



Factors Determining The Population Structures Of *Festuca Macrophylla* Hochst. Ex A.Rich. And *Helichrysum Splendidum* (Thunb.) Less In Guassa Community Conservation Area, Amhara Regional State, Ethiopia.

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Factors determining the population structures of *Festuca macrophylla* and *Helichrysum splendidum* in Guassa Community Conservation Area, Amhara Regional State, Ethiopia.

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GRADUATE PROGRAMMES

This is to certify that the thesis prepared by Sisay Wubie Zewde, entitled: Factors determining the population structures and the interaction of *Festuca macrophylla* and *Helichrysum splendidum* plant species in Guassa Community Conservation Area, Amhara region, Ethiopia and submitted in partial fulfillment for the requirements for the Degree of Master of Science in Plant Biology and Biodiversity Management complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

Several studies have been undertaken in afroalpine ecosystem of Ethiopia, to assess the diversity of flora mainly focusing on woody species composition. However, the information on the factors that affect the interaction of plant communities and how this interaction mediates the population structure along elevational gradient is lacking. Hence, the objective of this study is to examine the factors that determine the structure and interaction of *Festuca macrophylla* and *Helichrysum splendidum* plant species. The study was conducted in Guassa Community Conservation area that belongs to the afroalpine ecosystem and is located in North Showa Zone of Amhara Regional state, of Ethiopia. Following systematic sampling approach, two transects that were 200m far from each other were laid out along the altitudinal gradient (3300–3500m a.s.l.). On these transects, main sample plots were laid down at the interval of 100m to collect data. Moreover, within the main plots, five subplots (size, 1m× 1m each) that were arranged four at the corner and one at the center were also used to collect data and soil samples. In total, 30 main plots (15 from each transect) were laid to collect data. Here, from each subplot, composite soil samples were taken from the top layer (0-20cm depth) and by sum 30 samples were collected for soil nutrient analysis along with an altitudinal gradient. For soil seed bank study, first, the vegetation was stratified into three types as *H. splendidum* population, *F. macrophylla* population and *H. splendidum* and *F. macrophylla* community. From each of this vegetation type, 10 main plots (5m × 5m) where within which five subplots that were arranged four at the corner and one at the center (1m× 1m each) were randomly laid to collect composite soil samples from three layers (i.e., litter, 0-3cm and 3-6cm). In total, 90 composite samples (i.e., 10 from each type) were collected for soil seed bank study. The soil samples were collected using the plastic bags to retain the moisture contents and transported to Addis Ababa University. The soil nutrient analysis was performed at national soil laboratory while the soil seed bank study was undertaken at Addis Ababa University. Data were analyzed using general linear model (glm) with Poisson distribution using R statistical program and one-way ANOVA. The result indicates altitude, disturbance intensity, and herbivore were negatively correlated with abundance of the two species. The one-way ANOVA showed no significant variation between the three stratified site and soil properties. Total species abundance significantly affected by available phosphorus (A_v , $p=0.004$) and Organic matter ($p=0.007$). Vertical distribution of soil seed bank of *H. splendidum* shows significant difference ($P<0.001$) while *F. macrophylla* lacks significant difference. Overall, the current management system might be worthy and favoring the expansion of *H. splendidum* and declining *F. macrophylla* and should be changed by other well studied management approach system.

Keywords; *Festuca macrophylla* , Population structure, Guassa Conservation; *Helichrysum splendidum*

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ACRONYMS

AAU-Addis Ababa University

EBI-Ethiopia biodiversity Institute

E-East

g- gram

GCCA- Guassa Community Conserved Area

GPS- Global Positioning System

H- Height

Ha- Hectare

Km- Kilo meter

m- Meter

masl- Meter above sea level

mm- Millimeter

N-North

No.- number

NRC-Natural Resources Conservation Services

Sp-Species

SSB- Soil seed bank

1. INTRODUCTION

1.1 Background

The afroalpine ecosystem mostly covers the higher African mountains and serves as major water tower which is an essential source of water supply agriculture (Ahmed Abdikadir, 2013). The 2% Afroalpine habitat of Ethiopia, considered as the largest afroalpine in Africa and a home for a number of plants and animals of which some are endemic to Ethiopia (Habtamu Wodaj et al; 2016). The diverse geography of Ethiopia gives rise to wide range of habitat in which we can find many endemic plants and animals.

Guassa community conservation area (GCCA) is among those high altitude afroalpine habitat, in the central highlands in which we can find afro-alpine vegetation, endemic and rare fauna (like African wolf and Red fox) and endemic floral species like, *Festuca macrophylla*, *Kniphofia foliosa*, *Urtica simensis*, *Lobelia rhynchopetalum*, *Euryops pinifolius* and *Cynoglossum coeruleum* .(Zealelem Tefera *et al.*, 2012, Habtamu Wodaj, 2016). It is one of biodiversity ‘Hotspot’ area in the central high lands of Ethiopia (Engedasew Andarge, 2010).

Helichrysum splendidum (Thunb.) Less (Asteraceae) is well known from the study area and characteristically is a fast growing shrub, perennial with woody base, grow up to 1m high and canopy measure up to 1m in diameter (Mesfin Tadesse, 2004; Mashigo *et al.*, 2015). It is characterized by its gray color leaf, presence of woolly structure on stem (important for reducing water loss), aromatic in smell, bright yellow flower which are long lasting, extensive root systems (extended below the root zone of other plants (Pooley, 2003). Further both morphological and physiological factors such as high reproductive efficiency, small leaf areas to limit transpiration, allelopathic effect help *Helichrysum splendidum* to become successful and

able to grow at a wide range of altitudes from 2500-4300 m asl (Hae, 2016). Moreover, essential oil extracted from this plant is used to inhibit both fungal and bacterial activity (Chagonda *et al.*; 1999).

Festuca macrophylla Hochst. ex A.Rich. (Poaceae) is a perennial herb and afroalpine vegetation, which grows within an altitudinal range of 3000-4100m.asl and is characterized by its dense tussocks, with erect culms to 1m tall (Phillips, 1995). It is known only from the two floristic regions of Ethiopia that are the northern highlands of Gonder and Shoa floristic regions. It is endemic to Ethiopia (Phillips 1995). *F.macrophylla* is highly valued by the local people because of their multipurpose uses, such as rope making, floor mat fodder, rain hut, whip (Girafe) and providing income from the sale of the grass (Adam Phillipson, 2010; Gomeje Amessie, 2014).

Currently, *H. splendidum* is increasing in abundance while *F. macrophylla* is decreasing in the study area. Thus this research was initiated to find out the expansion of *H. splendidum* over the *F. macrophylla*.

1.2 Statement of the problem

Understanding the factors that determine vegetation diversity, abundance, and distribution has been a central issue of ecological studies (Zheng *et al.*, 2013). Both abiotic factors (elevation, soil properties) and biotic factors (shading, herbivory, interspecific competition) are determining factors that enable a plant to colonize a given area. The important reason for knowing those factors is a fundamental issue for the sustainable use of global biodiversity and conservation areas which contribute many aspects for people's livelihoods and well-being, providing products,

such as source of food, medicine, clothing, firewood, sources of different household utensils, tools whose values are widely recognized (Mulugeta Kebebew and Erchafo Mohammed, 2017).

Conservation areas on the alpine ecosystems are considered as free or host few non-native species due to a combination of factors such as limited propagule availability with species specialized to growing in alpine environments being very rarely introduced to high elevations and undisturbed native alpine vegetation poses a strong barrier to invasion (Kueffer *eta l.*, 2016).

Today, these conservation areas are increasingly exposed to non-native species and create problem as a result of a number of factors such as increasing anthropogenic pressures and climate change, phenotypic plasticity, dispersal mechanism (high persistent of seed) that brings opportunity to expand non-native species, to higher elevations. Invasion of native ecosystems by non-native plant species are the most important threats since it directly affects native plant communities by altering the composition and diversity (reduce, displace native through competition), reduces productivity, wildlife habitat, and changes ecosystem functions (Kueffer *eta l.*, 2016).

However, currently *Helichrysum splendidum* is creating a major problem on the study area due to its fast-growing and invading nature that affects economically important Grass (locally Gaussa) *F.macrophylla* (Ephrem Girma *et al*, 2011, Girma Nigussie, 2017,). Sillero-Zubiri and Macdonald (1997) also indicated high rate expansion of *H.splendidum* and its encroachment over other habitats like *Festuca* grassland.

Moreover, detail information regarding factors that favor the expansion of *H.splendidum* and its impact on *F.macrophylla* in GCCA was not clearly addressed. Therefore, this study is initiated to fill this missing gap of information by assessing the factors that favor the expansion of

H.splendidum on the study area. Further, this information will enable to put management option based on scientific result.

1.3 Objectives of the study

1.3.1 General objective

The general objective of the study is to assess the factors that determine the structure and distribution of *Festuca macrophylla* and *Helichrysum splendidum* in GCCA.

1.3.2 Specific objectives

- To explore the factors determining the structures of *Helichrysum splendidum* and *Festuca macrophylla* along altitudinal gradient in the study area.
- To examine the effect of the soil nutrients on the abundance of *H.splendidum* and *F. macrophylla* plant species
- To assess the status of soil seed bank of *H.splendidum* and *F. macrophylla* in relation to the different soil depths

1.4. Research questions

- What are the factors that determine the structures of *H.splendidum* and *F. macrophylla* plant species?
- Does the soil seed bank status vary between *H.splendidum* and *F. macrophylla* plant species along altitudinal gradient?
- What are the major adaptation mechanisms of *H. splendidum* and *F.macrophylla* in the study area?

1.5 Hypothesis

The population structures and soil seed bank status of *H. splendidum* and *F. macrophylla* vary along altitudinal gradient; both human and environmental factors affect the structures of *H. splendidum* and *F. macrophylla* plant species.

Chapter Two

2. LITERATURE REVIEW

2.1 Distribution, description and uses of *Helichrysum splendidum* (Thunb.)

Less

Helichrysum splendidum (Asteraceae) is characterized as fast-growing perennial Shrub or bushy perennial herb with woody base, 50-75 cm high, and sometimes up to 1 m in diameter (Mesifin, 1994). Leaves are linear, linear-oblong or lanceolate in shape, aromatic smell, densely greyish-white tomentose on both sides. Flowers have a sweet scent and are bright yellow in color growing in sandy grasslands or open woodlands. It is endemic to South Africa (Clark et al., 2009). In Ethiopia it is widely distributed within region such as Wollo (WU), Shewa (SU), Arisi (AR), Bale (BA), Harer (HA) and afro-alpine and *Erica arborea* bush vegetation. Grow at a wide range of altitudes from 2500-4300 m asl. Both morphological and physiological properties allow them to resist extreme climatic conditions and access resources beyond reach by preferred plants and become dominant. (Pooley, 2003). The following are some of morphological and physiological factors that contribute *Helichrysum splendidum* species successful as mentioned by Hae (2016).

Such as;

- Possession high reproductive
- The presence of small leaf areas to limit transpiration
- Allelopathic abilities through which they release allelo-chemicals that renders the environment not conducive for the neighboring plants.

- The presence of hairy or woolly on aerial parts which is important in reduces water loss so it can thrive even in periods of drought. well adapted to a wide range of climatic and soil conditions and have the ability to colonize bare ground
- Have extensive root systems which are extended both to below the root zone of other plants and to the sides to access water and nutrients out of reach of other plants.

Study on extraction of essential oil from *Helichrysum splendidum* indicated that oil extracted from *H. splendidum* has ability to inhibit fungal growth and has antibacterial activity (Mashigo *et al.*, 2015). Ethnobotanical uses of *Helichrysum splendidum* dates back to 1727 when Boerhaave noted that a species was used to treat nervousness and hysteria. South Africa uses ethnomedicine extensively treatment associated which infections and respiratory diseases and wound dressing (Chagonda *et al.*; 1999).

2.2 Distribution, description and uses of *Festuca macrophylla* Hochst. ex A. Rich.

The genus *festuca* comprises about 450 species and found mainly in temperate and subtropical regions extending to mountains in the tropics. *Festuca macrophyh* is Perennial herb which belongs to Poaceae family forming large dense tussocks, with erect culms to 1 m tall. Leaves filiform to acicular,scaberulous.panicles and spikelets as in *F. abyssinica* but distinguished by much shorter narrower glumes. It is afroalpine vegetation and Grow at altitudinal altitudinal range of 3000:-4100m.asl. It is known only from the northern highlands of Ethiopia Gonder and shewa regions.

Ethnobotanical uses of *F.macrophylla*, can be listed as primary uses such as thatching, mixed with mud to plaster wall,rope,floor mat (*Guzguaz*), marketable product in urban areas for plastering and Baskets of different uses in the household (*Sifet, Mesob*),Mattress, Farm

implements, whip (*Girafe*), torch, fodder, rain hut (*Gessa*) and brush (*mure*) particularly used ttpaing wall identified as secondary uses. *Festuca* species are highly valued by the local people because of their multipurpose uses, serving as raw material to make various equipment and providing income from sell of the grass as mentioned by many authors (Adam, 2010; Gomeje Amessie, 2014).

2.3 Factors influencing community structure

Community is characterized by a number of factors such as number of species, relative abundance of species (how different in abundance), Physical habitat, dominating organism, stational association among, or identification of sets of interacting species are some of the parameters helping to identify a community.

Plant distribution, dynamic and diversity within its environment also determined by abiotic factor such as temperature, light, nutrient availability, precipitation and soil pH. Other physical factors such as fire, trampling, burial, soil erosion, wind fall, landslide disturbances, seed or pathogen herbivore dispersal and other spatial process are greatly influence plant distribution (Larissa Hotra *et al.*, 2003).

In general, the distribution, abundance and diversity patterns of species can result from the interaction between biotic and abiotic factors at different spatial and temporal scales (Feyera Senbeta and Demel Teketay, 2002).

2.4 The influence of biotic interaction on the structure of plant community

Biological factors which are important in attributing community, are also has influence on the structuring the community of which they are part. Biotic interactions interaction such as competition, herbivory, seed predation, mutualism parasitism and disease may greatly influence plant dynamics and community structure (Tilman, 1990).

2.4.1 Effects of competition on Plant community composition

According to Tilman (1990), the abundance of plant species and its presistance in the locality with which it coexists are influenced by biological and physiological process. Predation, parasitism, and competition notable among biological factors attributes of a community and shaping of community structure, but are also important influences on the structure of the community of which they are part.

Almost all plants are negatively affected by neighbor due to the depletion of some limiting resource. Competition is an important factor in structuring plant communities and it is also defined as an interaction which an increase in the population density or biomass of one species leads to a decrease in the population growth rate and the population density or biomass of another species arise from similar resource requirements and limited resources needed by plant for growth and reproduction (Tilman1990; Fowler, 1986).

2.5 Abiotic factors affecting plant community structure

2.5.1 Effects of Soil nutrient on structure of plant community

Soil nutrients availability is one of the abiotic factors that determine plant community development and structure (Tilman, 1982). In addition to soil nutrient availability, plant species in a given area greatly determined by other abiotic factors such as precipitation, climate, temperature and rainfall distribution since variations on these factors reflected in the variations of the species composition and structure of communities. Soil resources are not evenly distributed in all natural environments, vegetation is heterogeneously distributed across spatial due to variability of soil nutrients and soil moisture. Moreover soil nutrient availability determines plant biomass production, plant species diversity and plant succession (Belete Kebede, 2012).

Some plants have the ability to construct thinner and less dense leaf and root tissue than the others which become allow them to build more leaf area and root length per unit mass and provide a growth rate size advantage to grow faster and establish a community (Sheley and James, 2014).

2.5.2 Effects of elevation gradients on plant community structure

Vegetation patterns are determined by environmental factors that exhibit heterogeneity over space and time, such as climate, topography, and soil, as well as human disturbances. Community composition, structure, and species diversity, of mountain vegetation are determined by complex of factors such as elevation which result strong influence on the structure of the vegetation in most mountains in the world (Zhang Ru *et al.*, 2006). Ecological factors and response to those factors such as, topography are combined effects responsible for grouping vegetation (Gholinejad *et al.*, 2012).

Elevation influences both local and regional microclimates by changing the pattern of precipitation and temperature; solar radiation, and relative humidity which could also result change in soil properties by affecting types and rates of chemical, physical, and biological processes, and the type and composition of vegetation species present (Fantaw Yimer *et al.*, 2006). Elevation gradients can also cause populations genetically different with respect to ecologically important traits such as growth traits (plant height and above-ground biomass) between populations of different elevations and due to such genetic difference ability to cope up with change with climate also differ which lead formation of different plant community (Haider *et al.*, 2012).

2.6 Disturbance

Disturbance has given different definition by different authors. For example, some define as abiotic processes or physical disturbance (biomass reduction or removal) which include fire, landslides, wave exposure, and floods and biotic processes such as predation and grazing that changes in resource availability of substrate, creates an opportunity for new individuals to

become established while others define more narrowly as a discrete event that reduces biomass and creates opportunities for new individuals to colonize (S. J. Hill *et al.*, 2005).

Other still define in terms of anthropogenic disturbances including agricultural, grazing activities, clearing, road construction and changes to water quality and infrastructure (Benedetti-Cecchi *et al.*, 2001). Any potential source of stress to natural populations and assemblages due to human activities, often interact with ecological processes at varying scales in space and time altering numbers of species and their relative abundances through direct and indirect effects.

The actual invasion of an environment by new species is influenced by three factors: the number of propagules entering the new environment (propagule pressure), the characteristics of the new species, and the susceptibility of the environment to invasion by new species

2.6.1 Anthropogenic disturbance

2.6.1.1 Impact of anthropogenic Disturbances on composition and abundance

Disturbance act as important factor plays role in determining spatial and temporal patterns of species diversity. Habitat destruction and fragmentation are the most widely accepted disturbance example that causes variations in species diversity (Mackey and Currie, 2001).

According to ecosystem -stress hypothesis, humans are detrimental for species diversity because removal of habitat and resources of most species which indicate a negative relationship between species richness and human influence (Rapport *et al.*, 1985). But the cases of intermediate-disturbance hypothesis (Connell, 1978) states that plant community under moderate levels of human impact have higher habitat and resource diversity compared with high disturbance. The availability of higher resource diversity may leads to higher species diversity and forms a negative relationship between species richness and human influence (Donnell and Pickett, 1990)

Deforestation and chronic human disturbance such as Overgrazing and the continuous extraction of vegetation product are the most important drivers, which may lead to the gradual local extinction of species and the alteration of vegetation structure (E. M. S. Ribeiro *et al.*, 2015) Change in species composition as a result of disturbances arise from differences in species-specific interaction that persist through disturbances intensity. Regeneration from seed may also be affected by disturbance intensity which means that less intense of disturbances such as canopy opening may stimulate many seeds to germinate

2.6.1.2 Effects of anthropogenic disturbances and the Natural Vegetation regeneration

Frequent but low- intensity disturbance (Grazing and browning fire wood extraction) may involve the combined effect of multiple factors, and may strongly affect forest structure and the ability of undestroyed species in the disturbed area to regenerate regimes involving a single factors (N.Ramirez-Marcial *et al.*, 2001). Beside natural disturbance that result forest dynamic at local and regional scale anthropogenic disturbance also contribute in regulating the regeneration dynamic, structure and floristic composition of a given forest (N.Ramirez-Marcial *et al.*, 2001)

Environment conditions such as light availability and soil moisture which act as environment barriers and affect the establishment of non-native plants in addition to landscape such as dense forest edges and closed forest canopy can act as physical barriers and affect dispersal and thus the pathway along which invasions travel but when these barrier become removed due to anthropogenic disturbance it become more vulnerable (Hansen and Clevenger, 2005)

Both intermediate disturbance and growing empirical evidence suggest that low intensity of disturbance foster maximum species richness. Regeneration from seed may detrmind by disturbance intensity level which mean that less intense disturbances such as canopy opening

may stimulate many seeds to germinate (Vazquez-Yanes and Orozco-Segovia, 1993) while on other way round high intensity of disturbances, such as intense fires, may kill seeds buried in surface soils (Brinkmann and Vieira, 1971; Uhl et al., 1981). colonizer species that regenerate and produce widely dispersed seeds may allow them to dominate following high disturbances intensity (Schimmel and Granstrom, 1996).

2.6.1.3 The role of anthropogenic disturbance for Invasion of non-native species:-Implication for conservation

One of the serious problem of anthropogenic disturbance especially on the conservation area is that it introduction of non-native species which may later result in displacing native species, altering water and fire regimes, changing the nutrient status of the soil, removing or introducing a food source, and altering geomorphological processes (S. Hill *et al.*, 2005). One of the possible reasons for factor determines susceptibility plant community and establishment of invasion is that an increase in the amount of unused resources.

One of determine factors for the susceptibility of a plant community by non-native species is that removal of habitats by anthropogenic disturbance that act as barriers to invasion (Johnstone, 1986). Dense forest edges and closed forest canopy can act as physical barriers and affect dispersal and divert the pathway along which invasions travel (Cadenasso and Pickett, 2001). such as availability of light and soil moisture are environment conditions act as environment barriers and affect the establishment of non-native plants (Parendes and Jones, 2000)

To establish in a given area invading species must efficiently use the available resources, e.g. light, nutrients, and water, than native species (in invading a community) and this happen if resident species does not encounter intense competition for these resources (competition intensity inversely correlated with the amount of unused resources). Anthropogenic disturbance

such as roads and buildings changes to flooding frequency changes in availability of resources such as light, water and nutrients have also been found to be associated with invasion.

On the other hand disturbance facilitates invasions by eliminating or reducing the cover or vigour of competitors or by increasing resource availability which can be explained by the theory of fluctuating resource availability. In both case whether the disturbance introduces additional resources into the community (e.g. nutrients from a flood), or decline of resource due to uptake by the resident vegetation invisibility increase.

Furthermore Frequent small scale disturbances, e.g. by burrowing animals, can create localized patches of unexploited resources, and may facilitate invasions.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Location

This research was conducted at Amhara Regional state, North Showa Zonal Administration, Menz-Gera Midir district (*Woreda*). Geographically Guassa, Community Conservation Area is found in the central highlands of Ethiopia. It is found between latitudes of $10^{\circ} 15' - 10^{\circ}27' N$ and longitude of $39^{\circ} 45' - 39^{\circ} 49' E$ (Gomje Amessie, 2014). It is located at 295km north-east from Addis Ababa (capital city of Ethiopia), and 165 Km North from Debre-Birhan city (Political and economic capital of north showa). The total land area of *Guassa* is about 111 km² and its altitude ranges between 3200 to 3700 m.a.s.l (Figure 1).

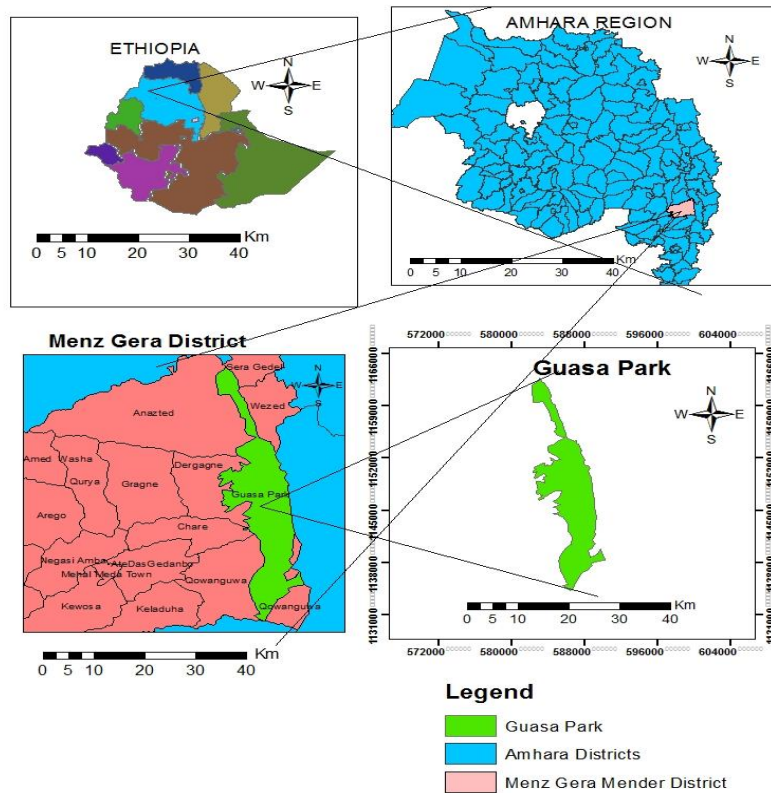


Figure1. Map of the study area. The left hand side figure shows map of Ethiopia and the right indicate the Amhara Regional state. Lower, left sides show kebel in menz Gera worda and zoomed in Guassa study area.

3.1.2 Topography and Hydrology

GCCA is characterized by its plateau which cross-cut by various gorges and river valleys that flow west and eastwards. It is one of the most important watersheds of Blue Nile and Awash basins (Eshetu Moges, 2015). It is the initial place for over 26 small and medium-sized rivers streams which flow to the west and east of the mountain block. The swamps of the area increase water holding capacity and also limit runoff in the rainy seasons, thus providing flow all year round (Zealelem Tefera and Leader-Williams, 2005).

3.1.3 Climate

Due to altitudinal gradient and seasonal change the climate of the Guassa area varies considerably. The high altitude wet season is characterized by a combination of rain fall, frequent fog and occasional snow. Frost is common during dry season. There are sharp temperature fluctuations between night and day time. There are two rainfall season on the study area which are one main rain season (Kiremt or Mehir) that stay from June to September and one small rain season (Belg) from February to April (Gomeje Amessie, 2014; Getachew Simeneh, 2010). Due to the absence of data specific to Guassa area, the data are taken from the nearby Mehal Meda (3000 m asl) town. From the twenty years data (1998-2016) the mean monthly temperature was 12.3°C while maximum and minimal mean monthly temperature is 5.0 and 20.03°C respectively. The mean monthly annual rain fall of the area is 880mm (Figure 2).

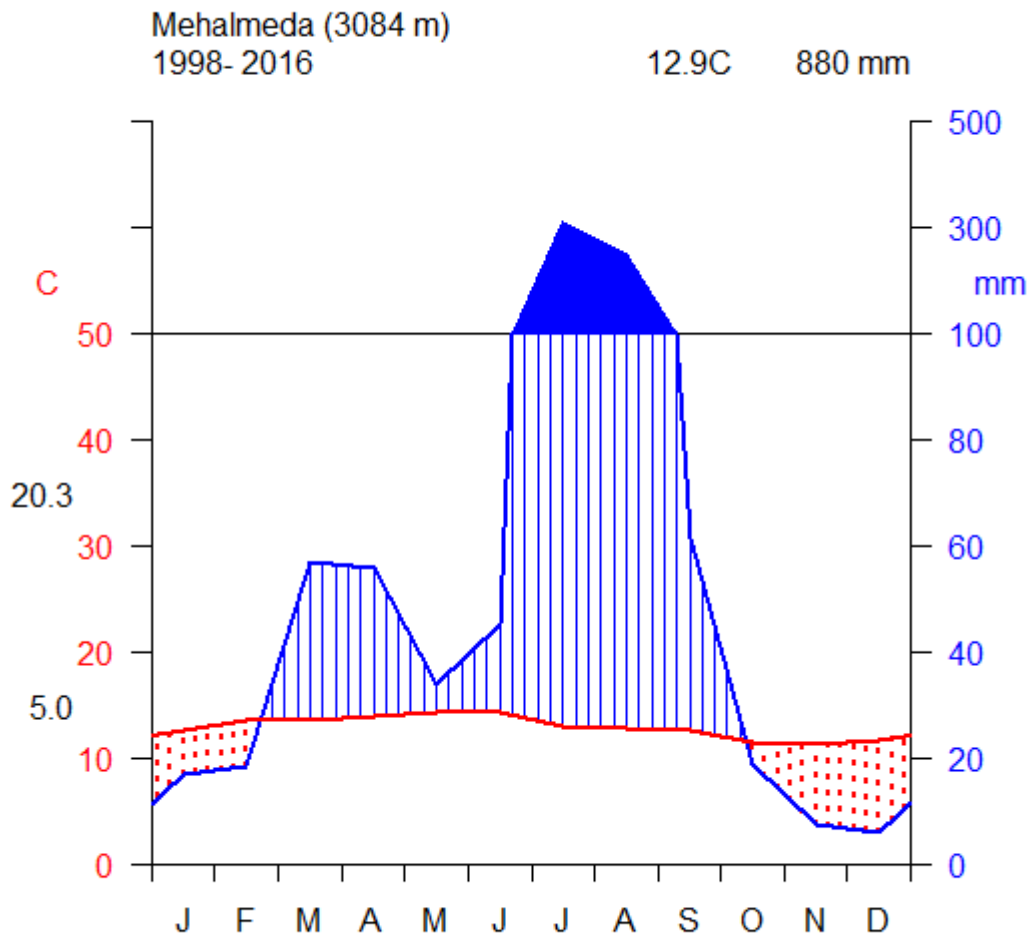


Figure 2 Climate diagram of GCCA, indication high and low rainfall and mean monthly temperature

3.1.4 Population and Economy

The current total population of the Menz-Gera District including GCCA is 92,687 of which 49,956 and 52,464 are males and females respectively (FDREPCC, 2008), among 11,049 live in urban and the rest 91,371 live in rural area. Ethnically the population is predominantly Amhara

and speak Amharic language. The main economic activity of the Menz people is farming which involves mainly crop production and livestock husbandry.

Guassa community conservation area is a critical natural resource area for the surrounding community in providing various essential ecosystem goods and services including fodder, fuel, building materials, household and farm implements. It is an important area for the livelihood of local communities who harvest *Guassa (Festuca)* grass which serve as an essential source of income for the local community (Engedasew Andarge, 2010).

3.1.5 Biodiversity

Guassa Community Conservation Area (GCCA) is one of the areas considerably rich in biodiversity and contains several endemic and threatened species of flora and fauna which are associated with the Afro-alpine ecosystem (Zealelem Tefera *et al.*, 2005).

3.1.5.1 Flora

Guassa Community Conservation Area is a place for important and endemic plant species including *Guassa* grass (*Festuca spp*), giant *Lobelia (Lobelia rhynchopetalum)*, *Helichrysum* and *Alchemilla* species and common plant species include *Carex monostachya*, *Carex fischeri* (Cyperaceae) and *Kniphofia foliosa* (Zealelem Tefera *et al.*, 2005).

According to Hailu Beyene (2010) and Getachew Simeneh (2010), there are six plant community types on the study site which are listed as follows;

1. *Festuca* grassland – plant species on this community type grow in an area where the drainage is good, deep soil and moderately steep slopes land up to altitude of 3500 m.a.s.l. Some of plant species found in this plant community are *Festuca abyssinica*, *Festuca*

simensis, *Festuca richardii*, *Festuca macrophylla*, *Andropogon abyssinicus*, *Poa shimperina*, *Alchemilla abyssinicus*, *Senecio vulgaris*, *Thymus schimperi*, *Helichrysum formosissimum*, and *Artemesia* species.

2. *Euryops* - *Alchemilla* Shrubland – This community is found on flat and gentle slopes and well drained areas, and plants grow at 3200 m.a.s.l. The most frequently observed list of plant species are:- *Thymus schimperi*, *Euryops pinifolius*, *Alchemilla abyssinica*, *Kniphofia foliosa*, *Urtica simensis*, *Anthemis tigreensis*, *Echinops steudneri*, *Ferula communis*, *Hebenstretia dentate*, *Agrostis gracilifolia*, *Geranium arabicum*, *Kalanchoe deficiens*, *Senecio gigas*, *S. vulgaris* and *S. schultz*.
3. *Euryops* - *Festuca* Grassland – Is characterized by scattered mounds that can reach a height of 1.5 m and a diameter of 5-10 m. It is predominantly covered by *Euryops* and *Alchemilla* consist of high organic and deep soil that is made by the activity of the rodent community. This community cover about 15.5% of the total area of Guassa. The dominant species of this area are; *Euryops pinifolius*, *Festuca abyssinica*, *Festuca richardii*, *Festuca macrophylla*, *Festuca simensis*, *Andropogonamethystinus*, *Alchemilla abyssinica*, *Anthemis tigreensis*, *Thymus schimperi*, *Rumexabyssinicus* and *Crisium vulgare*.
4. *Helichrysum* - *Festuca* grassland - This plant community occurs on tops of the hills and on the area where the soil is poor (low nutrient content). The Common plant species in this area are; *Helichrysum splendidum*, *H. gofense*, *H. formosissimum*, *Pinnisetum spp.*, *Alchemilla abyssinica* and *Echnnops spp.* It accounts 4.4% of the total area of Guassa.
5. *Erica* Moorland - *Erica* moorland is commonly found at high altitude areas with shallow and well-drained soil. The total area covered of the community is 10.4%. *Erica* species is collected for fire wood mainly during the wet season. Plant species such as;

Trifolium burchellianum, *Erica arborea*, *Thymus schimperi*, *Alchemilla abyssinica*, *Hellichrysum splendidum*, *Swertia abyssinica*, *Rubus abyssinicus*, *R. steudneri*, *Urtica simensis* and *Kniphofia foliosa* are some of the found on this community

6. Swamp Grassland - This community is dominated by grasses especially during the wet season. It provides green grass for the local cut and carries fodder system throughout the year. The dominant plant species are; *Carex monostachya*, *Carex fischeri* and *Alchemilla spp.*

3.5.2. Fauna

There are about nine (which accounts to 23 % mammal fauna of the country) endemic fauna including the Ethiopian wolf (*Canis simensis*), gelada baboon (*Theropethicus gelada*) and Ethiopian Highland hare or Abyssinian hare (*Lepus starcki*) and other mammals like klipspringers, jackals, leopards, spotted hyenas and civets (Zealealem Tefera *et. al*, 2005). Grey duiker (*Sylvicapra grimmia*), Klipspringer (*Oreotragus oreotragus*), Common jackal (*Canis aureus*), Spotted hyaena (*Crocuta crocuta*), Civet (*Civeta civettictis*), Rattle (*Melivora capensis*), Egyptian mongoose (*Herpestes ichneumon*) and Serval cat (*Felis serval*) are some other large mammals inhabiting Guassa

So far, 114 (12% of 861 bird species) have been recorded in the GCCA. It is a place for resident endemic birds as well as for migratory species of birds wintering in the highlands of Ethiopia and bearded vulture, the golden eagle and the augur buzzard are the common species. (Biniyam *et al.*, 2011).

3.2 Method of Data collection

3.2.1 Sampling design

Before the actual work reconnaissance survey was made on November, 2017 to get an impression about the study area, to locate sampling position from which samples to collect and to assess important ecological and environmental information.

3.2.2 Vegetation Data collection

Vegetation data were collected using systematic sampling approach. Two transects that were 200m far from each other were laid out along the altitudinal gradient (3300–3500m a.s.l.). On these transects main sample plots were laid down from South to North direction at the interval of 100m to collect data on shrub species. Moreover, within the main plots (5mx5m), five subplots (size , 1m× 1m each) that were arranged four at the corner and one at the center were also used to collect data on herbs and grasses . In total, 30 main plots (15 from each transect) were used to collect data on abundance of the two plant species, crown width, disturbance intensity and effect of herbivore. The location of each plot was recorded by using global Positioning System (GPS).

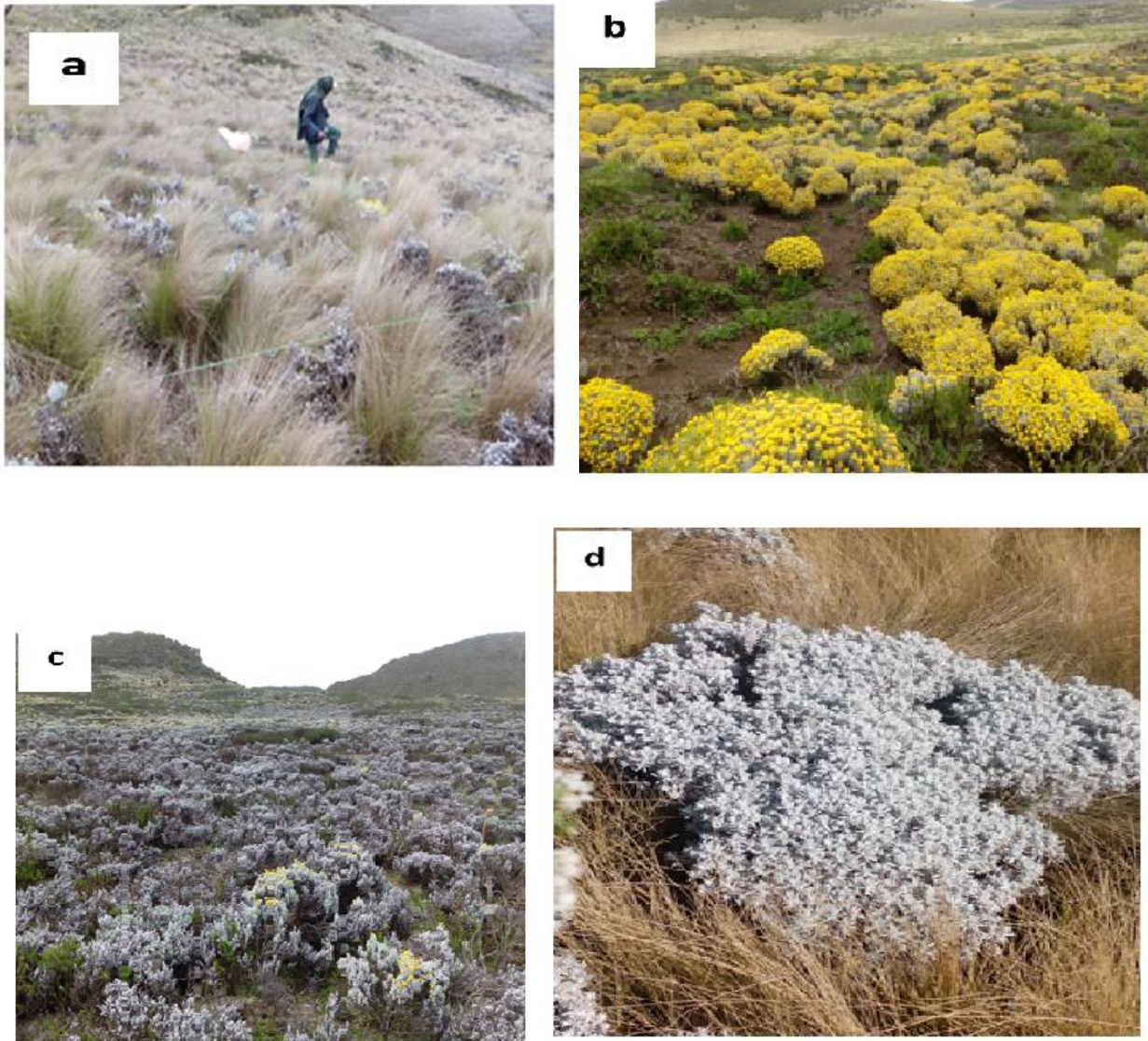


Figure 3 picture showing *Hellichrysum splendidum* (a) abundance of *H. splendidum* in *Festuca* stand, (b) flowering stage of *H. splendidum*, (c) abundance of *H. splendidum* along the road and (d) big canopy of *H. splendidum*

3.2.3 Soil sampling for seed bank germination

For soil seed bank study, first the vegetation was stratified in to three types as *H. splendidum* population, *F. macrophylla* population and *H. splendidum* and *F. macrophylla* community. From each of this vegetation type, 10 main plots (size, 5m × 5m) where within which five subplots that were arranged four at the corner and one at the center (size , 1m× 1m each) were randomly laid out to collect composite soil samples from three layers (i.e., litter, 0-3cm and 3-6cm). In total, 90 composite samples (i.e., 10 from each type) were collected for soil seed bank study. The soil samples were collected using augur as done by Getachew Simenh et al.,(2004), Feyera Senbeta and Demel Teketay (2002). To capture spatial heterogeneity of seed distribution soil samples from similar layers of the three sub plots were mixed and put in one plastic bag to form composites samples and to reduce variability within the plot. Pooled and packed in plastic bags were transported to Addis Ababa University for greenhouse germination.

Viability of seeds was determined by germination method (Mulugeta Lemenih and Demel Teketay, 2006; Feyera Senbeta Demel Teketay, 2002 and Yohannis Teklu, 2014). Before allowed to germinate soil sample were dried and passed a 2mm sieve to remove debris and then each soil layer was spread on labeled circular plastic tray. To facilitate proper drainage of water, the pots were perforated at the bottom. Watering was made every two days or three day accordingly. To reduce the possibility of germination suppression of other seeds due to competition Seedling readily identified at the species level were recorded, counted, pressed and dried. Species identification done at the National Herbarium (ETH). Seedlings that could not be identified were individually transplanted to pots and grown, where necessary, until flowering. soil seed bank study was undertaken at Addis Ababa University

3.2.4 Soil nutrient determination

To assess variation of soil properties (major soil physical and chemical parameters) of the study area samples were taken from main plot of 5m × 5m and from each subplot composite soil samples were taken from the top layer (0-20cm depth) using auger according to FAO,1990 guideline for soil description. A total of 30 samples were collected for soil nutrient analysis along altitudinal gradient. Samples were collected using purposive sampling techniques from stratified site in to three types as *H. splendidum* population, *F. macrophylla* population and *H. splendidum* and *F. macrophylla* community. Soil nutrient analysis were performed at the national soil testing center of Ethiopia using the following standard methods.

Soil pH was measured by using pH meter in a1:2:5 soils: water ratio using glass calomel combination electrodes (van Reeuwijk, 1992). Electrical conductivity (EC) was measured in water as soil to water ratio of 1:5 (van Reeuwijk, 1992). Soil organic carbon was determined following Walkley-Black oxidation method (Allison, 1965). Total nitrogen was determined by the micro-Kjeldahl digestion, distillation and titration method (Jackson, 1958).

Available phosphorus was analyzed according to the standard method described by (Olsen *et al.*;1954). Cation exchange capacity was determined at soil pH level of 7 after displaced by using 1N ammonium acetate method in which it was, thereafter, estimated titrimetrically by distillation of ammonium by sodium (Chapman, 1965). Particle size analysis was performed using Boycous hydrometric method, after removing organic matter using H₂O₂ and thereafter, dispersing the soils with sodium hexameta-phosphate (Day, 1965).

To characterize soil moisture and to determine its effect on plant biomass along altitudinal gradient soil was sampled from the area of 5 cm deep and 10cm diameter. Soil moisture

determination was made using gravimetric approach where the soil sample is placed in an oven at 105 °C and dried to a constant weight. The difference in weight is considered to be the water present in the soil sample. (Sparks et al., 1966).

3.3 Data analysis

All collected data including abundance, level of disturbance, effects of herbivore, soil nutrient soil, seed bank, altitude and aspect were organized in excel and checked for errors before the data analysis were run. The count data were analyzed using general linear model (glm) with Poisson distribution. Moreover, the abundance data was analyzed with two steps; (1) the abundance data of each plant species were separately analyzed; (2) the abundance data of each species were pooled together and analyzed accordingly. Here, the effects of altitude, disturbance, aspect and herbivore on abundance of the two species were analyzed using general linear model (glm) with Poisson distribution. Moreover, abundances of soil seed banks of *H.splendidum* and *F. macrophylla* and variation in each soil depth were also tested using the general linear model. The effect of the soil nutrients on the abundance of the *H.splendidum* and *F.macrophylla* plant species were analyzed with one-way ANOVA. All the analyses were performed using R statistical program (Version 3.5.0). Arc-GIS software was used to prepare map of the study area as well as climate diagram.

CHAPTER FOUR

4. Results

4.1. Above ground Information

4.1. 1. Abundance of *Festuca macrophylla* and *Helichrysum splendidum* plant species

The result of the general linear model analysis showed the pooled abundance and altitude were negatively correlated ($P < 0.001$, where abundance of the species showed decreasing pattern as altitude increase(Fig. 4)

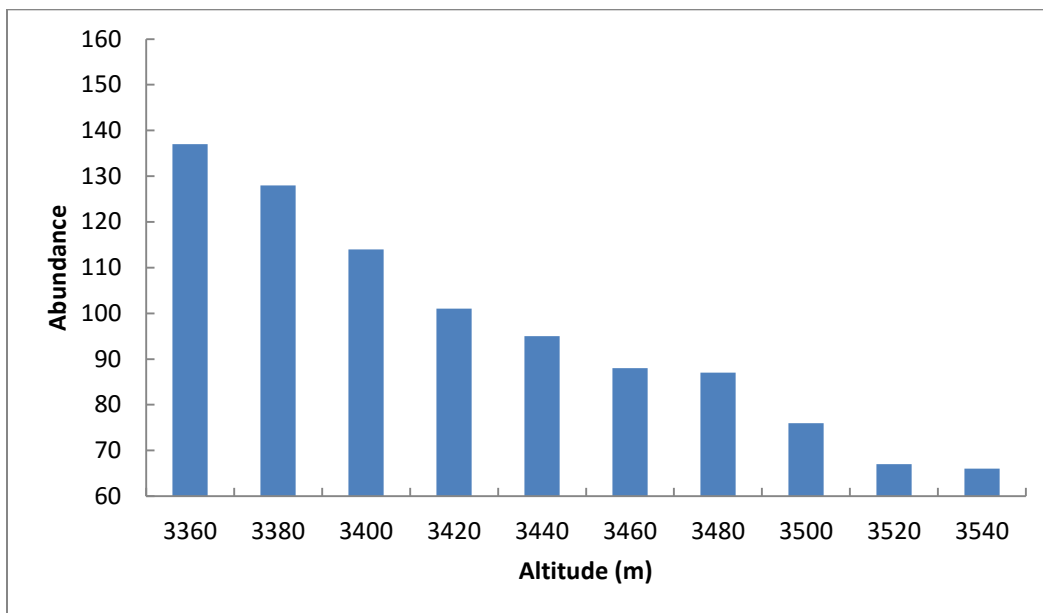


Figure 4:- Abundance of *H.splendidum* along altitude,

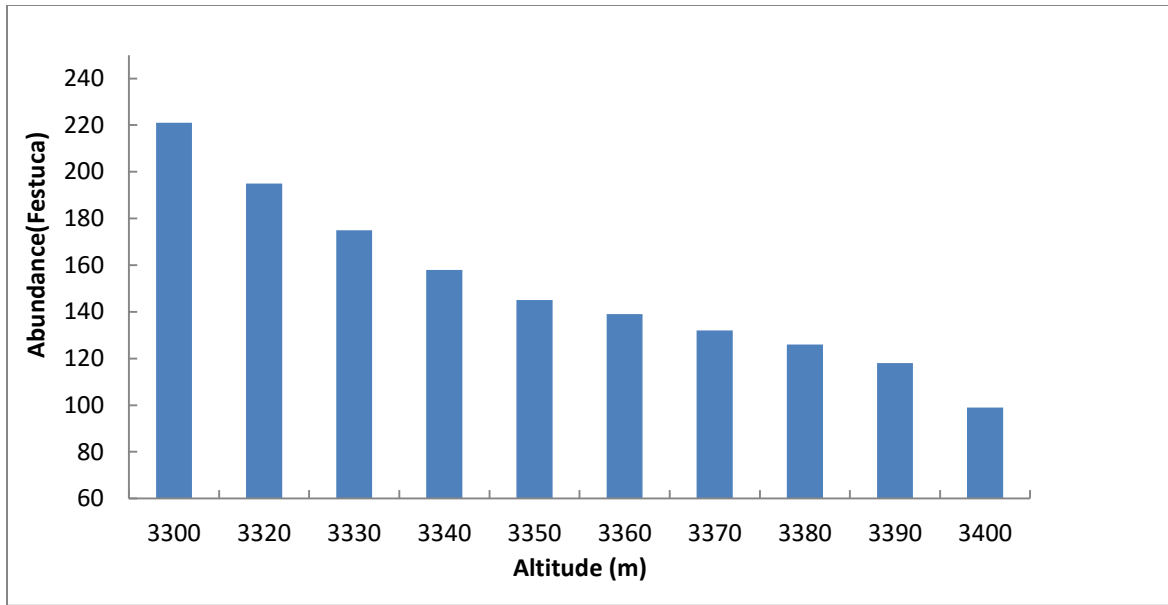


Figure 5:- A bar graph showing abundance of *F. macrophylla* along altitude

4.1.2. Intensity of disturbance in relation to abundance

Abundance of the species significantly mediated by intensity of disturbance. ($p < 0.001$, Figure 5&6) whereas pooled species abundance was higher at low disturbance than that of high intensity of disturbance.

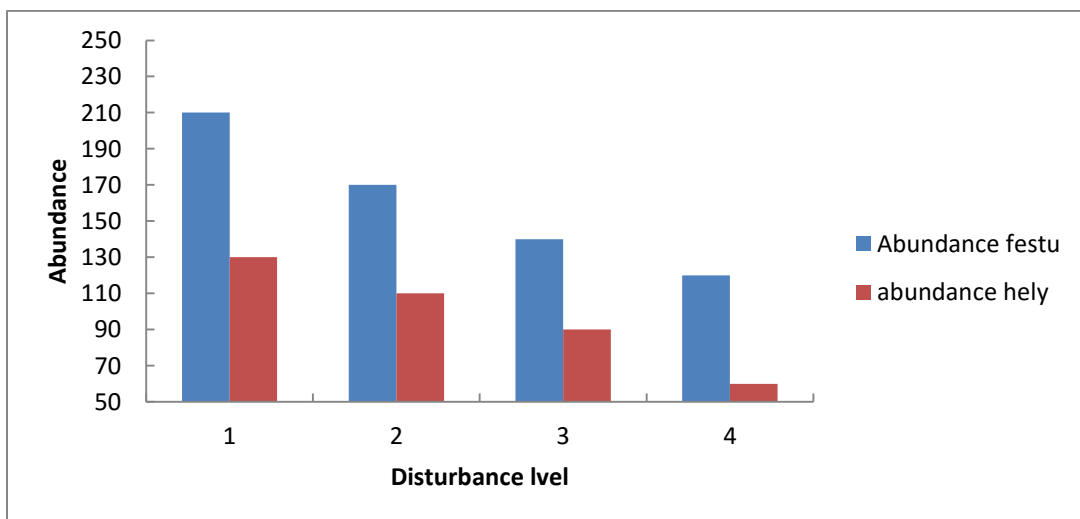


Figure 6:- A graph showing pooled species abundance (*H. splendidum* and *F. macrophylla*) within different disturbance level (1:-very low, 2:-low, 3:-moderate, 4:-high)

4.1.3 Abundance in relation to small herbivores (Rodent)

Results of the general linear model analysis showed ($P < 0.001$) that abundance of both species was negatively correlated with the small herbivore (rodent), but species abundance of the two species decreased with increasing number of small herbivore in the surrounding.

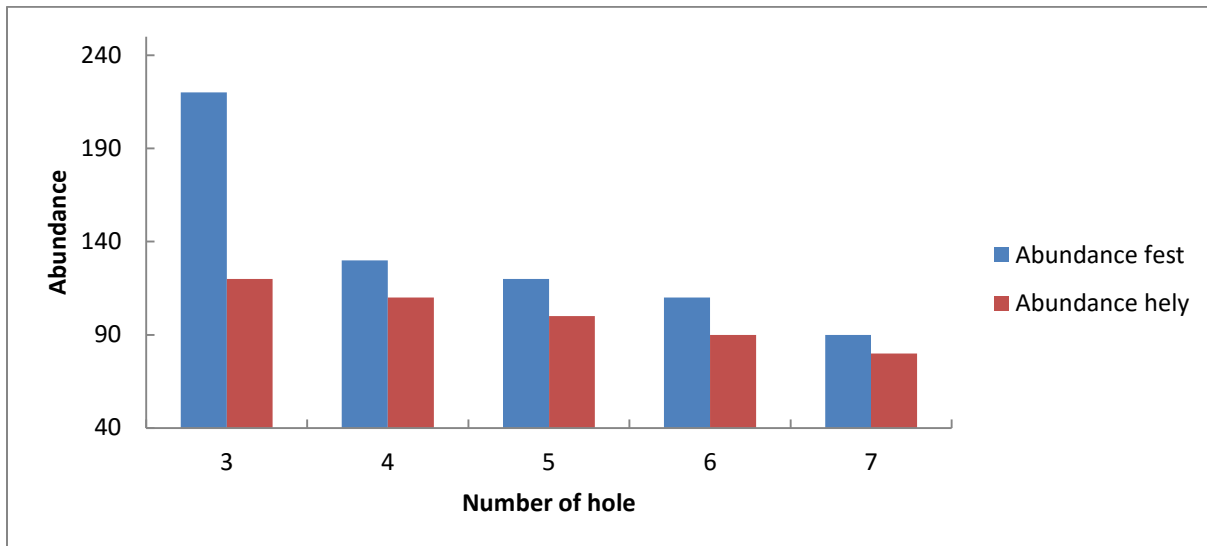


Figure 7:-Graph showing effects of herbivore on *F.macrophylla* and *H.splendidum* abundance

KEY:-festu-*festuca*, hely- *Helichrysum*

4.1.4 Effect of aspect on the species abundance

Within each plot, aspect significantly affected abundance of the two species ($p < 0.001$), where *F.macrophylla* recorded higher at west direction followed by East, South and North direction respectively. High abundance of *H.splendidum* recorded in East direction followed by West, south and North direction (Fig 8). However, high abundance of *H.splendidum* was observed in the North and South aspect of the whole study area..

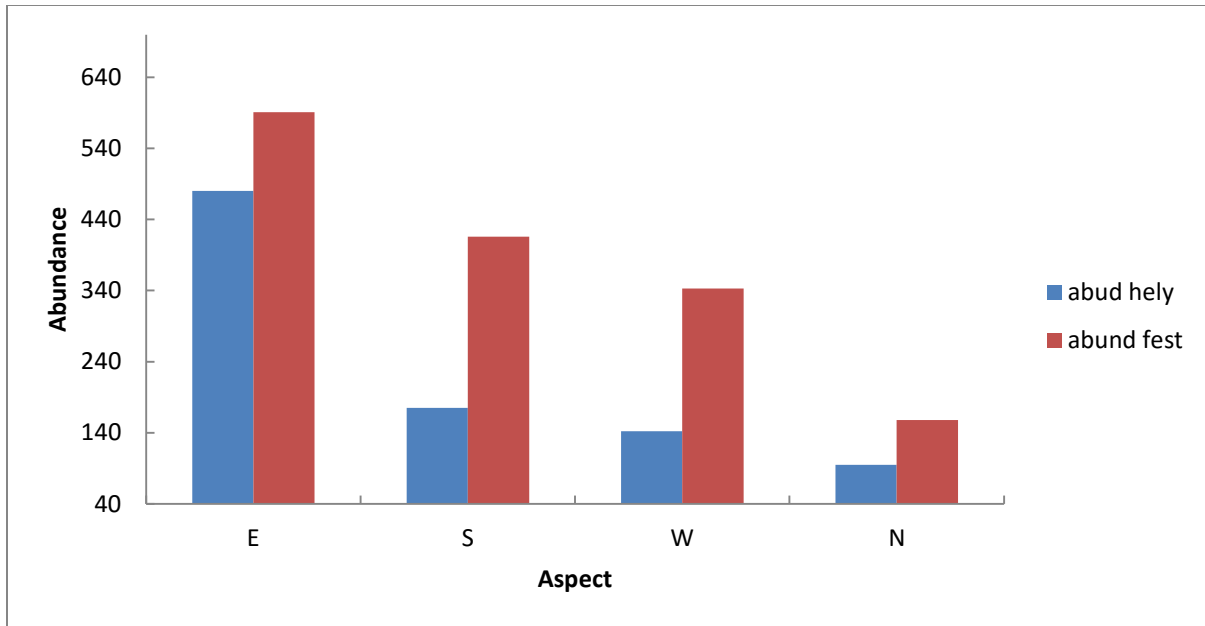


Figure 8, Effects of aspect on the abundance of the two species (**KEY**: abund *fest*- Abundance *Festuca*, abund *hely*- Abundance *Helichrysum*, N-North, S-South, E-East, W-West)

4.2 Soil nutrient properties

The one way analysis of variance showed that soil properties lacked significant variation among the three stratified site. However it was observed that total species abundance affected by both available phosphorus (avp $p = 0.0004$) and Organic matter (Om, $p = 0.0007$). The e available phosphorus (avp) was found to be negatively correlated with species abundance whereas Organic matter (Om) positively correlated with species abundance.

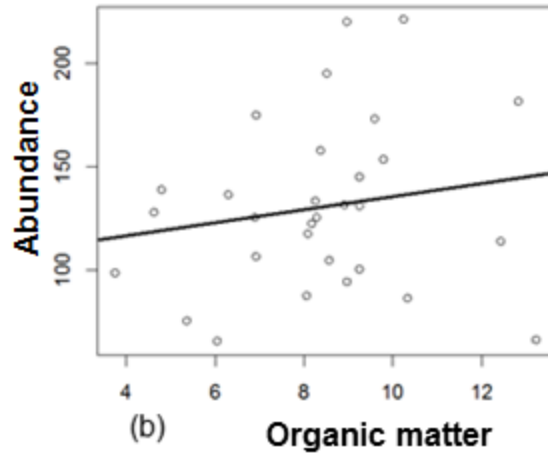
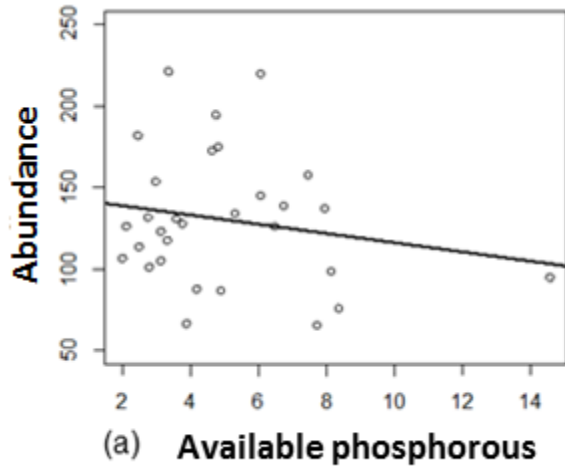
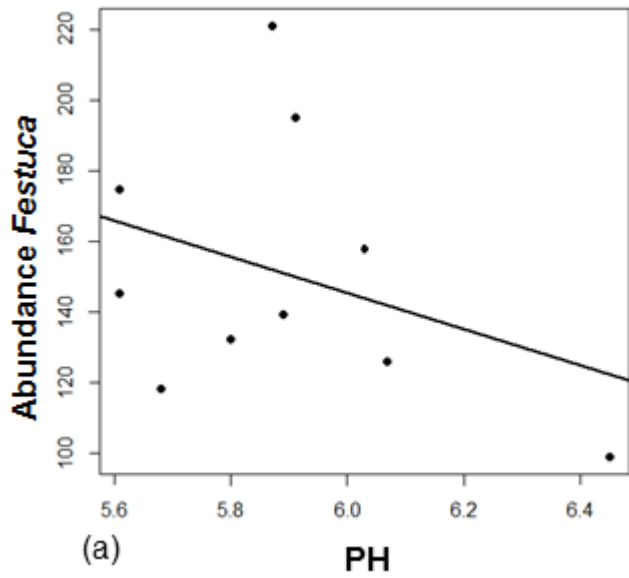
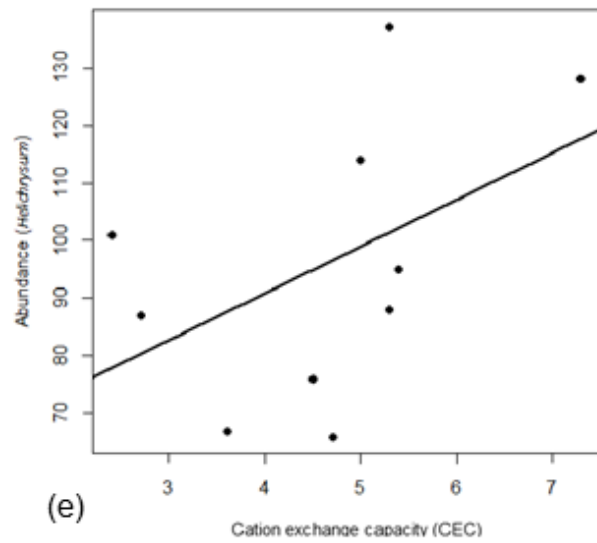
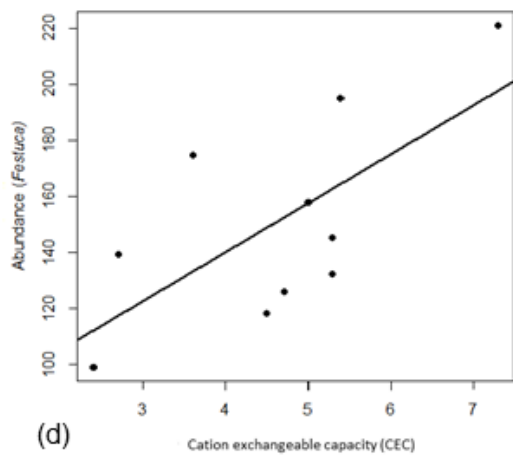
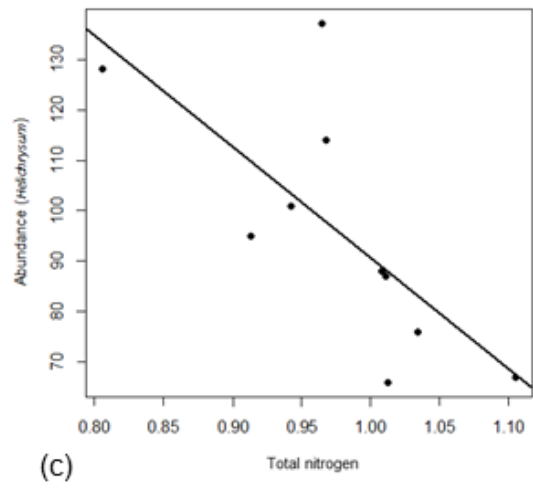
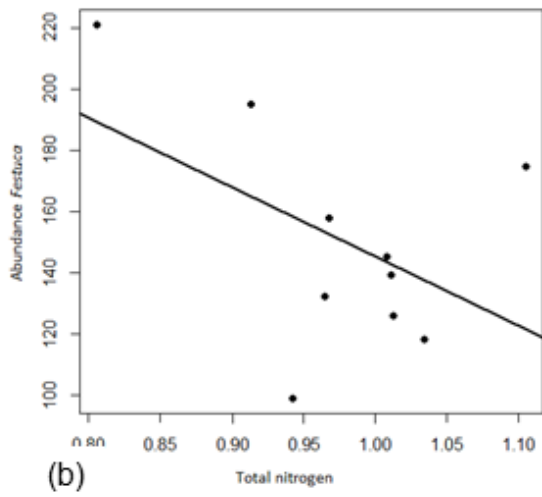


Figure 9 Line graph showing the relationship between (a) available phosphorus and (b) organic matter, and the pooled abundance of *F.macrophylla* and *H.splendidum*





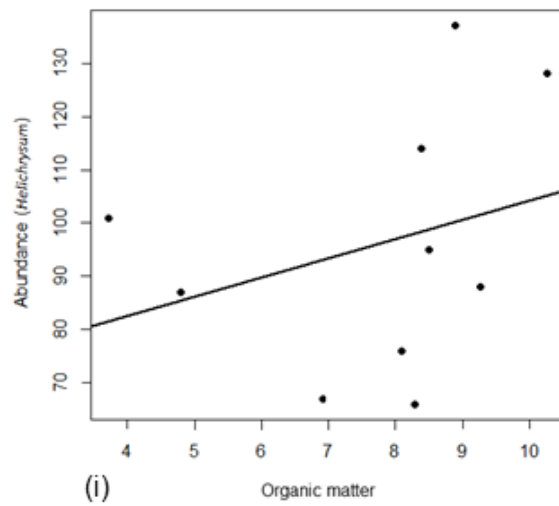
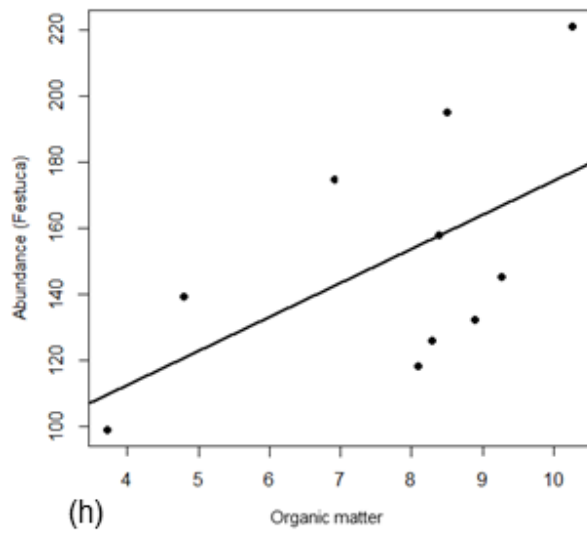
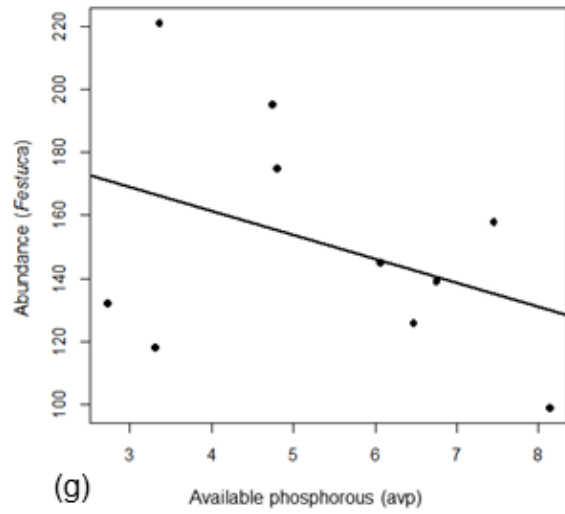
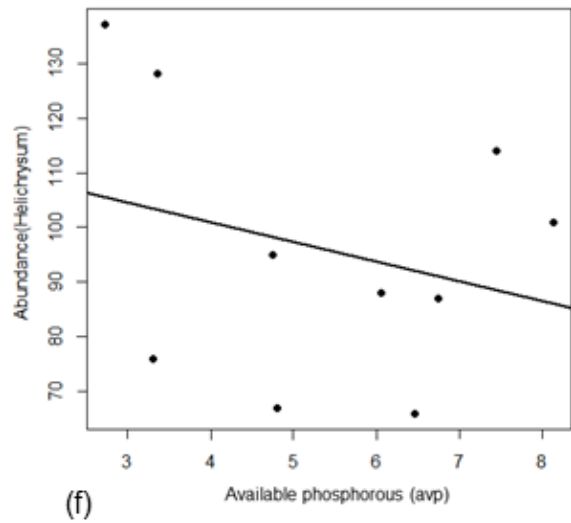


Figure 10 (a-i) showing soil nutrient as the response to abundance of *F.macrophylla* and *H.splendidum*

F. macrophylla species abundance positively correlated with organic matter ($p < 0.001$) and cation exchange capacity ($p < 0.001$) while negatively correlate with P^H ($P = 0.002$), available phosphorus (0.0005), total nitrogen ($P < 0.001$). Abundance of *H. splendidum* was positively correlated with soil chemical properties ($P < 0.02$) and cation exchange capacity ($p < 0.0004$) and negatively correlated with total nitrogen ($P < 0.001$) and available phosphorous ($P = 0.04$)

4.3 Soil seed bank

4.3.1 Soil seed bank density

Soil seed bank density of *Helichrysum* was found to be higher than seed of *festuca* which was opposite result with above ground density of the two species (*festuca* is more abundance than that of *Helichrysum*)

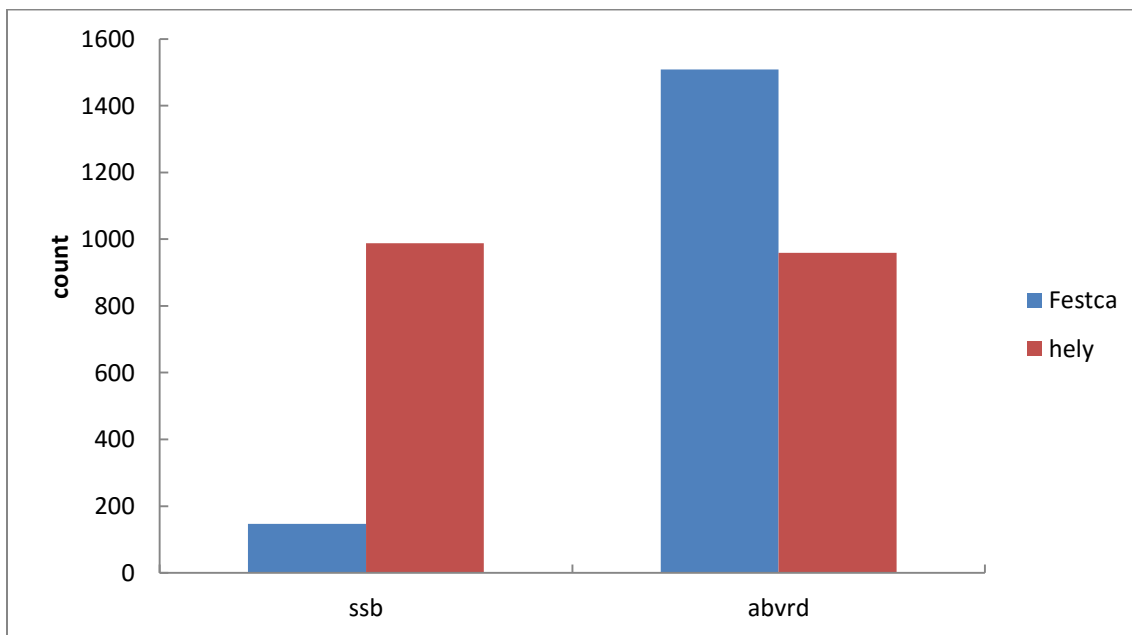


Figure 11, Soil seed bank status of the two species (*Festuca macrophylla* and *Helichrysum splendidum*), **KEY:-Festca-** *Festuca macrophylla*, **hely:-** *Helichrysum splendidum*, **abvrd:-** above ground information.

4.3.2 Depth distribution of seed banks

Vertical distribution of soil seed bank of the two species (*Festuca*, *Hellichrysum*) showed similar patterns. The highest seed bank density was recorded in the literal layer for *Hellichrysum* while small amount for *Festuca*. Viable seed of *Hellichrysum* showed significant variation along depth distribution ($P < 0.001$). It showed decreasing trend vertically following general trend but *Festuca* was absent totally from the next two layer (Figure 12).

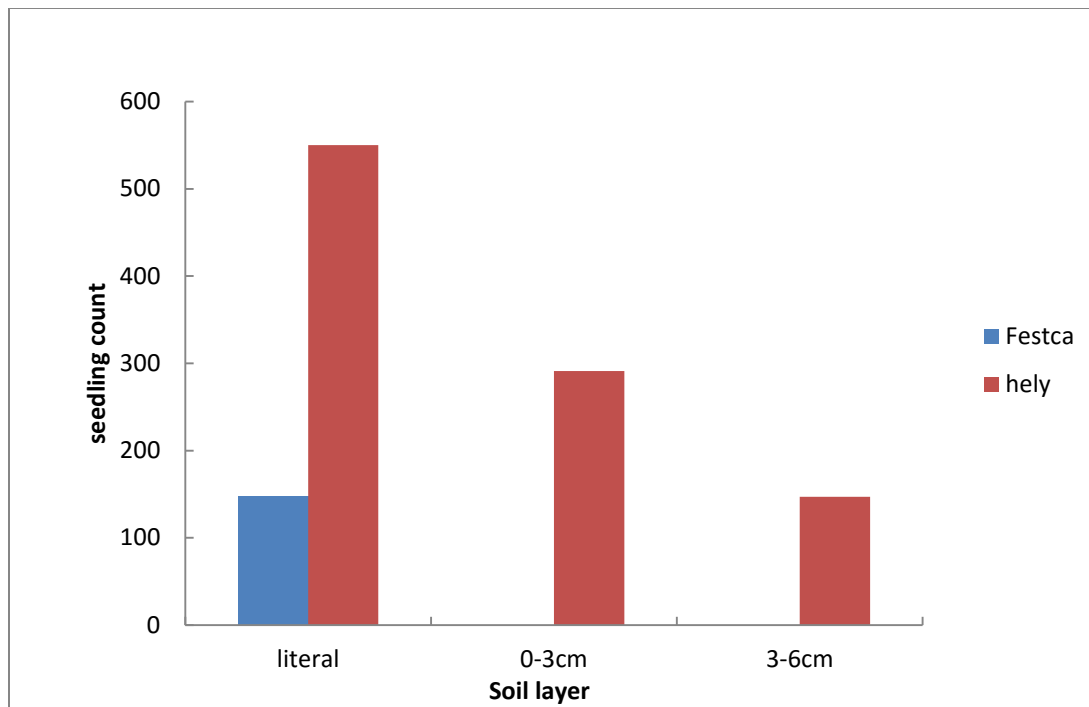


Figure 12, comparing vertical distribution of soil seed bank among the two species. **KEY:**

Festuca- *Festuca macrophylla*, **hely-** *Helichrysum splendidum*

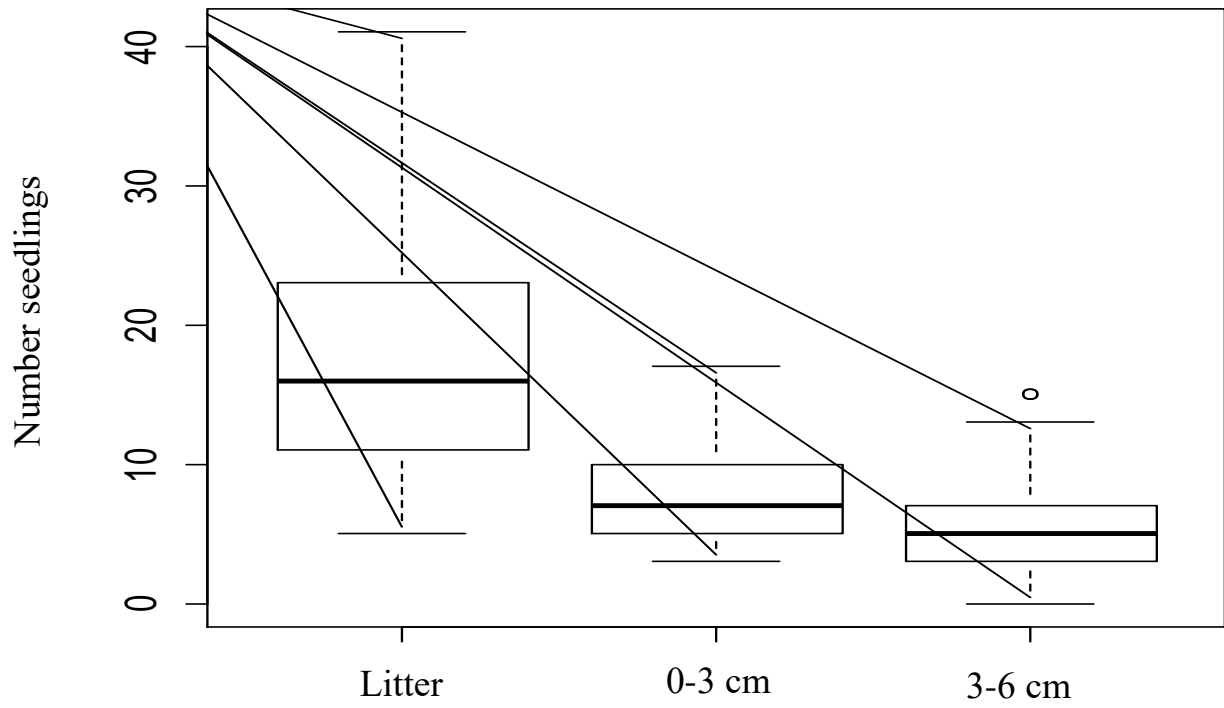


Figure13. The box plot indicating the abundance (number of seedlings germinated) of *H.splendidum* in relation to the three soil depths.

CHAPTER FIVE

5. Discussion, Conclusion and Recommendation

5.1 Discussion

5.1.1 above ground Information

Patterns of abundance of *F.macrophylla*, and *H.splendidum* was determined against altitude, disturbance intensity, aspect and herbivores. Abundance of the two species negatively correlated with altitude (P-Value $P = -0.028$). This result was similar with the one reported by Getahun *et al.*, (2017) who found that altitude is the most significant factor that affects species abundance and distribution in afroalpine. A reduction in species abundance might be due to harsh climatic condition and less competition as altitude increase

Species abundance and disturbance intensity negatively correlated with each other. A decrease in species abundance as intensity of disturbance increases could allow some non-native species like *H.splendidum* to grow more in abundance. The probable reason for the increase in *H.splendidum* species in the study area is that increase in resource availability and reduced competition which could be beneficial for non-native species success (Lembrechts *et al.*, 2016). The high number of such abundance species recorded in the study area could also explained by canopy opening as a result of physical disturbances or destruction of plant tissue, human activities such as grass cutting every two years which may give an opportunity to germinate widely dispersed seeds in the soil and compete *Festuca macrophylla* for nutrient and space as well (D.K. Kennard *et al.*; 2002).

The number of herbivore and abundance of the two species (*F.macrophylla* and *H.splendidum*) were negatively correlated ($P < 0.001$). High number of herbivore recorded at *H.splendidum* stand

(By counting the number of hole within each different site). The presence of high number of herbivore indicate that herbivore (rodents) may destroy the cushions by eating the roots and result increase in loss of vegetation cover or decrease in species abundance, (Dullo *et al.*,2015).

Species abundance significantly affected by aspect ($P < 0.001$). High number of *F. macrophylla* recorded in the West direction followed by East, South and North direction respectively. On the other hand high abundance of *H. splendidum* recorded along East direction followed by West, south and North direction. The high number of *H. splendidum* recorded in east direction may be attributed to the fact that seed dispersed by wind and facilitated by human activity giving an opportunity to germinate widely dispersed seed in the soil (Schimmel and Granstrom, 1996). But considering study area as a whole a high number of *H. splendidum* was observed from south and North aspect, possibility due to high disturbance pressure as a result of high population density living in the surrounding areas as compared to the other two aspects. Due to their remoteness and few number of local people assigned, both aspects were not well patrolled and monitored (Hailu Beyene, 2010). High disturbance may favor increase in non-native species hence opened area give an opportunity to geminate seed in soil.

5.1.2 Soil seed bank and soil nutrient properties

The result of soil seed bank study showed that *H.splendidum* had high density of persistent seeds in the soil as compared to *Festuca macrophylla* (Figure 11). The possible reason for the existence of high seed in the soil may be high seed production which may persist in the soil for a long period of time (Wanga *et al.*, 2005). The possible explanation for the existence of low viable seed of *F.macrophylla* in the soil is due to light small sized seed and frequently found on the steep slope. These small sized seeds are found on the steep slopes. For getting a chance to be washed by water (Looney *et al.*, 1995).

Another possible reason for low seed density of *F.macrophylla* is that, *F.macrophylla* is perianal herb and produce its seed every two year and grass cutting (disturbance) may be done before it produce seed which may also result in low persistence seed in the soil (Mulugeta Lemenih and Demel Teketay, 2005; Levassor *et al.*,1990).

Few number of *F.macrophylla* seedling recorded in seedling emergence method as compared to direct counting. The reason for such a weak similarity between soil seed bank and above ground flora by the germination method compared to the direct count method may relate to the transient nature of seeds, which germinate immediately after dispersal rather than staying for long period of time (Chaideftou *et al.*, 2009).

The vertical distribution of the seed in the soil showed that *Helichrysum* had high seed densities in the literal and upper three centimeters of soil and decrease densities with increasing depth. This observation is consistent with several previous studies in Ethiopia (Feyera Senbeta and Demel Teketay, 2001). The variations of seed density in successive layers may indicate *Helichrysum* had better seed longevity in the soil than *F.macrophylla* in addition to mode of seed dispersal and seed predation.

Both species abundance and available phosphorus (avp $p = 0.0004$) was negatively correlated while Organic matter ($P= 0.0007$) positively correlated with species abundance. The tricky result between species abundance and available phosphorous might be due to the presence of high organic matter in the study area. As indicated by T. R. Seastedt and Lynn Vaccaro (2001), Alpine Tundra, Colorado high organic matter may create obstacle plants in using available phosphorous and exhibit available phosphorous limitation on plant growth which may be the consequence of a decrease in species abundance.

Organic matter showed positive correlation with species abundance suggesting that high species abundance found at soils with high amounts of organic matter. This is in line with the result from northern Iran by F. Bazdid Vahdati (2017). The positive effects of organic matter in the soil include improving soil structure, increasing water holding capacity, and generally improving soil physical conditions. Soils with sufficient amounts of organic matter are more fertile and provide more favorable conditions for plant growth, and support high plant diversity, Melese et al (2017) also found that organic matter significantly associate (positively associated) with afro-alpine vegetation community formation and species distribution

Abundance of *H.splendidum* and *F.macrophylla* positively correlated with cation exchange capacity ($p < 0.0004$). The positive correlation between them may as a result of the presence of high organic matter within the study area which is consistent with the result of Fantaw Yimer (2006) who did on soil properties of Bale national park, and Mohammed Assen and Belay Tegene (2008). who did at Simen Mountains National Park

The result of total nitrogen in relation to abundance of the two species contradict with Melese *et al* (2017) who did on afro- alpine vegetation of simien mountains national park of Ethiopia and found that total nitrogen were the most positively correlated with species distribution and species abundance but it agree with the result of T. R. Seastedt and Lynn Vaccaro (2001) who did on Alpine Tundra, Colorado and his result showed that both species abundance and species richness decrease as total nitrogen increase within the area, which might be an increase in total nitrogen resulting in an increase in acidity that may not favorable for some plant species. The present study revealed that species abundance negatively correlated with PH meaning that species in the study area are acid lover. It is also confirmed that, Alpine soil are acidic nature (Alexander J M *eta l.*, 2016).

5.2 Conclusion

Guassa Community Conservation Area is one of the protected areas by which community based natural resources management system is operating for its special resources called Guassa grass

Our findings showed that abundance of the two species significantly affected by altitude. Herbivore (small rodent), disturbance and aspect were found to be significantly affected abundance of the two species. The result of soil nutrient analysis revealed that PH, total nitrogen and available phosphorus negatively correlated with abundance of the two species while organic matter and cation exchange capacity positively correlated. The soil seed bank results showed *H. splendidum* significant variation while *F. macrophylla* did not show variation.

From our result it could be concluded that current management system in the study area favorer the expansion of *H. splendidum* and might result in the loss of *F. macrophylla* . Loss of such threatened species would have great implications for the environment, biodiversity and socio-economic setup of the communities

Therefore, conservation and sustainable utilization of *F. macrophylla* through different management system approach is mandatory.

5.3 Recommendations

As indicated by different studies, Guassa community conservation area is rich in endemic plant and animal species. The area is becoming a destination place for tourists as well. However, currently *Helichrysum splendidum* (Locally-Nechilo) is creating a problem by expanding at alarming rate and even displacing the threathend Grass Guassa (*F. macrophylla*).

Therefore, to conserve and achieve sustainable utilization *F. macrophylla* , the following recommendations are forwarded.

- The current management approach system should take in to consideration as it is the main factors for the expansion of *H.splendidum* and continuing with the same fashion in the future can lead loss of *F. macrophylla* from the area.
- To control the expansion of *H.splendidum*, it is better allowed for community member to collect *H.splendidum* for fuel and forage while they are harvesting *F macrophylla* (Guassa). This is because the seed of *H.splendidum* buried soil may get an opportunity to grow in a high number and increase its abundance.
- *H.splendidum* is annual plant produce high number of seed every year and increase its abundance therefore to minimize the expansion, it is better to allow for the community to collect *H.splendidum* for fuel every year before it get flower but should be done in managed way.
- To use *H.splendidum* for access and benefit sharing research should be done on the extraction and potential of essential oil.
- Road that pass Mehalmeda and along the surrounding kebels are characterized by high dense of *H.splendidum* to minimized this, it is better to allow for community to collect from area.

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APPENDICES

Appendix 1

Sample plot location from the site

	Location		
plot	Latitude	Longitude	Altitude
1	10°17'07.9"N	039°47'51.2"E	3325m
2	10°17'10.1"N	039°47'49.5"E	3321m
3	10°17'13.4"N	039°47'47.1"E	3312m
4	10°17'19.9"N	039°47'44.8"E	3299m
5	10°17'22.9"N	039°47'40.5"E	3340m
6	10°17'26.5"N	039°48'11.8"E	3348m
7	10°17'33.7"N	039°47'35.6"E	3382m
8	10°17'38.2"N	039°47'34.6"E	3385m
9	10°17'42.9"N	039°47'35.3"E	3378m
10	10°17'48.4"N	039°48'20.2"E	3385m
11	10°17'52.9"N	039°47'35.5"E	3395m
12	10°17'57.7"N	039°47'33.9"E	3402m
13	10°18'01.7"N	039°47'33.8"E	3410m
14	10°18'08.8"N	039°47'34.3"E	3397m
15	10°18'15.3"N	039°47'33.4"E	3392m
16	10°18'16.7"N	039°47'41.3"E	3399m

17	10°19'31.3"N	039°48'06.4"E	3438m
18	10°19'33.6"N	039°48'12.7"E	3431m
19	10°19'36.5"N	039°48'13.1"E	3416m
20	10°19'43.1"N	039°47'58.6"E	3391m
21	10°19'44.5"N	039°47'55.4"E	3372m
22	10°19'47.8"N	039°47'53.9"E	3368m
23	10°20'08.7"N	039°47'50.9"E	3360m
24	10°20'54.5"N	039°47'53.5"E	3455m
25	10°20'59.9"N	039°47'58.1"E	3461m
26	10°26'16.8"N	039°48'15.5"E	3515m
27	10°22'08.3"N	039°48'22.1"E	3548m
28	10°23'30.6"N	039°48'30.1"E	3484m
29	10°23'12.7"N	039°48'11.7"E	3524m
30	10°24'03.07"N	039°47'40.5"E	3516m

Appendix 2 :- Soil analysis result 1(page 1)

	pH-H ₂ O	EC	Sand	Silt	Clay	Class
	1:2.5	ds/m	%	%	%	
plot - 1	6.45	0.29	69	18	13	Sandy Loam
plot - 2	6.31	0.19	69	18	13	Sandy Loam
plot - 3	6.07	0.22	71	16	13	Sandy Loam
plot - 4	6.03	0.28	69	18	13	Sandy Loam

plot - 5	5.97	0.13	69	20	11	Sandy Loam
plot - 6	6.11	0.22	67	20	13	Sandy Loam
plot - 7	6.03	0.21	67	20	13	Sandy Loam
plot - 8	5.86	0.18	65	22	13	Sandy Loam
plot - 9	5.89	0.20	61	24	15	Sandy Loam
plot - 10	5.83	0.22	71	18	11	Sandy Loam
plot - 11	5.87	0.18	65	20	15	Sandy Loam
plot - 12	5.91	0.24	67	20	13	Sandy Loam
plot - 13	5.95	0.18	71	16	13	Sandy Loam
plot - 14	5.83	0.17	67	18	15	Sandy Loam
plot - 15	5.88	0.16	73	16	11	Sandy Loam
plot - 16	5.91	0.18	57	28	15	Sandy Loam
plot - 17	6	0.20	61	26	13	Sandy Loam
plot - 18	5.8	0.23	63	24	13	Sandy Loam
plot - 19	5.87	0.18	59	26	15	Sandy Loam
plot - 20	5.8	0.11	69	18	13	Sandy Loam
plot - 21	5.97	0.18	57	30	13	Sandy Loam
plot - 22	5.91	0.24	61	26	13	Sandy Loam
plot - 23	5.77	0.12	57	28	15	Sandy Loam
plot - 24	5.68	0.15	67	20	13	Sandy Loam
plot - 25	5.89	0.17	57	28	15	Sandy Loam
plot - 26	5.73	0.17	55	30	15	Sandy Loam

plot - 27	5.61	0.17	59	26	15	Sandy Loam
plot - 28	5.61	0.14	51	22	27	Sandy clay loam
plot - 29	5.56	0.16	47	24	29	Sandy clay loam
plot - 30	5.71	0.17	47	20	33	Sandy clay loam

Appendix 3:- Soil properties result 2

Result Sheet For Soil							
Chemical and Physical							
Analysis							
<i>Study Area:-Amhara</i>				<i>Location:- Menz</i>		<i>Supplier :- Sisay Wubie</i>	
LAB.NO	Field No	Depth	T.N	O.C	C/N	Av.P.Ol.	%OM
		cm	%	%		ppm	%
558 /18	plot - 1	0 - - 30	0.94	2.16	2	8.13	3.72
559 /18	plot - 2	0 - - 30	0.26	5.37	21	2.79	9.26
560 /18	plot - 3	0 - - 30	1.01	4.81	5	6.46	8.29
561 /18	plot - 4	0 - - 30	1.14	3.50	3	7.73	6.03
562 /18	plot - 5	0 - - 30	0.92	7.21	8	2.5	12.43
563 /18	plot - 6	0 - - 30	0.96	4.79	5	5.31	8.26
564 /18	plot - 7	0 - - 30	0.97	4.86	5	7.44	8.38
565 /18	plot - 8	0 - - 30	0.89	5.99	7	4.91	10.33
566 /18	plot - 9	0 - - 30	1.01	2.78	3	6.75	4.79

567 /18	plot - 10	0 - - 30	1.17	2.67	2	3.76	4.60
568 /18	plot - 11	0 - - 30	0.81	5.95	7	3.36	10.26
569 /18	plot - 12	0 - - 30	1.04	3.65	4	7.96	6.29
570 /18	plot - 13	0 - - 30	0.94	5.37	5	3.59	9.26
571 /18	plot - 14	0 - - 30	0.94	5.20	6	14.56	8.96
572 /18	plot - 15	0 - - 30	0.91	7.44	9	2.44	12.83
573 /18	plot - 16	0 - - 30	0.88	5.57	6	4.63	9.60
574 /18	plot - 17	0 - - 30	0.83	5.20	6	6.06	8.96
575 /18	plot - 18	0 - - 30	1.10	3.10	3	8.36	5.34
576 /18	plot - 19	0 - - 30	0.87	5.68	7	2.96	9.79
577 /18	plot - 20	0 - - 30	0.97	5.16	5	2.73	8.90
578 /18	plot - 21	0 - - 30	0.90	4.01	4	1.98	6.91
579 /18	plot - 22	0 - - 30	0.91	4.93	5	4.74	8.50
580 /18	plot - 23	0 - - 30	0.98	3.99	4	2.1	6.88
581 /18	plot - 24	0 - - 30	1.03	4.69	5	3.3	8.09
582 /18	plot - 25	0 - - 30	0.93	4.97	5	3.13	8.57
583 /18	plot - 26	0 - - 30	1.06	4.74	4	3.13	8.17
584 /18	plot - 27	0 - - 30	1.01	5.37	5	6.06	9.26
585 /18	plot - 28	0 - - 30	1.11	4.01	4	4.8	6.91
586 /18	plot - 29	0 - - 30	1.02	4.67	5	4.17	8.05
587 /18	plot - 30	0 - - 30	0.84	7.67	9	3.88	13.22

Appendix 4:-Soil seed bank data collection format

Place of soil collected _____ Zone _____

Woreda _____ Name of collector _____

Date of collection _____

Collecti on code	Name of Germinated seedling	Family	seedling count in each depth (cm)		
			Literal	0-3cm	3-6cm
SSB1	<i>H.splendidum</i>	Asteraceae	11	8	7
SSB1	<i>F.machrophylla</i>	Poaceae	2	0	0
SSB 2	<i>H.splendidum</i>	Asteraceae	23	7	5
SSB 2	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 3	<i>H.splendidum</i>	Asteraceae	16	8	6
SSB 3	<i>F.machrophylla</i>	Poaceae	3	0	0
SSB 4	<i>H.splendidum</i>	Asteraceae	15	6	5
SSB 4	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 5	<i>H.splendidum</i>	Asteraceae	17	6	6
SSB 5	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 6	<i>H.splendidum</i>	Asteraceae	41	10	13
SSB 6	<i>F.machrophylla</i>	Poaceae	3	0	0
SSB 7	<i>H.splendidum</i>	Asteraceae	17	13	6
SSB 7	<i>F.machrophylla</i>	Poaceae	3	0	0

SSB 8	<i>H.splendidum</i>	Asteraceae	24	5	4
SSB 8	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 9	<i>H.splendidum</i>	Asteraceae	27	14	4
SSB 9	<i>F.machrophylla</i>	Poaceae	5	0	0
SSB10	<i>H.splendidum</i>	Asteraceae	32	7	3
SSB 10	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 11	<i>H.splendidum</i>	Asteraceae	9	3	2
SSB 11	<i>F.machrophylla</i>	Poaceae	4	0	0
SSB 12	<i>H.splendidum</i>	Asteraceae	10	6	9
SSB 12	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 13	<i>H.splendidum</i>	Asteraceae	41	10	13
SSB 13	<i>F.machrophylla</i>	Poaceae	3	0	0
SSB 14	<i>H.splendidum</i>	Asteraceae	5	4	3
SSB 14	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 15	<i>H.splendidum</i>	Asteraceae	42	12	4
SSB 15	<i>F.machrophylla</i>	Poaceae	2	0	0
SSB 16	<i>H.splendidum</i>	Asteraceae	16	6	5
SSB 16	<i>F.machrophylla</i>	Poaceae	1	0	0
SSB 17	<i>H.splendidum</i>	Asteraceae	8	5	7
SSB 17	<i>F.machrophylla</i>	Poaceae	4	0	0
SSB 18	<i>H.splendidum</i>	Asteraceae	14	8	5
SSB 18	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 19	<i>H.splendidum</i>	Asteraceae	13	7	5

SSB 19	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 20	<i>H.splendidum</i>	Asteraceae	8	3	2
SSB 20	<i>F.machrophylla</i>	Poaceae	1	0	0
SSB 21	<i>H.splendidum</i>	Asteraceae	11	4	3
SSB 21	<i>F.machrophylla</i>	Poaceae	2	0	0
SSB 22	<i>H.splendidum</i>	Asteraceae	11	3	3
SSB 22	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 23	<i>H.splendidum</i>	Asteraceae	15	7	4
SSB 23	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 24	<i>H.splendidum</i>	Asteraceae	24	8	7
SSB 24	<i>F.machrophylla</i>	Poaceae	1	0	0
SSB 25	<i>H.splendidum</i>	Asteraceae	9	7	5
SSB 25	<i>F.machrophylla</i>	Poaceae	3	0	0
SSB 26	<i>H.splendidum</i>	Asteraceae	21	17	15
SSB 26	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 27	<i>H.splendidum</i>	Asteraceae	17	13	6
SSB 27	<i>F.machrophylla</i>	Poaceae	3	0	0
SSB 28	<i>H.splendidum</i>	Asteraceae	17	15	3
SSB 28	<i>F.machrophylla</i>	Poaceae	2	0	0
SSB 29	<i>H.splendidum</i>	Asteraceae	26	12	9
SSB 29	<i>F.machrophylla</i>	Poaceae	0	0	0
SSB 30	<i>H.splendidum</i>	Asteraceae	21	17	15
SSB 30	<i>F.machrophylla</i>	Poaceae	0	0	0