ADDIS ABABA UNIVERSITYSCHOOLS OF GRADUATE STUDIES
DEPARTMENT OF BIOLOGY

ASSESSING INVERTEBRATE BIODIVERSITY IN GULLELE BOTANIC GARDENDURING WET SEASON.

BY

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DECLARATION

This is to certify that this thesis entitled "Assessing invertebrate biodiversity in Gullele Botanic Garden during wet season in Addis Ababa city, Ethiopia" submitted in partial fulfilment for the requirement of the award of the degree of Master in Biology from Addis Ababa University, Collegeof Natural and Computational Sciences Department of Zoological Science, submitted by Shoma Abdissa. The material embodied in thesis work has not been submitted earlier for award of any degree or diploma to the best of my knowledge and belief.

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Lists of Abbreviations

EMSA Ethiopian Meteorological Service Agency.

GPS Global Positioning System.

GBG Gullele Botanical Garden.

TFRA Tropical ForestResource Assessment.

ABSTRACT

Gullele Botanic Garden contains diverse types of invertebrates. The diversity, distribution, frequency, density and abundance of these invertebrates were investigated using 28 quadrats which were located at different habitat types. The study found that Gullele Botanic Garden support the presence of invertebrates in large quantity in mixed forest habitat. A total of 2854 invertebrate specimens belonging to 42 families were collected and recorded in the Gullele Botanical Garden. Higher diversity and evenness of invertebrates were observed in the mixed foresthabitat. On the other hand, the least evenness and diversity of invertebrates was observed in the grassland forest habitat in the study season. Based on jaccard's similarity index, the highest similarity was observed between mixed forest and grassland forest habitats.. The lowest similarity was observed between natural forest habitat and artificial forest habitat. Abundance of food on species of vegetation, stability of the habitats, human activities and settlement inside determined invertebrate diversity in the study areas.During data collection in Gullele Botanic Garden, careful observation showed that invertebrates had both positive and negative effect for humans, animals and insects. The positive effects were increasing soil fertility(earthworms),nutrient cycling(ants),increasing the rate of soil nutrient cycling(beetles) and indicators of environmental change and habitat disturbance(insects). Conversely, the negative effects were plant drying(termites) and attacking roots,trunks,stems,leaves, flowers ,seeds ,fruits and saps of vascular system(phytophagous invertebrates).

Keywords:-*Invertebrate biodiversity, Habitat types, Abundance, Frequency, and Diversity.*

1. INTRODUCTION

1.1 Background of the Study

Throughout most of the world, vertebrates are far better known than invertebrates since biodiversity research has largely shown a ‘vertebrate chauvinism’ (Wilson, 1985; Lovejoy, 1997). For example, much is known about the distribution, biology and threatened status of birds and large mammals, but similar data for invertebrates are almost nonexistent (Stork, 1997). Estimates of global species numbers are so imprecise because inconspicuous taxa, such as invertebrates, have been largely ignored (Primack, 2000). Vertebrates also drive many conservation efforts because it is often assumed that if vegetation and ‘charismatic mega fauna’ are protected, the invertebrates will be conserved as well (New 1998, Grove & Stork, 1999). However, these assumptions are unwarranted given the vast abundance, biomass and species diversity of the Earth’s invertebrates.

Invertebrates dominate all of the world’s faunal groups in terms of sheer numbers of individuals and biomass (Black *et al.,* 2001). This is particularly true of insects and their close relatives (Samways, 1993). Accordingto (Wilson, 1992), arthropods alone account for over 85% of the total weight of all land animals. The total biomass of soil invertebrates and microorganisms is greater than all of the above-ground vertebrates combined (Edwards, 2000). In the United States earthworm and arthropod biomass is estimated at 1000 kilograms per hectare, while all other terrestrial vertebrates combined, including humans, only account for 36 kilograms per hectare (Black *et al.*, 2001). Average annual spider abundance in the world ranges from 50 to 150 individuals per square meter, but can reach over 1000 individuals per square meter (Marc *et al.*, 1999).

Invertebrates comprise 95% of all described animal species (Brusca & Brusca, 1990) and most of the 10 to 100 million species estimated to live on Earth today (Lovejoy, 1997) are invertebrates. Over one million terrestrial arthropod species alone have been recognized and (Hawks worth& Kalin-Arroyo, 1995) estimated that two to 20 million remain to be described. Invertebrates have successfully invaded virtually every habitat on Earth and have exploited every imaginable lifestyle and developmental strategy (CloudsleyThompson, 1968; Brusca & Brusca, 1990). They constitute over 30 phyla (Brusca & Brusca, 1990) and include some familiar animals such as spiders, butterflies, snails, earthworms, crabs and flies. Although humans come into direct contact with many invertebrates every day, we have no clear idea of the true richness of global invertebrate diversity (Stork & Eggleton, 1992), as only a fraction has been discovered (Ehrlich & Wilson, 1991).

Although invertebrate groups are typically diverse, one invertebrate taxon, the arthropods, is hyper diverse, meaning that it contains more species than expected for a single group (Ehrlich & Wilson, 1991; Colwell &Codington, 1994) and most of the undescribed species in the world are arthropods (Stone, 1993). Within the Arthropoda, the Insecta are well known to be the most abundant, successful and species taxon (Ehrlich & Wilson, 1991; Stork & Eggleton, 1992; Stork 1997), with about one million known species (Hawks worth& Kalin-Arroyo, 1995). However, the described species only account for about seven to 10% of the true species number (Samways, 1993) and Stork (1993) estimated that two to 30 million species of insects remain unknown. Importantly, insects also appear to be the group threatened with the greatest number of extinctions (Stork, 1997).

In addition to our poor knowledge of global invertebrate species numbers, information on the distribution and vulnerability for known species is lacking. At regional and local levels, there are few data on the turnover of species with distance, altitude and habitat (Stork & Eggleton, 1992) and we know little about the biology and habitat requirements of most described invertebrates (Moore, 1991). Data on the threatened status of insects and other invertebrates are almost nonexistent (Stork, 1997). Most of the undescribed species of invertebrates in the world will be found in tropical canopies (Erwin, 1988). All Gullele Botanic Garden habitats are rich in other species such as amphibians, reptiles, birds, mammals and invertebrates (Fassil Adugna, 2010).

As indicated by(SeyoumMengistu ,2006) in summarizing the main findings of his review paper, invertebrate research is poor in Ethiopia. Therefore, this study aims to contribute some information on the invertebrate composition of the GBG, which was primarily designed for protection of highland vegetation around the capital city of Addis Ababa.

1.2. Statement of the Problem

Because the world`s biodiversity is severely threatened ,biodiversity conservation is currently one of the most important challenges facing humanity. Yet meaningful conservation cannot take place if the species involved are not known(Foord et al.,2002). Species inventorying is the approach commonly used to identifyquantify and map species and to provide the baseline information necessary for the assessment of communities,prioritization of areas for conservation and monitoring of environmental change(Stork and Samways,1995).On top of that, information on the distribution and vulnerability for known species is lacking. At regional and local levels, there are few data on the turnover of species with distance,altitude and habitat (Stork and Eggleton,1992) and we know little about the biology and habitat requirements of most described invertebrates(Moore,1991). On the other hand , (Fassil Adugna (2010) on the recommendation part of his insect diversity study at GBG, invited researchers to fill the gap of what he did not study as follows – the invertebrates – as noted that all Gullele Botanical Garden habitats are rich in other vertebrate species such as mammals,amphibians ,reptiles birds and invertebrates

1.3 Objectives of the study

1.3.1 General objective

- The main objective of the thesis was to asses' invertebrate diversity in Gullele Botanical Garden at different habitats during wet season.

1.3.2 Specific objectives

- To collect, identify and preserve invertebrates into their proper order and family.
- To identify the major invertebrates in Gullele Botanical Garden.
- To determine the composition, diversity and distribution of invertebrates in the GBG.

1.4. Research Questions

Based on the problem stated and the objectives formulate, the following basic research questions were posed:

- What invertebrate families are found in Gullele Botanical Garden ?
- What major invertebrates are found in GBG?
- What is the percentage composition of invertebrates of the study area?

1.5. Significance of the Study

- To contribute some information on the invertebrate composition of the Gullele Botanical Garden, whichwas primarily designed for protection of highland vegetation around the capital city of Addis Ababa.
- To fill the knowledge gaps concerning invertebrate study.
- To documentthe invertebrate families of the study area.
- To invite other researchers so as to conduct further research in other area to increase the overall understanding of invertebrate biodiversity conservation.

2. LITERATURE REVIEW

2.1 Global forest and biodiversity

Forest ecosystems vary widely throughout the world and can be categorized into broad global biomes such as boreal or northern conifer forests, temperate deciduous or mixed forests, temperate rain forests, tropical rain forests, tropical deciduous forests and tropical dry or scrub forests (Meadows ,1985; Burley ,2002). Within these categories, there are a range of more specific forest types, each with its own characteristic faunal and floral components and unique assessment and management needs (Burley, 2002).

Forest biodiversity is the variation of all life within the forests, including all of the plants, animals and microbes (Burley, 2002). The diversity of forests is great and the vast majority of the estimated 10 to 100 million species on Earth occur in forests (Bar bier*et al.* 1994). In particular, tropical forests are the best-recognized concentration of the world's diversity (Lovejoy, 1997), are the most complex vegetation type on Earth, are the most productive of the biomes (Meadows, 1985) and are important centers of endemism (Spellerberg, 1996a). Here species numbers well exceed those of temperate climate zones (Kanashiro *et al.,* 2002). Some 50% of all vertebrates, 60% of plant species and possibly 50 to 90% of the world's total species are found in tropical forests (Lovejoy, 1997; Reid and Miller, 1989; Stone, 1993; Primack, 2000; Burley, 2002). This amounts to at least three million species, but the true number could be ten or more times greater than this estimate (Raven, 1988).

Tropical forests are likely home to thousands, perhaps millions, of undescribed species of less studied taxa such as insects, nematodes, protozoans and plants (Kanashiro *et al.,*2002). Because they are home to such a large number of species, it may be surprising that tropical forests comprise only about 7% of the total land surface of the earth (Stone, 1993; Lovejoy, 1997; Primack, 2000). The Tropical Forest Resources Assessment (TFRA) estimated the area of natural forests to be 1756 million hectares in 1990, or about 36% of the total land area of the tropics (Bar bier*et al.,*1994).

The largest extent of tropical forest is found in Latin American and the Caribbean (918 million hectares), followed by Africa (528 million hectares), then Asia and the Pacific (311 million hectares) (Bar bier et al., 1994).

Our current knowledge of forest biodiversity is still very limited (Mooney *et al.*,1995) and much still remains to be discovered about the identity and interactions of animal, plant and microbial forest species (Burley, 2002). Only about 500 000 tropical and subtropical species are named and catalogued (Raven, 1988) and a complete species inventory of a single tropical ecosystem does not exist (Lugo, 1988). Forests are complex in structure and contain many types of habitats, each with unique faunal components. For example, the assemblage of life in the tropical forest canopy is entirely different from that of the forest floor. The two habitats share only one common species – the trees themselves (Lovejoy,1997). According to Erwin (1988), most of the undescribed species of arthropods in the world will be found in tropical forest canopies. Because of their great species richness, complexity and importance in maintaining the world's species diversity, any discussion of biodiversity must include forests.

2.2 Forest invertebrate abundance and diversity

Despite our poor understanding of invertebrate species, some general patterns of world invertebrate distribution have been recognized. Most of the world's invertebrate species diversity is found in terrestrial environments and the greatest diversity occurs in the tropical forests, where five to ten times more invertebrate species occur than in temperate environments (Stork & Eggleton, 1992). In fact, the overall high levels of tropical forest species diversity are primarily due to the great diversity of invertebrates (Primack, 2000). An immense species diversity of invertebrates can occur in a single small forest patch (Grove &Stork,1999) or even in a single small habitat within a forest. For example, more than 4000 species of arthropods were collected from only 10 trees in Borneo (Stork, 1991) and 1200 species of beetle were collected from a single tree in Panama (Erwin, 1982). If estimates are correct, 90% of the world's species may be tropical forest insects (Primack, 2000).

Because of their generally small size and cryptic behavior, invertebrates often go unnoticed in forest communities. However, their abundance fully compensates for their small size and their biomass is usually greater than that of vertebrates (Dajoz,2000). Many studies have shown that insects account for the highest faunal biomass in forests, reaching several tons per hectare, compared to the few kilograms of mammals and birds (Dajoz, 2000)(Stork ,1988) examined the abundance of tropical forest invertebrates in Indonesia and estimates that one hectare of forest contains 42.5 million arthropods, of which 23.7 million live in the soil, 6.0 million in the litter, 0.1 million in the herbaceous layers, 0.5 million on tree trunks and 12.0

million live in the canopy. A study in a German oak and beech forest found that the abundance of winged insects is 4123 individuals per square meter, with a biomass of 14.321 kilograms per hectare (Dajoz,2000). Ants and termites are known to comprise as much as 25% of all animal biomass in the Amazon (Samways, 1993).

Forests are able to support such great abundance and species diversity largely due to their climate and structure. Forests are generally damp by nature and many terrestrial invertebrates are restricted to relatively moist areas and microhabitats (Brusca & Brusca, 1990). Indigenous forests are also very complex in structure and provide a vast range of microhabitats and a multitude of niches for invertebrates to exploit (Endrody-Younga, 1989). In particular, insect species diversity increases as the structural diversity of vegetation increases (Dajoz, 2000). The high diversity of plant species in forests also encourages a high number of invertebrate species because the diversity of one group of organisms can promote the diversity of associated groups (Purvis & Hector, 2000). Further, forests are relatively stable environments and climatic variations in forests are usually low and predictable, offering opportunities for specialized invertebrate species that cannot tolerate climatic or resource fluctuations (Dajoz, 2000).

Tropical forests contain more diversity than any other environment and most of the species are invertebrates. However, no complete inventory exists of forest invertebrate fauna (Dajoz, 2000). It is not surprising that many invertebrate forest species are unknown to science, as few insect and other arthropod species sampled in tropical forests can be found in existing collections or in the world’s literature (Raven, 1988; Stork, 1997). This is in contrast to temperate environments where it is quite unusual to find a new species of invertebrate (Stork, 1997). Due to the alarming rate of forest destruction, it is vital that forest species, especially invertebrates, are catalogued immediately (Erwin, 1988).

2.3 Invertebrates Distribution

Biogeography can be defined simply as the branch of science concerned with plants and animals and their patterns of distribution (Meadows, 1985).By examining the distributions of organisms, scientists can (1) identify affinities between different areas;(2) determine the processes that influence distribution;(3) model historical changes in distributions ;(4)locate areas where diversity ,endemism or relict faunas are concentrated and (5) develop theories to explain colonization and extinction of species(Meadows,1985;Burgess et al.,1998).

2.4The importance of studying forest invertebrates

The diversity of forest invertebrates is so vast and unique that it alone warrants their study. However, there are many additional reasons why forest invertebrates are useful subjects for research. These include their roles in ecosystems, their specialization, vulnerability to extinction and potential as environmental indicators.

Invertebrates play vital roles in the functioning of forest ecosystems. Some of these roles include:

1) Herbivory: Herbivory (eating plant material) by animals, including invertebrates, influences the structure and composition of vegetation (Burley, 2002). Invertebrates consume flowers, fruits, foliage and seeds, which affects the population dynamics, dispersal and regeneration of trees (Dajoz, 2000; Burley, 2002; Armstrong, 2002).

2) Predation: Predators and parasitoids regulate populations and keep outbreaks of pest species in check (Dajoz, 2000; Burley, 2002). For example, parasitoids in the genus *Aphytis* prey upon diaspidid scale insects that otherwise can over-exploit and completely destroy their plant resources (Samways, 1993)

3) Pollination: Pollination of plants by invertebrates and other animals is crucial to the functioning of ecosystems, including forests, and the perpetuation of food webs (Kevan, 1999; Black *et al.*,2001). Insects are the main pollinators in tropical forests, where wind pollination is rare (Dajoz, 2000).

4) Soil maintenance: Invertebrates are vital components of forest soils and can determine their productivity by enhancing microbial activity, accelerating decomposition, regulating the intensity of carbon and mineral recycling and mediating transport processes (Brown, 1991; Stork & Eggleton, 1992). Insects, worms, mites and other detritivores break down organic waste materials and release it as minerals usable to plants and other organisms (Primack, 2000; Black *et al.*, 2001).

Many forest invertebrates are highly specialized and local and regional endemism is common. Many invertebrate genera and species are confined to the forest biome or are totally dependent upon forests for at least one stage of their lives (Geldenhuys & MacDevette, 1989). Many species of invertebrates are very specific in the resources that they exploit, such as feeding upon a single species of plant (Geldenhuys, 1993) or even on a particular part of a certain plant species, and others have very precise habitat requirements (Kirby, 1992). In some forests, entire invertebrate communities may be dependent upon water-filled tree cavities, for example (McComb & Lindenmayer, 1999). Such specialization allows whole invertebrate populations to be sustained by small areas and relatively few resources (New, 1998).

Many forest invertebrate species and groups are vulnerable to extinction. According to(Primack ,2000), ecologists have recognized 14 specific categories of species that are particularly susceptible to extinction and must be carefully monitored and conserved. The following is a list of these categories that apply to many forest invertebrate groups:

1) Species with narrow geographical ranges.

2) Species with only one or a few populations.

3) Species that are not effective dispersers.

4) Species with specialized niche requirements.

5) Species that are characteristically found in stable environments.

6) Species that form permanent or temporary aggregations.

Because at least six of the 14 recognized categories pertain to many forest invertebrate groups, such species must be considered to be at great risk of extinction.

Invertebrates are useful as indicators of environmental change and habitat disturbance due to a variety of characteristics. Many invertebrates have very limited powers of dispersal (Kirby, 1992) and cannot move easily to new areas when conditions are altered. Invertebrates often have very specialized diets, habits or habitat requirements that may vary according to life stage (Moore, 1991) and any alteration in the environment that affects these needs will be reflected in changes in invertebrate populations. In addition, most invertebrates have annual life cycles or even have two or more generations in a year and specific conditions must be present each and every year to successfully breed (Kirby, 1992). All of these factors cause invertebrates to be much more sensitive to habitat change than most plants or vertebrates (Desender *etal.*, 1991; Kirby,1992;Kotze&Samways, 1999a). This sensitivity is compounded by the fact that invertebrates, particularly insects, can have complex life cycles and each different stage may have different habitat requirements (Kirby,1992). Further, invertebrates are usually small and spend much of their lives in a specific microhabitat and microclimate (Kirby, 1992). As a result, problems in conservation are often first seen in invertebrates

(Dempster, 1991), even minor habitat disturbance or climate change can prove to be significant (Kirby,1992) and invertebrates can alert humans to larger or growing environmental issues.

3. MATERIALS AND METHOD

3.1 Descriptions of the study area

Gullele Botanical Garden(GBG), the first of its kind in the horn of Africa, was officially established on July 7th 2010 by Addis Ababa city proclamation 18/2005 E.C. The forest of Gullele,on the northern edge of the city was selected for the benefits associated with the location .The area has significant environmental value because it lies on both the upper urban watershed for Akaki River and expanse of the metropolitan area .The conservation area is projected to be an economically competitive alternative to urban expansion and serve as a destination for ecotourism . The social impacts of the project are expected to take many forms including educational outreach ,public works projects and the establishment of the gardens as a center for research . To prioritize future goals and objectives for the area ,the government of Addis Ababa agreed on the following four mandates , for GBG:(1)Native Species Conservation, (2)Education ,(3)Ecotourism, and (4)Research .To realize these mandates ,the gardens must identify existing natural resources and adapt best conservation management practices to their needs and capacity .

The Entoto Mountain range in Addis Ababa dictates the elevation gradient of Gullele and influences a sharp increase in precipitation supporting the forest along the northern rim of the capital city .The forest of Gullele has a reputation for containing historically significant trees in the city , which is part of the motivation to preserve the location .The gardens are comprised of 621 hectares of conservation forest and approximately 100 hectares of cultivated gardens ,which are located on the northern periphery of the capital city Addis Ababa. The southern boundary of the gardens is located at 9.1degreeS, and 9.06 degree N, 38.74 degree E, and 38.7 degree W make up the extent of the boundary from north, east, and west, respectively .The dry evergreen afro-moutane forest is dominated by *E. globulus* .An assortment of native species and *E. globulus* forest is present throughout the elevation range of the garden between 2,538 -2,890 meter above sea level . The area is topographically diverse given the extent; slopes in the garden range from 0 to 40 degree with a mean of 11.7 degree. The conservation area contributes to the headwaters of the Akaki River, which transects Addis Ababa from north to south .The northern hills of the region receives 1,196 mm of precipitation annually with an average temperature of 15.9 degreeC. Historically ,seasonal precipitation is bimodal with a short rainy season beginning in March and ending before June .The long rainy season is present from June to mid-September (World clim

,2009).The remaining six months constitute only 16% of total annual rainfall (Conway et al. ,2004).

The flora of Ethiopia is estimated to include about 6000 species of higher plants with 10-12% endemism, but these are now in the verge of needing forever due to deforestation, overgrazing, soil erosion, desertification and others (Sebsebe Demissew, 1988).There are diverse approaches to conserve threatened and endangered species, thus Botanic Gardens can play a crucial role in complementing in-situ conservation besides of its various roles such as recreation, education and research. Botanic Gardens assemble and maintain a diversity of plant species, in the open, in glasshouse and for reference and study, in herbaria (Birhanu Belay, 2009).

Location: - The Gullele Botanic Garden is located at the north western part of Addis Ababa city administration. It belongs to the central plateau of Ethiopia, which shares its vegetation zone and climatic characteristics with adjacent part of Oromia National Regional state. The geographical co-ordinate of the garden lies between latitude 80 55' N and 90 05' N and longitudes 380 05' E and 390 05' E. The Botanical Garden covers a total area of 936 hectare, from this 736 is in Addis Ababa city administration whereas the remaining 200 hectare is found in Oromia administrative region. It has two topographic landscapes units or physiographic features. The northern half is a plain land; the southern half is mountainous with the maximum elevations of 2960 m above sea level. The two perennial watercourses originate from this mountainous area and flow down to the town. The garden is also characterized by many smaller rivers which flow through the town seasonally (Ensermu Kelbessa, 2005).

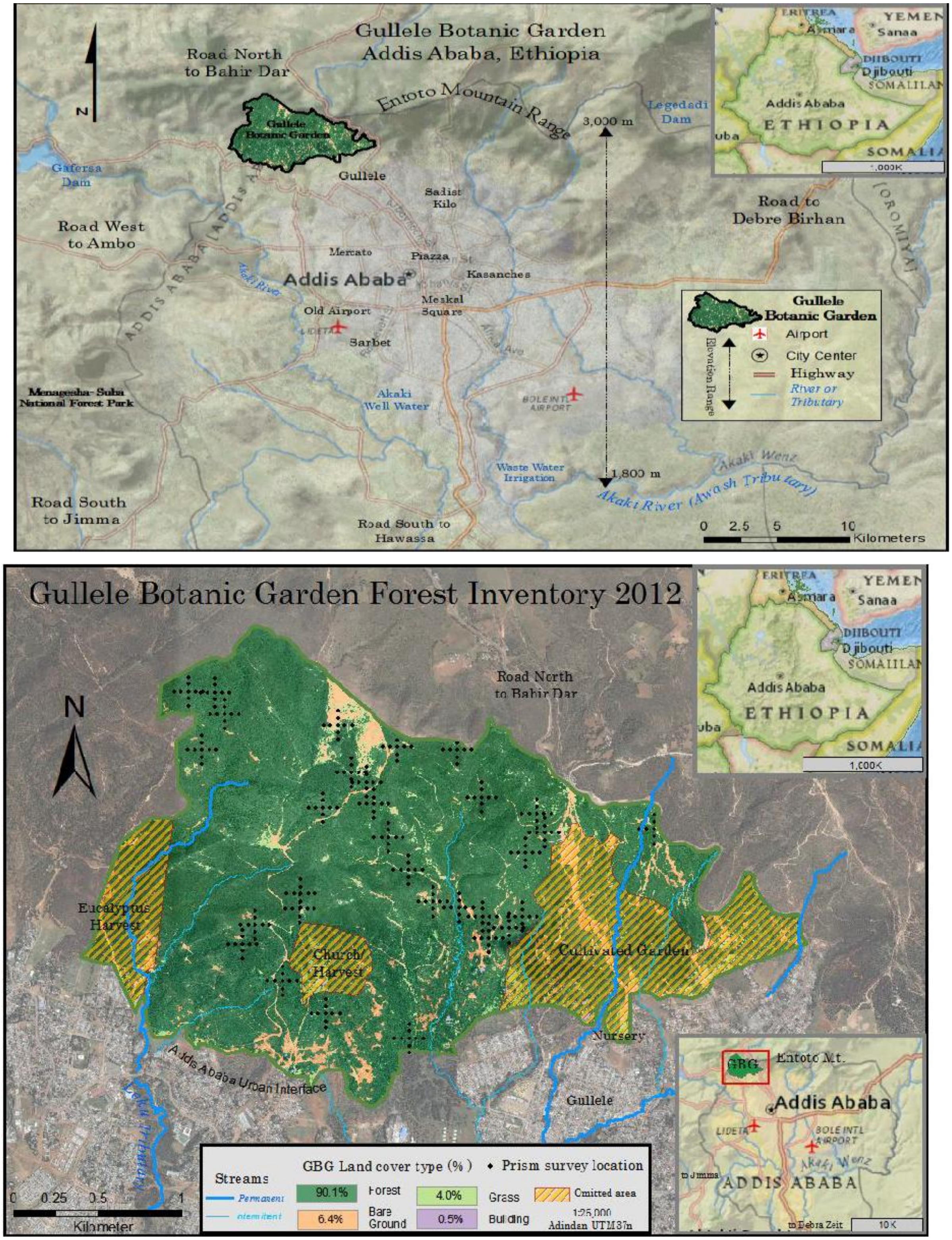

Figure 1. Map of the study area (After.Reeder, 2013).

3.2 Climate and vegetation (Flora)

Climate: **-** The rainfall and the temperature condition of the area were described based on the data collected from 1993-2006 by the Ethiopian Meteorological Service Agency (EMSA) from Entoto station. According to the data from EMSA, the result of the analysis showed that the mean annual temperature of the study area is about 13.4C^0. The range of mean monthly minimum and maximum temperatures of the study area is 7.5C^0 and 20.7C^0 in December and February, respectively. The mean annual minimum and maximum temperature is 8.4C^0 and 18.4C^0, respectively. The hottest month is February with maximum temperature of 20.7C^0, followed by March (20.2C^0) and May (20C^0) and the coldest month is December with minimum temperatures of 7.5C^0. The mean annual rainfall of the area is 1215.4 mm per year and is bimodal type. The mean monthly minimum and maximum rainfall is 16.6 mm (January) and 278 mm (August), respectively. The short rainy season extends from March to May and the long rainy season starts from July and extends to September, but unexpected showers may occur in all months of the year (Birhanu Belay, 2009).

Vegetation (Flora): - The Gullele Botanical Garden is mostly covered by *Eucalyptus globulus*tree species, but the land closer to the river banks and inaccessible areas arecovered by more than 250 trees, shrubs, herbs, climbers, ferns and other plant species.

From this there are also some endemic and endangered plant species. Some of the dominant indigenous woody species in the project site are *Juniperus procera, Hypericumrevolution, Olinia rechetiana, Myrsine melanophleos, Myrsine africana* and *Ericaaraborea.*

3.3 Selection of the study site

Sampling sites from Gullele Botanic Garden were systematically selected (Birhanu Belay, 2009). The study area was divided into different sections based on the transect line. These techniques involved dividing the study site into different habitats (Tamrat Aydagnhum, 2007; Tayyab *et al*., 2006). The study area was divided into 28 transects, starting at the edge of the road from the bottom (Sansuzi) to the upper (Fitesha of Gojam-ber). The distance between two successive transects and plots was 50m and 100m , respectively. The number of quadrats were 28 (2m by 10m) which cover a total area of 0.6 hectares. The quadrats were laid on different habitats, such as natural forests, artificial forests, grasslands, and mixed forests.

Seven quadrats were laid on each habitat type and invertebrate collection was done on each habitats.

Figure.2.Plate showing laying of quadrats.

3.4 Invertebrate data collection techniques

The species diversity, composition, distribution and abundance of Gullele Botanical Garden was investigated on systematically selected sampling units of each habitat type (natural forests, artificial forests, grasslands and mixed forests) in the study area. The data was collected and recorded on note book through a series of field works exclusively during the high rainfall when invertebrates were active by using quadrat method, aspirators, forceps collection, sweep nets, soil and litter extraction, modified Berlese funnel and beating cloth(umbrella). The study was conducted for 21 days in the wet season in 2019.

3.4.1 Using quadrat sampling

Soil-dwelling invertebrates were collected through active searching of standard sized quadrats. Quadrat sites were selected according to systematic method. Each quadrat was two by ten meters and all quadrats were subdivided into five two by two meter plots.

3.4.2 Using aspirator

Aspirator wasused to collect small and non-flying insects in their habitats. Therefore, the researcher collected the named invertebrates using this tool.

3.4.3 Forceps collection

Forceps collection was one of invertebrate collecting tool used by invertebrate zoologist to collect spiders, millipedes, centipedes, grasshoppers and land snails for further study. Therefore, the researcher used this tool and collected the named invertebrates and other invertebrates which were put in killing jar were with sponge soaked in chloroform (Tanaka and Tanaka, 1982).

3.4.4 Using sweep nets

Sweep net was one of the most important pieces of equipment an insect collector should have (Bekele Jembere et al., 2006). Active and flying insects were collected using sweep net. Investigator collected samples by sweepingnets within each quadrat. After sweeping, the contents of the net were emptied into killing bottle (jar) with chloroform soaked sponge in it (Tanaka and Tanaka, 1982). The killing bottlewas kept clean and invertebrates were removed as soon as they died. Moth and butterflies were killed separately to avoid them contaminating other invertebrates with their scales.

3.4.5 Soil and litter extraction

Soil and litter-dwelling invertebrates were best collected together with the soil and litter in which they were found in the field (Bekele Jembere et al., 2006). Hence, investigator collected soil and litter-dwelling invertebrates from each habitat type of the study area. Then, the extracted invertebrates from the soil and litter later in the laboratory were done by using the modified Berlese funnels.

Figure 3:-Modified Berlese Funnel.

3.4.6 Using beating cloth (umbrella)

A beating cloth or beating umbrella was placed beneath vegetation. The vegetation was then shaken or beaten with a stick. Invertebrates dislodged from the bush or shrub fall on the beating cloth and can be collected (Bekele Jembere et al., 2006).

Figure 4:-Beating umbrella collection (Shoma ,2019).

Finally, the collected invertebrates were taken to Addis Ababa University, Zoology Laboratory to be preserved and stored (in preserving bottle), sorted, counted and placed into various taxa with the help of binocular microscope. All the invertebrates wereidentified to order level and then to the family level using identification tools.The preserved samples were deposited in the Zoology Laboratory.

3.5 Data analysis

Data analysis was done using quantitative and qualitative methods. This means that invertebrate's diversity which needed numberwas analyzed by using quantitative method. On the other hand, invertebrate diversity which did not need number was analyzed by using qualitative method. So, the researcher used the following indexes to measure invertebrate diversity.

- **The Shannon-weaver index (H')** is the most commonly used measure for diversity and it is defined as H' = - (pi) (lnpi), where pi is the proportion of ith species in the total sample (pi= ni/N). A species with higher value of H' is more diverse than species with lower value of H'. This indicates that, in a low diversity a community of one or two species will be more abundant than others, in diversesituation a few species cannot be very dominant. More number of species and greater evenness increases the diversity of insects (Afzan *et al*., 2006).

- **Evenness (j)** can be estimated by using the formula J=H/Hmax= lnS, where S is the number of families present. Evenness from calculation would be larger for large J value. This Means insect with larger J value has more even distribution (Price, 1976; Smith, 1992).
- **Simpsons diversity index (D)** is a measure of diversity and often used to quantify the diversity of insect habitats. It takes into account the number of species present and the abundance of each species (D= 1- (Pi) 2), where 1 is probability of picking two individual of the same species. ü (Pi)2 = (Pi)(Pi) ü D is Simpsons' index of diversity ü Pi is proportions of families in the sample (community) Invertebrates abundance, frequency, distribution and density were estimated by the following formulae.

Family abundance (the ratio between total number of individuals of a family in all study plots and total number of sampling units in which the family observed),

Frequency (F) is the ratio of quadrats of occurrence and total number of quadrats studied. Families having a high frequency value are a widely distributed family through the study area; the same is not necessarily true for a high abundance value.

Relative frequency (RF) =frequency of species A*100/total frequency of all.

Distribution (Di)is the ratio between abundance and frequency.

Density of families (D) is the number of that families /area sampled. It is closely related to abundance, but more important in estimating of the number of families.

Relative density (RD) = density of family A*100/total density of all families.

The similarity of invertebrates in different habitats will be determined by: Jaccard's index (Cj) = j / (a+b-j) Where, j = the number of families found in both sites.
a = the number of families infirst site.
b = the number of families in second site.
The Jaccard's Index is equal to zero for two sites that are completely dissimilar. One indicates that two sites are completely similar.

4. RESULTS

4.1 Comparison of mean number of invertebrates per habitats

A total of 2854 invertebrates were collected in which mixed forest habitat was more populated habitatwith mean number of (70) than natural forest habitat(61), artificial forest habitat (48) and grassland forest habitat (25).Mixed forest habitat is the most susceptible hostfor invertebrates with mean number of (70), but natural forest habitat, artificial forest habitat andgrassland forest habitat are relatively less susceptible for invertebrates with means of (61),(48) and (25) invertebrates, respectively. So, invertebrate population significantly differs in allhabitats (Table 1).

Table-1: *Mean Abundance of Invertebrate per Habitats*

Habitat types	Mean abundance of invertebrates
Natural	61
Mixed	70
Grass land	25
Artificial	48

4.2 Invertebrates composition in Gullele Botanic Garden

Table 2 shows the percentage compositions of invertebrates in Gullele Botanic Garden. Fromthe total of 2854 (Appendix 3) invertebrates species collected, 14 orders were identified inGullele Botanic Garden. Invertebrates in the Order Hymenoptera are the most dominant 1601(56.1%) followed by order Orthoptera which contain 366 (12.8%), Order Diptera 226(7.9%), Order Areanae 207 (7.3%) Order Blattodea 144 (5.4%),Order Hirudinida73 (2.56%)… and the smallest ones is order Geophilomorpha with 15 (0.53%). Therein, orders like Polydesmida and Geophilomorpha are vulnerable and in need of conservation.

Table 2. The percentage composition of invertebrates by order in Gullele Botanic Garden

Order	No. of individuals	% composition
Diptera	226	7.9
Hymenoptera	1601	56.1
Lepidotera	38	1.3
Orthoptera	366	12.8
Areanae	207	7.3
Haplotaxida	29	1.01
Stylomaatophora	22	0.77
Geophilomorpha	15	0.53
Polydesmida	17	0.59
Odonata	47	1.65
Mantodea	44	1.54
Blattodea	144	5.04
Coleoptera	25	0.88
Hirudinida	73	2.56
Total	2854	100

From the totals of 42invertebrates families collected (Table 3), invertebratesin Areanae order contained the largest number of families 11 (26.2%). The secondposition of the family numbers was also occupied by Blattodea 6 (14.3%). The third positions were occupied by Lepidoptera and Coleoptera withnumbers and percentages of 4 (9.5%) each. The fifthposition was held by Odonata and Hirudinida with similar number andpercentage of 3 (7.1%) each. The seventh position were held by Diptera, Hymenoptera, and Geophilomorpha with similar number and percentage 2(4.8%) each.The least number of families were also occupied by Orthoptera, Stylomaatomorpha, Polydesmida and Haplotoxidawith similar number and percentage of 1 (2.4%) each.

Table 3. Number and percentage of invertebrates families examined in each invertebrates order during the study

Invertebrate Order	No. of Families	% composition of invertebrate Families
Diptera	2	4.8
Hymenoptera	2	4.8
Lepidotera	4	9.5
Orthoptera	1	2.4
Areanae	11	26.2
Haplotaxida	1	2.4
Stylomaatophora	1	2.4
Geophilomorpha	2	4.8
Polydesmida	1	2.4
Odonata	3	7.1
Mantodea	1	2.4
Blattodea	6	14.3
Coleoptera	4	9.5
Hirudinida	3	7.1
Total	42	100

4.3 Frequency, abundance, distribution and density of invertebrates in GulleleBotanic Garden

Appendix 1 shows the frequency, abundance, distribution, percentagecomposition and density of invertebrates in Gullele Botanic Garden. From a total of 2854invertebrates collected, 42invertebrate'sfamilies were identified in Gullele Botanic Garden whichbelongs to 14 orders. Formicidae is the most dominant frequently occurring and distributed family with 1568(54.8%) individuals followed by Acrididae having 366(12.8%) individuals, Muscidae 181 (6.3%), Culicidae 45(1.57%), Mantidae 44(1.5%), Apidae 33(1.15%), Lumbricidae 29 (1.01%), Glossiploidae 28(0.98%)…and Saturniidae, Trogossitidae and Lithobiidae had the smallest families with 5 (0.17%) each.

Appendix 1 shows the invertebratefamilies, such as Formicidae, Acrididae,Mucidae, Culicidae, Mantidae and Apidae had the highestvalues of frequency, abundance, distribution and density in the study area. So, they werethe most dominant, frequently occurring and distributed family in Gullele BotanicGarden. On the other hand, Lithobiidae, Trogossitidae and Saturniidae had the least valuesof frequency, abundance, distribution and density in the study area. So, they were thesmallest dominant, frequently occurring and distributed family in Gullele BotanicGarden. Consequently, Lithobiidae, Trogossitidae and Saturniidae need conservation.

4.4 Diversity of invertebrates in Gullele Botanic Garden at different habitats

Invertebratediversity in Gullele Botanic Garden is shown in Table 4. The highest diversity ofinvertebrates in Gullele Botanic Garden was observed in the mixed forest (Plate1C) inthe wet season. The second was artificial forest habitat (Plate1D), the third was natural forest habitat (Plate 1A) and the fourth was grassland forest habitat (Plate1B). Totally, themost even distribution of invertebrates in the study season was that of the mixed forest habitat.Simpsons diversity index (D) showed that the presence of highest and least diversity ofinvertebrate habitats at mixed forest habitat and Grassland forest habitat, respectively. Here, although the results of Shannon-weaver index, Evenness and Simpsons diversity index shown almost at medium level ; mixed forest,artificial forest and natural forest habitats in general and grassland forest habitat in particular need conservation.

Table 4.Invertebratediversity in Gullele Botanic Garden in different habitats

Habitat type	Number of individuals	$H^{'}$	$H^{'}$/Hmax	D
Natural	859	1.815	0.486	0.65
Grass land	356	1.813	0.485	0.61
Mixed	971	1.831	0.491	0.69
Artificial	675	1.827	0.489	0.67

Note: - H’= Shannon Wiener Index of diversity

H’/H max = Evenness.

D = Simpson’s diversity index

4.5 Similarity and difference in invertebrates' species richness at GulleleBotanic Garden

Similarity and difference in distribution of invertebrates in Gullele Botanic Garden is shown inTable 5. In the wet season, the most similar habitats of Gullele Botanic Garden were found betweennatural forest habitat and grassland forest habitat, whereas the most difference habitatswere found between mixed forest habitat and artificial forest habitats. On the other hand,the second, the third, the fourth and the fifth rank similarity of invertebrates distribution inGullele Botanic Garden was occupied by grassland forest habitat and artificial forest habitat,natural forest habitat and mixed forest habitat, natural forest habitat and artificial forest habitat and grassland forest habitat and mixed forest habitats, respectively.

Table 5. Similarity and differences in distribution of invertebrates in Gullele Botanic Garden

Jaccard's similarity index				
Comparison(a*b)	J	a	B	j/(a+b-j)
Natural*Grass land	29	32	29	0.91
Natural*Mixed	30	32	40	0.71
Natural*Artificial	29	32	39	0.69
Grass land *Mixed	27	29	40	0.64
Grass land*Artificial	29	29	39	0.74
Mixed*Artificial	29	40	39	0.58

High values indicate high similarity in distribution of invertebrates.

Note: j = the number of families found in both sites.

a = the number of families in first site.

b = the number of families insecond site.

*=between.

5. DISCUSSION

In the wet season of Gullele Botanic Garden high diversity and evenness of invertebrates were observed in all forest habitats due to stability and easy availability of food. It is generally accepted fact that the most species breed when the amount offood in nature is at its peak (Tov, 1974). The stability of food resources for herbivores invertebrates varies temporarily and specially (Pfadt, 1962). For example, aging of leaves is a major determinant of food resources available to leaf eating invertebrates. Many studies have shown that leaf eating invertebrates are restricted in their feeding to a certain- age class of leaves.

Several study of tropical invertebrates seasonality have suggested as the increases in number of invertebrate in wet season, are primarily caused by increased precipitation. The precipitation has, therefore, initiated enormous amount of grass in habitats. This is as a result of increased phytophagous insects (Tamrat Aydagnhum, 2007).

Diversity of invertebratesin an area depends primarily on the availability of mixedplant species, which constitute their major food resources. Heterogeneity of the habitat is the main reason for species richness in Gullele Botanic Garden. As indicated by Tewet al.,(2004) , structurally complex habitats may provide moreniches and diverse ways of exploiting the environmental resources and thusincrease species diversity. In most habitats, plant communities determine thephysical structure of the environment, and therefore, have a considerableinfluence on the distributions and interactions of animal species).Generally, rainfall, human activities, environmental factors and food playedgreat roles in the distribution, density, abundance and habitat association ofinvertebrates in Gullele Botanic Garden.

During data collection in Gullele Botanic Garden, carefully observationshowed that invertebrateshad both positive (Appendix5A-B) and negative (Appendix 4A-C)impactson humans, plants, animals and invertebrates. Invertebrates can increase soilfertility (Appendix 5A) bydigging the ground and with their waste materials.Invertebrates have several functions in the ecosystem. For example, ants areabundant invertebrates, a large component of the arthropod community on ground inforest ecosystems (Sakchoowong et al., 2008) and are considered important inecosystem functioning. They have diverse ecological roles, including nutrientcycling (Graham et al., 2004; Fergnani et al., 2008). By burying dung andcarrion as food to their offspring, dung beetles may also increase the rate ofsoil nutrient cycling (Vinod et al., 2007).

On the other hand, invertebratesin the Gullele Botanic Garden can facilitate theprocess of cross pollination, for plants which had no capability of self-pollination.Butterflies are one of the groups playing a central rolein numerous ecosystem processes as pollinators (Hawes et al., 2009). Theflower most frequently visited by insects and partially dependent on them forseed-set. Pollinations of the most common plants are primarily by flies, butbumble bees are also important (Metcalf and Flint, 1979).(Hill, 1997) studiedabout beneficial invertebrates for the purpose of pollination, apiculture (honey bee),sericulture (moth), and invertebrates farming (butterflies).(Daly et al ,1998) stated thatflies are common visitors to flowers, which provide the only food for adults ofsome families (e.g.Bombyliidae, Conopidae, Acroceridae, and Apioceridae).However few Diptera have engaged in the intimate type of symbioticrelationship displayed by the angiosperm plants and hymenoptera, and fliesappear to be of sporadic important in pollination.

The feeding relationships of invertebrateswere different in different living habitats.Some invertebrateswere predators (mantids) and others were also prey. So thisfeeding relationship created a constant balance of invertebrates' populations in theBotanic Garden. The carnivorous invertebrates feed on other invertebrates and are said tobe Entomophagous (Connahs et al., 2009). Snails, earth-worms, millipedes,mites and other terrestrial and fresh water invertebrates are also eaten byinvertebrates. The victims are called prey if killed directly, host if fed upon while stillliving. Entomophagous insects are divided into three major groups: predators,parasitoids and parasites (Daly et al., 1998; Ehrlick, 1978). Lepidoptera larvaerepresent an important food source for a variety of predators, including ants, spiders, birds and small mammals (Steward et al., 1988).

Some of the invertebrateswhich were found in the Garden showed the environmentalcleanness of the Garden. Species of butterflies and bees were the bestindicators of environmental cleanness. Invertebrateshave been used as indicators ofbio-diversity and endemism, prioritization for establishment of protected areas,bio-geographic relationships and bio-indicators of anthropogenic changes inthe forest and water quality (Schuster and Cano, 2006). Invertebrates are goodindicators of the impact of large herbivore and human included change inforest habitats (Vinod and Sabu, 2007).

Honey bee produces wild honey and wax which are very important for humanfood and other purposes. African bee is the superior foragerand gives high yields of honey. The bee collects nectar, pollen and water as their foodstuffs and any excess to their daily requirement is stored in thecells for later use. Honey's main commercial use is for sweet a wide variety offoods (Hill, 1997). Honey is produced from natural hole in a cliff.

On the other hand, invertebrateshad negative effects for both human and animalspecies. Some species of invertebrates, such as bees, wasp, ant and termite had a painful sting for both human and animal species(Appendix4A). The African bee is native to East Africa and it is responsible for many cases of unprovoked attack on people and(sometimes livestock): people have been stung to death (Hill, 1997). Most ofthe phytophagous (herbivorous) invertebrates were the major cause for plant dryingby feeding both the external and internal parts of the plant (Appendix4B).Some species of the invertebrates also decreased the quality of external appearanceof plant by the process of eating, defecation and laying their eggs on the parts of the plants. Invertebrates that feed on green plants (phytophagous invertebrates) attackroots, trunks, stems, twigs, leaves, flowers, seeds, fruits, and sap in the vascular system. Invertebrateseither feed externally by chewing tissue or by sucking sap orcell contents, or they feed internally by boring into the plant tissues.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- The presence of 42 families in Gullele Botanic Garden revealed the importance of these areas as good habitats for invertebrates.
- Out of the total invertebrate families, Formicidae had the highest frequency, whereas Lithobiidae, Trogossitidae and Saturniidae had the least frequency in the Garden. Therefore, the later three families need conservation more than others.
- The Highest diversity and evenness of invertebrates were found in mixed forest habitat in Gullele Botanic Garden. This was due to less exposure of these habitats to humans and animals' activity and availability of food.
- On the other hand, less diversity and evenness of invertebrates in Gullele Botanic Garden was observed in grassland forest habitat. The reasons were the intensive interference of human to root out grasses from another place and transfer to the degraded areas of the study habitat and the absence of food (plant diversity) in the area. These areas were only dominated by Monophagous invertebrates. Therein, this habitat type needs conservation more than other habitats.
- Invertebrate population significantly differs in all habitats. The reason was because of mean difference.Therein, mixed forest habitat was the most suitable host for invertebrates with mean number of 70,but natural forest,artificial forest, and grassland forest habitats were relatively less suitable host for invertebrates.
- Based on Jaccard's similarity index, natural forest habitat and grassland forest habitat showed highest similarity in the study season. The reason behind the similarity was the presence of grass in these sites which is the main food stuff of phytophagous invertebrates.
- Generally, the study area has an appreciable diversity of invertebrates.
- During data collection in Gullele Botanic Garden, careful observation of the study area showed that invertebrates had both positive and negative effects for humans, plants and animals. The positive effects were increasing soil fertility(earthworm),nutrient cycling(ant),increasing the rate of soil nutrient cycling (beetles),facilitating the rate of cross pollination(beesand moths),indicators of environmental change and habitat disturbance(insects) and environmental cleanness(butterflies and bees).On the other hand, the negative effects were plant drying(termites),decreasing the qualities of plants(phytophagous insects),attacking

roots, stems ,leaves, flowers, seeds, fruits and saps in vascular system(phytophagous invertebrates).

6.2 Recommendations

Generally the results of the study in Gullele Botanic Garden indicate the needof the following recommendations:

- In the study area, the most diverse invertebrates were located in mixed forests habitat, which are highly protected to human activities and animal grazing. So, to keep up the diversity, all habitats in the garden should be well protected from high human interferences.
- This study identified 42 families of invertebrates in Gullele Botanic Garden at all habitats. This does not mean that these families are the only ones in the study areas. Because, this study did not include first the smallest sized, immature stage and nocturnal invertebrates. Second plant specific invertebrates' diversity study to determine which plant is most suitable host for invertebrates was not done, so further study should be conducted to fill these gaps.
- All Gullele Botanic Garden habitats are rich in other vertebrate species such as mammals, amphibians, reptiles, birds and invertebrates like nematodes and other arthropods.
- On the other hand, these habitats have also got appreciable diversity of plants. Therefore, a multidisciplinary approach is needed to conserve the biota. Generally the well conservations of plants increase the diversity of invertebrates because plants are the main source of food for invertebrates.
- As any organism, invertebrates distribute themselves in areas of suitable climatic conditions,where sufficient food for survival and reproduction is available area. Therefore, critical action should be taken to stabilize disturbed habitats especially in the grassland forest of stud**y.**

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8. APPENDICES

Appendix 1- Frequency, Abundance, Density and Distribution of insects in Gullele Botanic Garden (NI=number of individual, A=abundance, F= frequency, Di=distribution, RF=relative frequency, D=density, RD=relative density).

Family name	NI	A	F	Di	RF	D	RD
Muscidae	181	6.5	1	6.5	5.6	646.4	6.29
Apidae	33	1.2	0.57	2.1	3.2	117.8	1.15
Piedidae	20	0.70	0.43	1.65	2.4	71.4	0.69
Acrididae	366	13.1	0.96	13.6	5.4	1307.1	12.73
Theraphosidae	19	0.68	0.57	1.19	3.2	67.8	0.66
Pholcidae	19	0.68	0.57	1.19	3.2	67.8	0.66
Popilidae	19	0.68	0.57	1.19	3.2	67.8	0.66
Thomisidae	19	0.68	0.57	1.19	3.2	67.8	0.66
Salticidae	19	0.68	0.57	1.19	3.2	67.8	0.66
Gnaphsidae	20	0.71	0.60	1.18	3.4	71.4	0.69
Therididae	19	0.68	0.57	1.19	3.2	67.8	0.66
Liphostidae	19	0.68	0.57	1.19	3.2	67.8	0.66
Pisauridae	19	0.68	0.57	1.19	3.2	67.8	0.66
Phalangiidae	17	0.61	0.36	1.36	2.01	60.7	0.59
Miturgidae	14	0.5	0.5	1	2.8	50	0.49
Lumbricidae	29	1.04	0.57	1.82	3.2	103.6	0.01
Formicidae	1568	56	0.96	58.3	5.4	5600	54.52
Culicidae	45	1.61	0.17	9.47	0.95	160.7	1.56
Achatinidae	22	0.79	0.46	1.7	2.6	78.6	0.76
Oryidae	10	0.36	0.36	1.69	2.01	35.7	0.35
Lithobiidae	5	0.18	0.17	1.05	0.95	17.8	0.17
Anthroleucosmatidae	17	0.61	0.53	1.15	3.0	60.7	0.59
Aeshnidae	17	0.61	0.53	1.18	3.0	60.7	0.59
Gomphidae	15	0.54	0.53	1.01	3.0	53.6	0.52
Libellulidae	15	0.54	0.53	1.01	3.0	53.6	0.52
Manthidae	44	1.57	0.60	2.6	3.4	157.1	1.53
Rhinoiermitidae	24	0.86	0.07	12.28	0.4	85.7	0.83

Hodotermitidae	24	0.86	0.07	12.28	0.4	85.7	0.83
Termopsidae	24	0.86	0.07	12.28	0.4	85.7	0.83
Termitidae	24	0.86	0.07	12.28	0.4	85.7	0.83
Termitoidae	24	0.86	0.07	12.28	0.4	85.7	0.83
Kalotermitidae	24	0.86	0.07	12.28	0.4	85.7	0.83
Scarabaeidae	7	0.25	0.25	1	1.4	25	0.24
Coccinellidae	7	0.25	0.21	1.19	1.18	25	0.24
Trogossitidae	5	0.18	0.18	1	1	17.8	0.17
Sphaeriusidae	6	0.21	0.21	1	1.18	21.4	0.21
Hirudinidae	22	0.79	0.43	1.83	2.4	78.6	0.77
Glossiploidae	28	1	0.46	2.17	2.6	100	0.97
Piscloidae	23	0.82	0.46	1.78	2.6	82.1	0.79
Sphingidae	7	0.25	0.25	1	1.4	25	0.24
Tineidae	6	0.21	0.21	1	1.18	21.4	0.21
Hedylidae	6	0.21	0.21	1	1.03	21.4	0.20
Saturniidae	5	0.18	0.18	1	1	17.8	0.17
Total	2854						

Appendix 2- The percentage composition of invertebrate families and their order in Gullele Botanic Garden

Invertebrate Family name	No. of individual	Order name	% composition of Invertebrate Family
Muscidae	181	Diptera	6.3
Apidae	33	Hymenoptera	1.15
Piedidae	20	Lepidoptera	0.7
Acrididae	366	Orthoptera	12.8
Theraphosidae	19	Areanae	0.66
Pholcidae	19	Areanae	0.66
Thomisidae	19	Areanae	0.66
Salticidae	19	Areanae	0.66
Gnaphsidae	20	Areanae	0.7
Therididae	19	Areanae	0.66

Liphostidae	19	Areanae	0.66
Pisauridae	19	Areanae	0.66
Phalangiidae	17	Areanae	0.59
Miturgidae	14	Areanae	0.49
Lumbricidae	29	Haptotoxida	1.01
Formicidae	1568	Hymenoptera	54.8
Culicidae	45	Diptera	1.57
Achatinidae	22	Stylommatophra	0.77
Oryidae	10	Geophilomorpha	0.35
Lithobiidae	5	Geophilomorpha	0.17
Anthrolucosmatidae	17	Polydesmida	0.59
Aeshnidae	17	Odonata	0.59
Gomphidae	15	Odonata	0.52
Libelluidae	15	Odonata	0.52
Mantidae	44	Mantidae	1.5
Rhinoiermitidae	24	Blattodea	0.84
Hodotermitidae	24	Blattodea	0.84
Kalotermitidea	24	Blattodea	0.84
Termitoidae	24	Blattodea	0.84
Scarabaeidae	7	Coleoptera	0.24
Coccinellidae	7	Coleoptera	0.24
Trogossitidae	5	Coleoptera	0.17
Sphaeriusidae	6	Coleoptera	0.21
Hirudinidae	22	Hirudinida	0.77
Glossiploidae	28	Hirudinida	0.98
Piscloidae	23	Hirudinida	0.80
Sphingidae	7	Lepidoptera	0.24
Tineidae	6	Lepidoptera	0.21
Saturniidae	5	Lepidoptera	0.17
Termopsidae	24	Blattodea	0.84
Popilidae	19	Areanae	0.66
Termitidae	24	Blattodea	0.84

Appendix3: Total number of invertebrates in each habitat during wet season.

NO.	Order name	Natural	Mixed	Grassland	Artificial	Total
		WS	WS	WS	WS	
1.	Haplotaxida	20	4	2	3	29
2.	Stylomatophora	12	4	4	2	22
3.	Mantodea	21	12	6	5	44
4.	Odonata	18	16	3	10	47
5.	Blattodea	0	72	0	72	144
6.	Hirudinida	51	6	6	10	73
7.	Orthoptera	68	77	172	49	366
8.	Coleoptera	17	4	2	2	25
9.	Hymenoptera	511	564	97	429	1601
10.	Diptera	40	146	21	19	226
11.	Lepidoptera	4	14	7	13	38
12.	Geophilomorpha	6	4	1	4	15
13.	Polydesmida	8	3	2	4	17
14.	Areanae	77	46	33	51	207
Total		853	972	356	673	2854
MA		61	70	25	48	204

Plate 1:- Different habitats of the study area (A=Natural forest habitat, B=Grassland forest habitat ,C=Mixed forest habitat and D=Artificial forest habitat.)

A. B.

C.

D.

Appendix 4:- Some identifieddamage ofinvertebrates of the study area(A=Ant destroying plants , B=Termites in drying plants and C= Inside settlement).

A.

B.

C.

Appendix 5:- Some identified positive effects of invertebrates of the study area(A=Earthworm facilitating soil fertility and B=Ants in facilitating nutrient cycling).

A.

B.

Appendix 6 The representative invertebrate families preserved and pinned in G.B.G in wet season.

A. Preserved

B. Pinned

Appendix 7: Researcher in collecting invertebrate samples from the study area(A=Forceps collection, B=Aspirator ,C=Butter fly net ,D=Sweep net, E=Soil extraction, F=Photo capturing and G=Modified Berlese funnel).

A. B.

C.D.

E. F.

G.

Appendix 8:-Researcher in killing invertebrate samples of the study area(A=Specimen soaked in 70% Ethanol).

Appendix 9:-Researcher in identifying invertebrate samples of the study area.

Appendix10:-Total lists of invertebrates collected, identified, preserved and pinned from GBG

No.	Common name	Order name	Total no. of family	Family name	Phylum name	Class name
1	Housefly	Diptera	2	Muscidae	Arthropoda	Insecta
2	Honeybee	Hymenoptera	2	Apidae		
3	Butterfly	Lepidoptera	2	Piedidae		
4	Grasshoppe r	Orthoptera	1	Acrididae		
5	Spider	Areanae	11		Myriopoda	Chelicerata
6				Theraphosidae		
7				Pholcidae		
8				Popilidae		
9				Thomisidae		
10				Salticidae		
11				Gnaphsidae		
12				Therididae		
13				Liphostidae		
14				Pisauridae		
15				Phalangiidae		
16				Miturgidae		
17	Earthworm	Haplotoxida	1		Annelida	Oligochaeta
18				Lumbricidae		
19	Ant	Hymenoptera		Formicidae	Arthropoda	Insecta
20	Mosquito	Diptera		Culicidae		
21	Snail	Stylomaatophor a	1	Achatinidae	Mollusca	Gasthropoda
22	Centiped	Geophilomorph a	2	Oryidae	Myriopoda	Chilopoda
23				Lithobiidae		
24	Milliped	Polydesmida	1			Diplopoda
25				Anthrolucosomatidae		
26	Dragonfly	Odonata	3	Aeshnidae	Arthropoda	Insecta
27				Gomphidae		
28				Libellulidae		
29	Mantids	Mantodea	1	Mantidae		
30	Termite	Blattodea	6	Rhinoiermitidae		
31				Hodotermitidae		
32				Termopsidae		
33				Kalotermitidae		
34				Termitidae		
35				Termitoidae		
36	Beetle	Coleoptera	4	Scarabaeidae		
37				Coccinellidae		
38				Trogossitidae		

39				Sphaeriusidae		
40	Leech	Hirudinida	3	Hirudinidae	Annelida	Clitellata
41				Glossiploidae		
42				Piscloidae		
43	Moth	Lepidoptera	3	Sphingidae	Arthropoda	Insecta
44				Tineidae		
45				Saturniidae		
Total	17	14	42	42	4	7

Appendix 11:-Habitat type and GPS Information of the study area

Quadrat no	Date	Time	GPS Information				Materials used to collect, identify ,&preserve	Chemicals , used to collect, identify ,&preserve	Methods ,used to collect, identify ,&preserve	Identified invertebrates from phylum to family				
			El	N	E	Note				phylum	Class	Order	Family	Common name
01.			2655	09042 4.3	03842 49	1203	-Killing jar -Forceps -Glove -Meter -VI lies -GPS -Digger -plastic zipper -sweep net -Cotton -Dissecting Tares	Chloroform Alcohol (70%)	-Soil &litter Extraction -Hand collection. -Sweep net. -Beating cloth.					-snail. -leech. -grasshopper -spider.
02.			2673	09042 4.9	03842 47.8	1205								-leech. -earthworm -spider. -Milliped.
03.			2679	09042 5.6	03842 47.1	1212								-leech. -snail. -grasshopper -spider.
04.			2689	09042 6.7	03842 46.2	1215								Millipede -earthworm -leech -ant.
05.			2687	09042 7.7	03842 46.2	1228								-earthworm -grasshopper -spider. -ant.
06.			2689	09042 8.4	03842 46.4	1233								-fly. -ant. -beetle -spider.
07.			2693	09043 0	03842 46.6	1244								Spider. -grasshopper -ant. -fly.