	41	13	**250**	**11,111**
34	*Impatience hochstetteri* Warb	12	267	32	5	**316**	**14,044**
35	*Kalanchoe petitiana* A. Rich.	8	36	1	0	**45**	**2,000**
36	*Laggera crispata* (Vahl) Hepper & Wood	0	22	4	1	**27**	**1,200**
37	*Macaranga capensis* (Baill.) Sim	0	55	12	2	**59**	**2,622**
38	*Measa lanceolata* Forssk.	10	102	13	0	**125**	**5,556**
39	*Milettia ferruginea* (Hochst.) Bac	0	3	2	0	**5**	**222**
40	*Medicago polymorpha* L.,	7	39	2	1	**49**	**2,178**
41	*Olea welwitschii*(Knobl) Gg & Schellenb	0	2	1	0	**3**	**133**
42	*Olyra latifolia* L.	4	150	2	0	**156**	**6,933**
43	*Oxalis radicosa* A. Rich.	87	312	102	95	**596**	**26,489**
44	*Oplismenus hirtellus* (L.) P. Beauv.	13	96	15	4	**128**	**5,689**
45	*Pavonia Schimperiana*	0	15	4	1	**20**	**889**
46	*Pavonia urens*	2	12	1	0	**15**	**667**
47	*Pilea rivularis* Wedd	0	10	2	1	**13**	**578**
48	*Physalis peruviana*	0	7	0	0	**7**	**311**
49	*Phyllanthus limmuensis*	44	62	9	6	**121**	**5,338**
50	*Plantago palmata* Hook.f.	0	5	7	5	**17**	**755**
51	*Pycnostachys eminii* Gurke	17	56	1	0	**74**	**3,289**
52	*Podocarpus falcatus* (Thunb.) R.B. ex Mirb.	0	0	1	0	**1**	**44**
53	*Rubus niveus* Thunb	4	12	5	2	**23**	**1,022**
54	*Rununclus multifidus*	1	5	1	0	**7**	**311**
55	*Salvia nilotica*Jacq.	0	9	1	0	**10**	**444**

56	*Sida rhombifolia* L.	0	22	2	1	**25**	**1,111**
57	*Solanum nigrum* L.	0	58	7	4	**69**	**3,067**
58	*Sonchus asper* (L.) Hill	0	26	2	0	**28**	**1,244**
59	*Stellaria media*	17	136	6	2	**161**	**7,156**
60	*Syzygium guineense* (Willd.)DC	0	7	2	1	**10**	**444**
61	*Triumfetta brachyceras*	0	13	2	0	**15**	**667**
62	*Veronica persica* Chiov.	4	68	27	4	**103**	**4,578**
63	*Vernonia amygdalina*	12	217	10	7	**246**	**10,933**
64	*Vernonia auriculifera* Hien	29	137	23	4	**195**	**8,667**
65	*Vernonia hochstetteri* Sch. Bip. Ex Walp.	3	17	2	0	**22**	**978**
66	*Zehneria scarba* (L.f.)	0	34	6	0	**38**	**1,689**
Total		**616**	**4165**	**738**	**282**	**5815**	**257,404**

Appendix 4: List of species recorded from the soil sample in each of the five habitat types with the total number of seedlings

No	Species Name	Life form	WCOF	NCOF	MCOFP	RI	VA	Seed/m^2
1	*Abutilon logicuspe* Hochst.ex A.Rich.	Shrub	3	5	-	5	6	**933**
2	*Achyranthes aspera* L.	Herb	9	20	5	12	4	**2,222**
3	*Alchemilla abyssinica* Fresen.	Herb	5	11	-	6	3	**111**
4	*Allophylus abyssinicus* (Hochst) Radlkor	Tree	3	1	-	-	2	**267**
5	*Bidens pilosa* L.	Herb	16	21	9	7	10	**2,756**
6	*Bidens prestinaria* (Sch. Bip.) Fiori.	Herb	2	6	-	3	-	**489**
7	*Cardamine africana*	Herb	8	10	2	5	16	**1,822**
8	*Carduus leptacanthus* Fresen.	Herb	3	5	1	4	1	**622**
9	*Caesalpinia decapetala*	Shrub	4	3	-	-	2	**400**
10	*Commelina benghalensis* L.	Herb	4	2	1	1	5	**578**
11	*Cordia africana* Lam.	Tree	3	4	-	1	2	**489**
12	*Croton macrostachyus* Del.	Tree	2	4	1	1	2	**444**
13	*Conyza stricta* Willd.	Herb	-	1	-	2	-	**133**
14	*Coffea arabica* L	Shrub/Tree	14	-	13	-	2	**1,289**
15	*Crassocephalum crepidioides*	Herb	4	16	4	4	6	**1,511**
16	*Crassula alsinoides* (Hook.f.) Engl.	Herb	54	58	15	20	45	**8,533**
17	*Cynoglosum amblifolium*Hochst.ex A.DC.	Herb	1	5	-	3	6	**667**
18	*Cyperus pulchellus* R.Br.	Herb	35	103	5	12	20	**7,600**
19	*Dichondra repens* J.R. & G. Forst.	Herb	27	193	20	97	103	**19,556**
20	*Dichrocephala integrifolia* (L.f.) O.Kuntze	Herb	31	59	12	21	20	**5,911**
21	*Dissotis rotundifolia*(Sm.)	Herb	2	7	1	3	5	**800**
22	*Drynaria cordata*(L) Schultes	Herb	3	5	1	4	6	**844**
23	*Droguetia iners*	Herb	42	79	2	18	48	**8,400**
24	*Erythrina brucei* Schwenf	Tree	-	3	2	-	1	**267**
25	*Ficus sur* Forssk	Tree	5	2	3	2	5	**667**
26	*Galinsoga quadriradiata* Ruiz & Pavon	Herb	81	99	80	83	106	**19,911**
27	*Geranium arabicum* Forssk.	Herb	11	12	9	15	13	**2,578**
28	*Scoparia dulcis*	Herb	46	89	16	66	80	**13,200**
29	*Hibiscus vitifolius* L.	Herb	4	8	2	12	18	**2,044**
30	*Ehretia cymosa* Thonn	Shrub	5	7	-	3	5	**889**
31	*Hypericum peplidifolium*A. Rich	Herb	20	24	5	16	42	**4,756**
32	*Impatience ethiopica*	Herb	50	45	40	55	60	**11,111**
33	*Impatience hochstetteri* Warb	Herb	55	75	45	67	71	**14,044**
34	*Kalanchoe petitiana* A. Rich.	Herb	9	11	5	7	13	**2,000**
35	*Laggera crispata* (Vahl) Hepper & Wood	Herb	3	4	1	10	9	**1,200**
36	*Macaranga capensis* (Baill.) Sim	Tree	12	18	2	14	13	**2,622**
37	*Maesa lanceolata* Forssk.	Tree/Shrub	35	58	7	10	15	**5,556**
38	*Milettia ferruginea* (Hochst.) Bac	Tree	2	-	1	-	2	**222**
39	*Medicago polymorpha* L.,	Herb	8	12	2	10	16	**2,178**
40	*Olea welwitschii* (Knobl) Gg & Schellenb	Tree	2	-	-	-	1	**133**

41	*Olyra latifolia* L.	Herb	73	20	13	25	25	**6,933**
42	*Oxalis radicosa* A. Rich.	Herb	123	205	40	58	170	**26,489**
43	*Oplismenus hirtellus* (L.) P. Beauv.	Herb	40	35	12	20	21	**5,689**
44	*Pavonia Schimperiana*	Herb	5	4	1	6	4	**889**
45	*Pavonia urens*	Herb	1	9	-	2	3	**667**
46	*Pilea rivularis* Wedd	Herb	1	7	-	3	2	**578**
47	*Physalis peruviana*	Herb	1	3	-	1	2	**311**
48	*Phyllanthus limmuensis*	Shrub	26	32	11	28	24	**5,338**
49	*Plantago palmata* Hook.f.	Herb	3	6	1	3	4	**755**
50	*Pycnostachys eminii* Gurke	Herb	13	26	2	15	18	**3,289**
51	*Podocarpus falcatus* (Thunb.) R.B. ex Mirb.	Tree	-	-	-	-	1	**44**
52	*Rubus niveus* Thunb	Shrub	2	12	1	3	5	**1,022**
53	*Rununclus multifidus*	Herb	1	2	-	1	3	**311**
54	*Salvia nilotica*Jacq.	Herb	1	3	1	2	3	**444**
55	*Sida rhombifolia* L.	Herb	5	3	2	5	10	**1,111**
56	*Solanum nigrum* L.	Herb	15	20	9	11	14	**3,067**
57	*Sonchus asper* (L.) Hill	Herb	5	6	-	10	7	**1,244**
58	*Stellaria media*	Herb	45	65	10	20	21	**7,156**
59	*Syzygium guineense* (Willd.)DC	Tree	1	5	-	1	3	**4644**
60	*Triumfetta brachyceras*	shrub	2	7	1	2	3	**667**
61	*Veronica persica* Chiov.	Herb	8	10	5	57	23	**4,578**
62	*Vernonia amygdalina*	Shrub	20	150	10	16	50	**10,933**
63	*Vernonia auriculifera* Hien	Shrub	20	40	20	50	65	**8,667**
64	*Vernonia hochstetteri* Sch. Bip. Ex Walp.	Shrub	-	16	-	2	4	**978**
65	*Ardisiandra wettsteinii* R. Wagner	Herb	50	60	13	70	130	**14,356**
66	*Zheneria scarab*	Climber	6	14	-	8	10	**1,689**
Total								**257,404**

Appendix 5 picture of seedlings regenerate from soil seed bank

Abutilon logicuspe

Cynoglosum amplifolium

Dichondra repens

Maesa lanceolata

Erythrina brucei

Podocarpus falcatus

Croton macrostachyus

Oplismenus hirtellus

Plantago palmata

Syzygium guineense

Sida rhombifolia

Phyllanthus limmuensis

Coffea arabica

Ehretia cymosa

Croton macrostachyus

Macaranga capensis

Alchemilla abyssinica

Solanum nigrum