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Impact Assesment on an Invasive Species, *Lantana camara* on Indigenous Species Composition and Socio-economic Environment around Adama and Bishofitu Areas, Ethiopia.

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfilment of MastersDegree in Environmental Science.

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Abstract

Impact assessment of Lantana camara L. on indigenous species composition and socioeconomic environment was carried around Aroge Adama, Soloqe and Bishfitu areas, Ethiopia. Fifty-four 5m x 5m releve's were systematically sampled across 3 main transects laid 50m from the left side of the main road. In order to reduce the effects of human interference, the sites selected were, as much as possible, far away from the main road. The releve's were equally distributed for the three study sites. In each site equal number of releve's with & without Lantana camara were sampled from the same habitat types. All indigenous species in all non-invaded and along with Lantana camara in all invaded releve's were counted, identified & recorded. Diversity & richness was analyzed using Shannon-Weiner species diversity & richness index. Herbivory was found to be the most prevalent form of disturbance. ANOVA results at p<0.05 level of sig. showed that levels of disturbances were variable but are higher in the invaded releve's as compared to the non-invaded releve's. Independent sample t-test & one-way ANOVA showed significance difference at p<0.05 level. To asses invasion impact Spearman correlation coefficient was calculated for altitude, disturbance, density of Lantana and diversity of native plants. Disturbance and density of Lantana were highly correlated to diversity of native plants. ANOVA results showed significance difference in disturbance, density of Lantana and altitude in invaded releve's and only disturbance showed insignificance difference in the non-invaded releve's. The study revealed disturbance as the major factor, which facilitated the invasion of Lantana camara.

Different respondents have different views on its introduction & current status. Fifty six percent of them agree with its deliberate while 44% with its accidental introduction. Seventy-fourpercent of the key informants admitted the benefits obtained from it even though they maintained the disadvantage out-weighs its advantages. Thirty seven percent of the key informants responded as there are methods to minimize the detrimental effects & use it to improve biophysical & socioeconomic condition of the areas.

1. Introduction

The invasion of habitats by exotic species is a global phenomenon with ecological, economic and social consequences. This issue is expressed in published litrature on invasive species such as Williamson (1999); McNeely (2000); Witenberg *et al*., (2000); McNeely (2001), among others. (The 1996 UN conference on invasive species ranked these species second only to habitat distruction as a threat to species and biodiversity loss (UNEP, 2000b, 2000c; Katerina *et al*., 2004).

It is reported that the attributes of successful invaders, and the characteristics that make a community prone to invasion, are poorly understood and a global explanation for invasiveness may simply not exist. However (D'Antonio *et al*., 1992; Drake *et al*., 1989), life history traits that promote establishment of populations after disturbance, such as rapid germination and initial growth to be the means for the success of invasive species.

The attributes of a community in which species are introduced are important in determining the outcome of an invasion. Segrtain *et al*., (2004) and Annon, (2003) claim the outcome of an invasion to be influenced by both abiotic factors such as type and frequency of disturbance and biotic characteristics such as the abundance of natural enemies, competition and mutualism in the host community and propagule supply.

Williamson (1996), stated that non-indigenous species interact with indigenous species as well as previously established non-indigenous species. These interactions and abiotic factors determine the establishment success of new species. McNeely (2000), wrote that altered competitive interactions are one possible ecological consequence of invasive species by which they outcompete native species.

Non-indigenous species come from somewhere else and are not natural to the ecosystem they have been introduced. Cronk *et al*. (1995), stated that they may be harmless and beneficial in their natural surroundings, but where there are no established natural controls such as natural predators to keep the non-native harmful species in check, there can be a population explosion of the non-native invasive species causing an ecological catastrophe. They can disrupt natural balance, reduce biodiversity, and alter native genetic diversity, transmit exotic genetic diseases to native species, and further jeoparardize endangered plants and animals.

The simplification of ecological communities might make them more vulnerable to invasion or render them less stable or predictable in species composition. In extreme cases, invasive species may also reduce nature species richness that the original natural community no longer exists (McNeely, 2001; Mack *et al*., 1998).

Studies indicate that *Lantana camara* L. is one of the invasive species, which is native to tropical America, and is now found in most tropical and sub tropical regions of the world including Ethiopia. It has been declared noxious weed as it is detrimental to many human activities (e.g. Agriculture, Tourism) as well as a threat to natural ecosystems (Thaman, 1974; Dessalegn, 2000; EARO). *Lantana* tolerates a wide range of climates and is found any where between sea level and 1000m asl and in places even at higher altitudes, but is limited by frost (Gentle and Duggin, 1997). It can grow in high rainfall areas with tropical sub tropical and temperate climates. It doesn't tolerate salty or dry soils, water logging or low temperature ($<5^0$ c). It thrives on rich, organic soils but also grows on well-drained clay and basalt soils. Sandy soils tend to dry out too rapidly for *Lantana* unless soil moisture is continually replenished. In the study areas *Lantana* is given the local name "Yewef Kollo" (Probably because it is mostly dispersed by birds). And "Tikure" (May be because the seeds turn dark upon maturity).

Currently *Lantana* is rapidly invading agricultural and grazing areas; and has encroached hundreds of kms from its initial areas along the roadsides of the study areas (local people, personal communication). As a result of its rampant invasion it has become the cause of discussion among farmers, development agencies, scientists and policy makers. The farmers and concerned government bodies are looking for knowledge/experience/technologies that can assist in either controlling or eradication of the species.

The Environmental Policy of Ethiopia (EPE) and the National Biodiversity Strategy and Action Plan (NBSAP) have identified invasive species as posing a major threat to biodiversity and economic well being of the population. However, little attempt to assess the status of invasive alien species (IAS) has been made; so those species known to be threats are those that are already widespread Ethiopian Agricultural Reaserch Organization(EARO). Attempts to combat the threat of invasives in Ethiopia have followed the usual piecemeal approach, they have not been coordinated across sectors, and have focused mainly on attempting to address the major invaders. The emphasis is on tackling problems that threaten agriculture and human activity, there being insufficient resources, capacity or information available to address the threats to natural ecosystems.

Under the Ethiopian Agricultural Research Organization (EARO), as an executing agency there is a project with a goal to protect ecosystem, species, and genetic diversity from invasive alien species, for global, national and community benefit. The project will contribute to this goal through its purpose of removing the barriers to effective prevention and management of IAS in four pilot countries; Ethiopia, Ghana, Uganda and Zambia. The focus will be on invasive plants, as this group poses the greatest current threat, and because a number of invasive plant species of both terrestrial and aquatic ecosystems have been identified in the four countries requiring immediate attention.

Therefore, the need to study the impact of *Lantana* on the selected areas is essential for the management of biodiversity, monitoring of the existing situation and to evaluate the current status of the species. Furthermore, this study will contribute to the decision on the conservation, use and management of plant biodiversity in the region.

The analysis of socioeconomic impact of *Lantana* will also contribute to the environmental measures taken by environmentalists, ecologists, ethnobotanists, and range managers in the region. In addition, the result of the study will also be used in the strategic actions to participate the local community in the management and control measures of this alien species with environmentally friendly actions and actions which consider cost-benefit analysis and in relation to the surrounding plant biodiversity in the region.

2. Objectives

2.1 Main Objective

The main objective of the study was to asses the impact of *Lantana camara* L. on the indigenous species composition and socioeconomic environment around Adama and Bishofitu areas.

2.2. Specific Objectives

The specific objectives of the study were:

1) To determine the impact of *Lantana camara* on the indigenous species composition of the study areas.
2) To identify source and extent of vegetation disturbance.
3) To determine the relationship between vegetation diversity and environmental factors.
4) To determine the relationship between *Lantana* impact and environmental factors.
5) To gather information on socioeconomic impact and importance of *Lantana* and attitude towards it.
6) To suggest measures/strategies to control/manage the adverse environmental effects of the species on the study areas.

Research questions

1. What will be the impact of *Lantana* on indigenous species composition?

2. What will be the impact and importance of *Lantana* on socioeconomic environment?

3. What are the basic environmental factors that determine its impact?

4. What are the sources and levels of vegetation disturbance?

3. Litrature Review

3.1. Invasive Species

Each species has a distinct distribution, which is a product of its evolutionary and ecological history (Whittaker, 1975; Heywood, 1995). Hobbs (2000); Weber (2003) defined an invasive plant as a "plastic pereinnial" that germinates under a wide range of physical conditions, grows quickly, flowers early, is self compatible, produces many seeds that disperse widely, reproduce vegetatively and is a good competitor and has the ability to thrive and spread aggressively outside its natural range since the insects, diseases and foraging animals that naturally keep its growth in check in its native range are not present in its new habitat.

Invasive species affect survival prospects of animals by altering food supplies, nest sites, cover and protection from other animals .For example, **(**Pimental *et al*., 2000), noted that, shrubby invaders such as *Lantana camara* grow vigorously, but since they are unsuitable as browse material, their occurrence reduces food for herbivores. Gentle and Duggin (1997), reported that ecosystems such as wet lands, sand dunes, fire prone areas, islands and serpentine barriers where rare plants are found are highly threatened. They often alter ecosystems drastically, upsetting species composition, changing soil chemistry, hydrology and fire frequency. They thrive where the continuity of natural ecosystem is breached and are abundant on disturbed sites, like construction areas and road cuts. Even foot traffic can create a temporary void that is quickly invaded.

Not all non-native species are invasive and harmful but many can completely take over and entirely change whole established ecosystems. Pimental *et al*., (2000); Kingstun *et al*., (2003) discussed the use of metalliferous invasive species to clean up metal-contaminated ecosystems.

3.1.1 Introduction of Invasive Species

Most long distance introductions of non-native species to new areas is direct or indirect results of human activities, and social and economic factors are often as critical as biological factors. According to Segretain *et al*. (2004), introductions can be intentional with the purpose and intention that they will become established, or intentional with subsequent escape under captive condition, or unintentional without being noticed.

Litratre relates the origin of deliberate plant introduction with the history of agriculture (McNeely *et al*., 2001; VanWilgen *et al*., 1997). Exotic plants are introduced deliberately as forage fiber, medicine, or ormnamentals, for erosion control, and for timber plantations, for soil improvement (plants with nitrogen fixing abilities) or for horticultural attributes (McNeely *et al*., 2001).

Wittenberg *et al*., (2000), described pathways of unintentional introduction of exotics species as seed contaminants in hay carried as animal feed or in cargo, arrival of exotic species via ports of entry, forage, as seeds in grain, attached to livestock, potted plants (soil, surrounding roots of nursery stocks), military vehicles.

3.1.2 Impacts of Invasive Species

Every alien species that become established alters the composition of native biological communities in some way. Studies noted that invasive species can transform the structure and species composition of ecosystems by repressing or excluding native species, either directly by out competing them for resource or indirectly by changing the way nutrients are cycled through the system (Segertain *et al*., 2004; Perrings *et al*., 2000). The change to the state of the ecosystem may be initiated by natural disturbance (storm, earth quake, volcanic eruption, climate, fire), or management regimes but are enhanced or accelerated by the invasion of alien species (Gentle and Duggin, 1997; Mack, 1998). There are three ways by which biological invasions alter ecosystems. According to Hobbs (2000), they alter rates of resource supply, trophic level relationships and the disturbance regime. VanWilgen *et al*., (1997), add changes in stability to this list.

Invasive species have many negative impacts on human economic interests whether it becomes invasive (harmful) depends on the particular characteristics of the invasive species, the vulnerability of the host ecosystem and chance (Roothaert, 2000). Wittenberg *et al*., (2000), noted that invasives reduce crop yields, increase control costs, and decrease water supply by degrading water catchment areas and fresh water ecosystems and drive up management costs in national parks. They are also pests and pathogen of crops, livestock and trees, reduce yields and increases pest control costs, destroy communally important fisheries, and introduce harmful aquatic organisms including, diseases, bacteria, and virus.

Perrings *et al*., (2000), noted that in addition to the direct costs of management of invasives the economic costs also include their indirect environmental consequences and other non market values, for changes in ecological services by disturbing the operation of the hydrological cycles, including flood control and water supply, waste assimilation, recycling of nutrients and controlling pests. The economic impacts of invasive species are the results of their effects on agricultural production as well as activities to control/eradicate them, and remediate their damages (Birdlife International, 2000;Mooney *et al*., 2000).

According to Henderson (2001), an impossible loss to monetarily quantify is biodiversity loss, ecosystem degradation, and aesthetic changes, but those are important effects of invasive species. Some exotic plants also present health hazards; for example allergies that cause contact dermatites and respiratory difficulties in many people (Roothaert, 2000).

3.1.3 Disturbance and Invasive Species

Disturbances are resource fluctuations, which are discrete in relative temporal scale and can be human and natural mediated. According to Richardson *et al*., (2000) they are facilitators of exotic plants in the early stages of invasion process by increasing the availability of limiting resources. Disturbance often creates an imbalance in distribution of resources, which may alter species composition through shifts in resource availability. This inturn may create conditions favouring invasions of non-native species and deletion of native species.

Mack (2000) and D'Antonio (2000), explained the association between disturbance and invasion as diturbance creates new microclimates and niches for invading species, it directly removes or decrease populations of native predator and competitor species, thereby making them less capable and controlling or resisting a growing population of invading species and, introduce non-indigenous species propagules in to areas that were inaccessible.

D'Antonio, (2000) and Keeley (2001), stated that when an invasive exotic species is introduced into a relatively undisturbed ecosystem, it may not displace many individuals of native species at first. But once there is a disturbance, whatever its source, the invasive exotic may outcompete or overeat the natives in the new succession.

3.1.4 Climate Change and Invasive Species

Change in climate produces conducive conditions for the establishment and spread of invasive species. Williamson (1996) and Sutherst (2000), noted that climate change brings change in patterns of production and trade in agricultural commodities thus the opportunities to contaminate in new range will also increase .Changes in frequency and intensity of extreme climatic events that disturb ecosystems make them vulnerable to invasions thus providing exceptional opportunities for dispersal and growth of invasive species (Ghorden, 1998).

Kowarik (2003) wrote that both drought and freezing are likely to change in frequency and intensity under climate change by reducing the resistance of trees to insect attack and altering the frequency, intensity and duration of flooding. Climate change will affect the incidence of episodic recruitment events by enabling aggressive species to escape from local constrained refuges. Climatically induced stress on plants can reduce their ability to resist invaders (Sutherst, 2000).

3.1.5 Agriculture and Invasive Species

Agriculture presented vast new opportunity for some species to benefit from human modifications of habitats. Mooney *et al*., (2000), noted that the problem of invasive species became significant only after the advent of agriculture. Agriculture (the domestication of both plants and animals) involves the intentional and beneficial movement of many species around the world. The intentional introduction of pests and diseases of agriculture as contaminants in crops and animals has led to particularly severe alien species problem.

Many of invasive weeds affecting agriculture and natural grasslands have been spread around the world as contaminants in crop seeds, emergency food aid. For example, the new tropical weed *Parthenium hystrophrous* recently arrived in Africa through grain shipments to Ethiopia; and agricultural trade is also a pathway of agricultural invasive (Pimentel *et al*., 2000).

3.1.6 Habitat Fragmentation and invasive Species

Spread of invasive species may occur more rapidly in fragmented landscapes. Hobbs (2000) and McNeely (2000), reported that fragmentation of natural habitat makes an area vulnerable to invasion; edges of natural habitats are especially vulnerable.

Ghorden (1998), wrote that human activities that modify ecosystems cause most of the problems. The likelihood of establishment of weeds is improved due to growing human disturbance of habitats around the world.

3.1.7 Fire and Invasive Species

Human caused disruption of natural fire regimes have contributed to the widespread invasion of communities. D'Antone, (2000); (Keeley, 2001), reported that pre-fire fuel manipulation contributes to alien plant invasions, for example, use of prescription burning on sites that currently have higher than natural fire frequencies potentially favors aliens. Also fuel breaks may act as invasive high ways, carrying invasive species in to uninfested wild lands, which contribute to enhanced survivorship of alien seed banks, resulting in source populations possible for invasion of adjacent burned sites. Post-fire site re-habilitation is responsible for widespread introduction of alien species that may increase fire frequency and further increase expansion of aliens (Keely, 2001).

3.1.8 Globalization and Invasive Species

The growth of global economic activity will result in greater invasive impacts because the spread of potentially invasive species will accelerate as the trade in biological products expand**.** World Resource Institution and Word Bank reports indicate globalization of the economy which is demonstrated by the increase in the value of total imports from US $192 billions in 1965 to US

$5.4 trillion in 1998, a 28 fold increase just over 30 years (World Resource Institution, 1994;World Bank, 2000).

According to Wittenberg *et al*., (2000), the increase in the imports of agricultural products and industrial raw materials from US $482 billion in 1990 have the greatest potential to contribute to the problem of invasive alien species, because unwanted species, especially insects and other invertebrates, may be physically transferred with the traded commodity.

3.1.9 Human Health and Invasive Species

Invasive pathogens are of particular concern to human health relative to rapid environmental changes and ecological disturbances. Pimental *et al*., (2000), repored that Invasive species combined with inter-annual rain fall, temperature, human density, population mobility and pesticide use all contribute to one of the most profound challenges of invasive species: the threat to human health.

McNeely (2000), indicated that free from their natural controlling factors, invasive organisms often reach sustained outbreak levels that encourage widespread and chronic pesticide use as a result the type, scale and tempo of change in health risk is accelerating under the contemporary conditions of global change.

3.1.10 Invasive Species and Drought Tolerance

Studies indicate that drought brings about changes in plant physiology thus growth becomes slower, cuticle thickened, nitrates, oxalates and other chemicals are accumulated (Craige, 2005). The outcome being foliar herbicides become less effective and potentially increased toxicity to grazing and browsing animals. Keeley (2001), wrote that invasive species drought tolerant; contribute to fire fuel and flammable biomass. The possible outcome being competitive replacement of native plants, decrease in plant cover, increase landscape fire vulnerebility, domination of early succession by invasive and flood plain /riparian areas are highly impacted.

3.1.11 Invasive Plant Species and their Geographical Distribution in Ethiopia

Invasive plants have until recently received scanty attention and only a few invasive species have been highlighted in the local literature (Dessalegn *et al*., 2002). Typically invasive plant species in Ethiopia are under recorded and under reported; however, many introduced species are now spreading in the country (Dessalegn Dessisa, 2003).

1. *Acacia melanoxylon* (tree) (Oromiya, Afar).
2. *Pennisetum polystachion* (grass)
3. *Eichhornia crassipes* (aquatic plant)(Oromia, Southern Nations Nationalities and Peoples, Gambella).
4. *Leucaena leucocephala* (tree)
5. *Opuntia stricta* (shrub)(Oromiya, Tigray, Amhara)
6. *Parthenium hystrophorus* (herb)(Oromia, Somalia, Afar, Tigray, Amhara, Southern Nations Nationalities and Peoples).
7. *Lantana camara* (shrub)(Oromiya, Somalia,Gambella)
8. *Prosopis juliflora* (Oromia, Tigray, Amhara, Somali, Afar)
9. *Acacia decurrens*
10. *Argemone mexicana*
11. *Cupressus lusitanica*
12. *Impatiens granduliflora*
13. *Nilotica glauca*
14. *Opuntia ficus-indica* (Tigray, Amhara)
15. *Pinus patula*
16. *Psidium guajava*
17. *Salvinia mollesta*
18. *Tagetus minuta*

3.2. *Lantana camara*

Lantana camara L. one of the world's worst invasive species is a perennial woody shrub, belonging to the family Verbeneceae. Litrature indicated the natural occurrence of *Lantana* in Mexico, the Caribbean and Tropical and subtropical Central and South America. The species was only widely distributed around the world during the 19^{th} and early 20^{th} century. During the 18^{th} century *Lantana* became a favorite green house plant and numerous new varieties were bred (Sharman, 1974; Gentle and Duggin, 1997).

Reports on its geographical range indicates its presence in many Pacific island nations; on the Pacific ream it occurs in Australia, Newzeland, China, Thailand, Cambodia, Viet Nam, Malasia, Indonesia and Philippines. In the Indian Ocean islands it occurs on Mauritius, La Reunion, and Rodrigues (Sharman, 1974).

Lantana is described as a highly variable species it may be erect in the open and scrambling in scrubland, ranging in height from 2-5 centimeters. Variation in flower size, shape and colour; leaf size, hairiness and colour; stem thorniness; growth rates; shade tolerance; toxicity to livestock; chromosome number and DNA content have been widely reported (Binggli *et al*., 1998).

Lantana flowers when the soil is moist and the air is warm and humid. Germination may occur at any time of the year when sufficient moisture is present. Initial seedling growth is slow until the roots become established after which close stems interwine and begin to form thickets. It can reproduce from the base if the shoot dies, extending the life of the individual plant (Sharman, 1974; Craige, 2005). Butterflies, bees and other insects are attracted by the nectar and pollinate *Lantana* flower. About half of the flowers produce seeds, typically 1-20 seeds on each flower head. Mature plants can produce up to 12,000 seeds every year. Seeds are thought to remain viable for several years under natural conditions (Erasmus *et al*., 1993; Morton, 1992).

Studies on its spread mechanism documented layering in which stems send roots in to the soil, allowing it to quickly form dense stands and spread short distances (Sharman, 1974). Also birds and other animals consume and pass the seed in their droppings, potentially spreading it over quite long distances. Invasive pathway to new localities is also nursery trade. Local dispersal methods are digestion, excretion and garden escape /garden waste (Sharman, 1974; Thakur *et al*., 1992).

Lantana occurs in agricultural areas, disturbed areas, natural forests range/grasslands, scrub/shrub lands, urban areas, and wetlands. Many studies documented disturbance, decreasing competition, and increasing resource availability associated with fire and grazing as promoters of *Lantana* invasions whereas shedding is a limiting factor but some invasive populations are somewhat shade tolerant(Gentle and Duggin, 1997).

Studies noted many importances of *Lantana*. For example, it is grown as hedge plant; its sticks are used as raw materials for paper and pulp, which is used for wrapping, writing and printing paper. Its bark is a stringent and is used as a lotion in cutaneous eruptions, leprous ulcers, etc.; seeds as lamb food, biogas production when its straw is mixed with dung. Alkaloid fractions obtained from *Lantana*, have been found to lower the blood pressure, accelerate deep respiration and stimulate intestinal movements in experimental animals. It is also used as ornamental, erosion control, and antifeedant and repellant of harmful insects, as fodder for cattle and goats (Syed *et al*., 2004; Amare Getahun, 1976; Sharma *et al*., 1988).

Lantana camara have significant levels of nitrogen and phosphorus, when grown as a cover crop and incorporated in to the soil; it contributes to fertility at no cost except for the labor of planting and soil incorporation (DiCastri, 1989; Deka, 1978; Binggli *et al*., 1993; Baars, 1999).

Lantana camara is introduced into Ethiopia as an ornamental shrub often used as hedge plant. *Lantana* is well known in Ethiopia especially as a showy garden plant, for instance, the horticultural society recommends its planting in Addis Ababa home gardens. It has also seen growing around home farmsteads as a live hedge along the Nazareth Welenchiti road (Dessalegn Dessisa, 2002; Binggli *et al*., 2002).

4. Materials and Methods

4.1 The Study Area

4.1.1 Location and Description

The town of Adama is found in the Ethiopian rift valley, about 90kms,South East of Addis Ababa, the capital. It is located at $8^0$30’N latitude and 39^0 12’ E longitudes at an average altitude of 1600m (range 1550-1600). It has a typical arid climate.

The soils range from sandy to loamy and are intensively cultivated.The area grows teff, maize, millet, etc., and is also favorable for growing vegetables and fruits like onion, potato, orange,papaya, grapes and the like. With respect to vegetation, spiny-leaved plants, dominated by Acacia, typical of arid areas, characterize the region.

Bishofitu lies at latitude $8^0$44’N and longitude 38^o58’E ,with an average altitude of 1,850m asl. The town is located on the escarpment of the Great Rift Valley. The lakes and the position of the town on the escarpment of the great valley, has influence on the climate of the area.

● ● ● Sampling Points

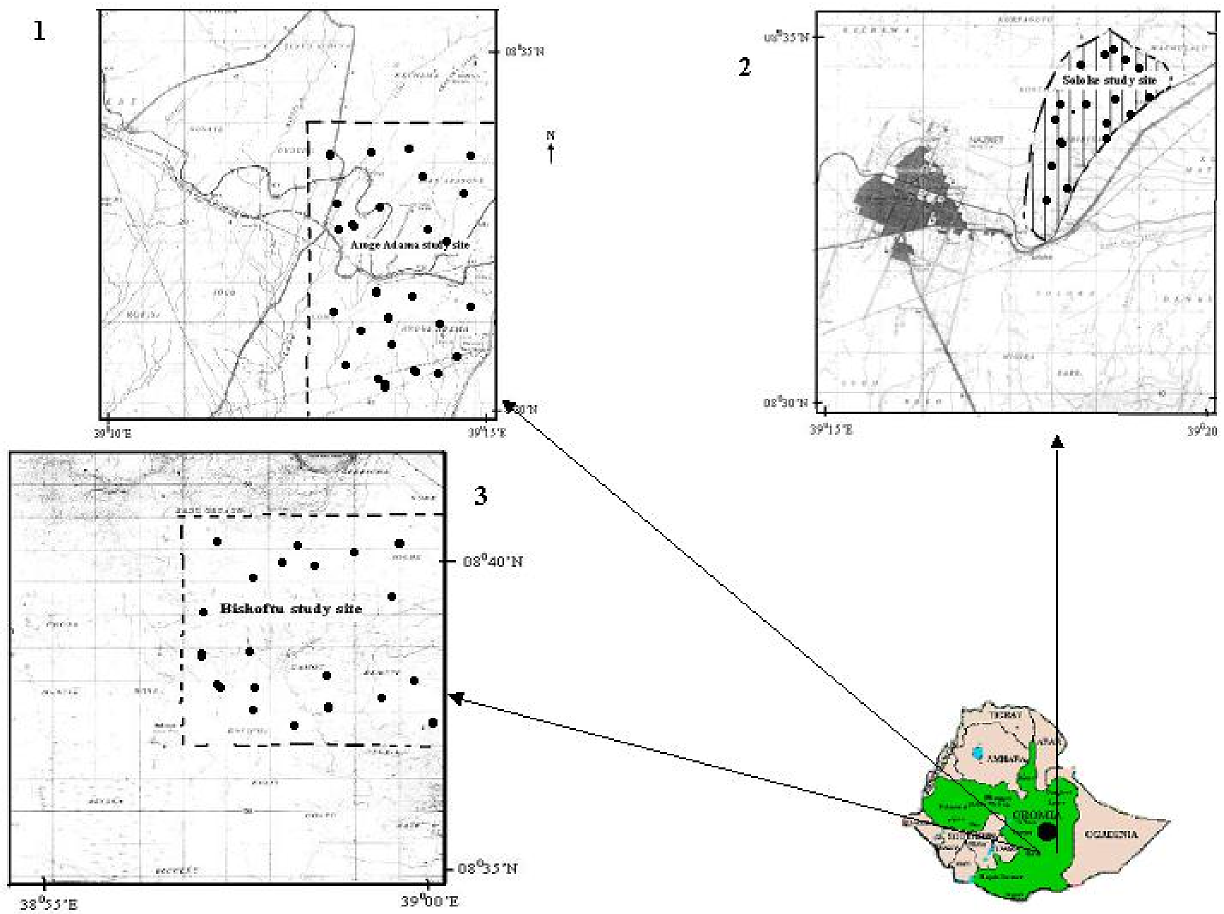


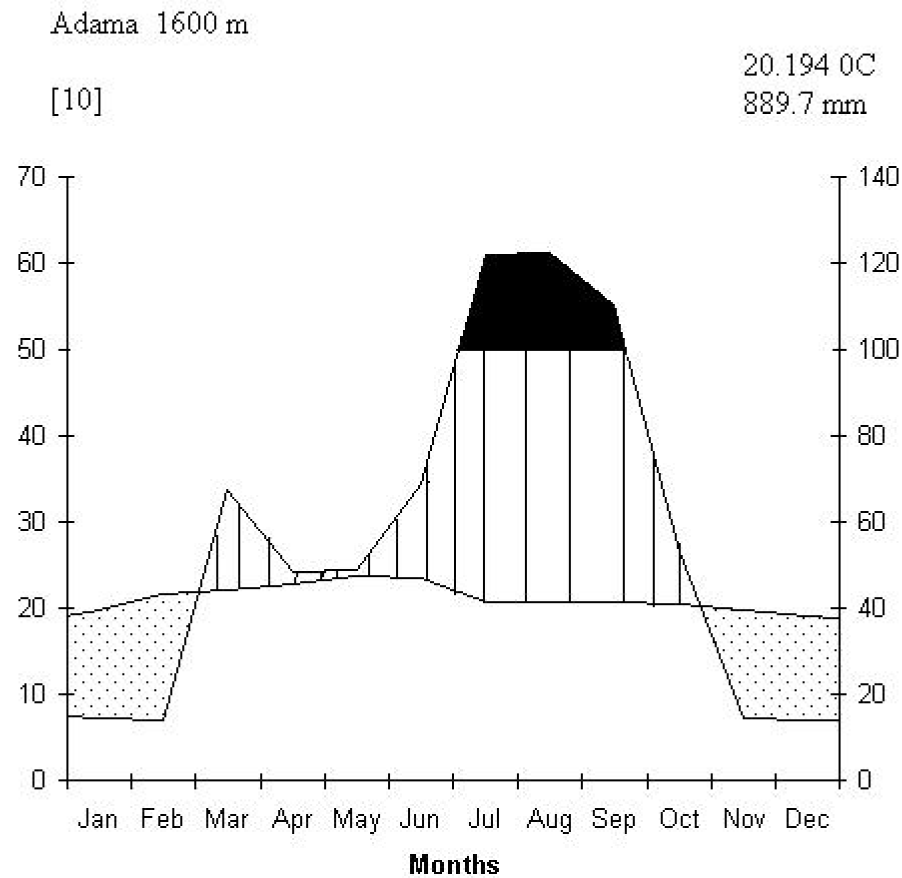
Fig 1 Map of the Study Sites: (1). Aroge Adama (2). Soloqe (3). Bishofitu

Source Ethiopian Mapping Authority.

4.1.2 Climate

The mean annual temperature and rainfall of Adama is 20.194^0C and 741.43mm respectively. Its mean maximum temperature reaches 30.8^0C in May, where as the mean minimum temperature is 12^0C in December.Its wettest season is between July (219.282mm) and September (104.455mm) of rainfall, but the mean maximum and minimum rainfall are 223.45mm and 13.8mm in August and February respectively.

The mean annual temperature and rainfall of Bisihofitu is 18. 8^0C and 711.84mm respectively. its mean maximum temperature reaches 29.5^0C in May where as the mean minimum temprature is 9^0C in January. The wettest season of Bisihofitu is between June (115.22mm) and August (214.47mm) of rainfall but the mean maximum and minimum rainfall are 226.99mm and 12.36mm in July and November respectively.


Adama 1600 m
[10]
20.194 0C
889.7 mm
70
60
50
40
30
20
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140
120
100
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40
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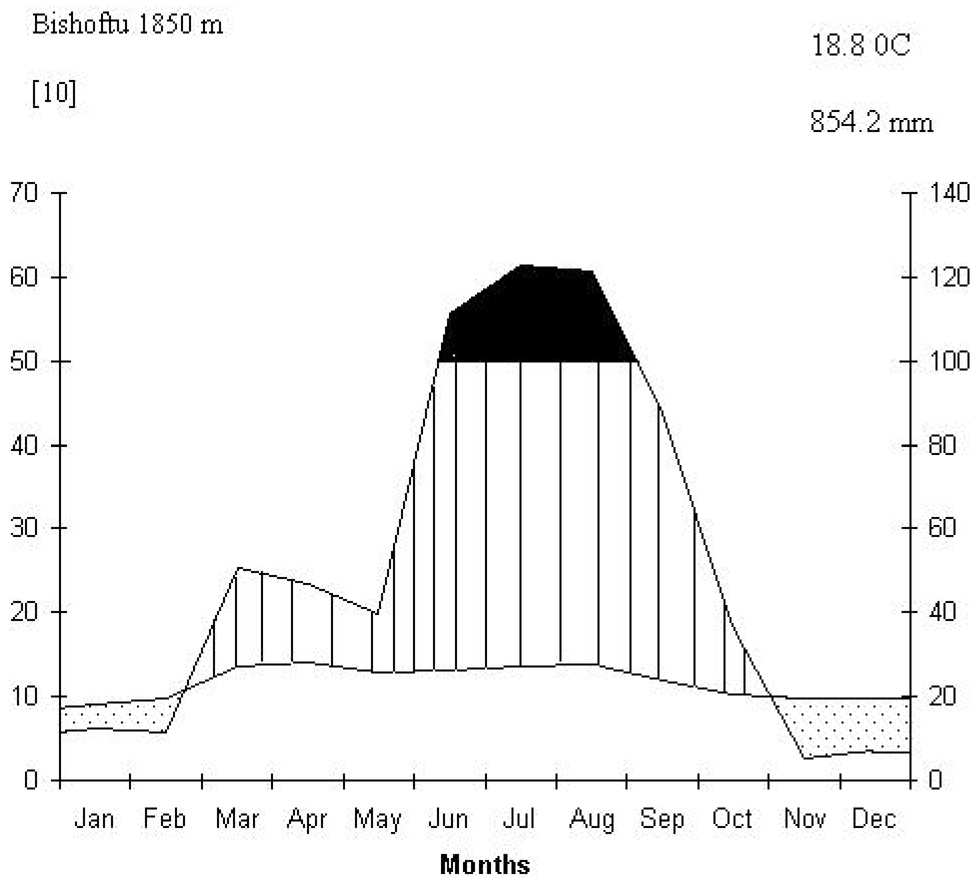
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Months

(a)



(b)
Climate diagram showing sixteen years temperature and rainfall Data for a. Adama b. bishofitu .Source:(Walter, 1975).

4.1.3 Topography

The town of Adama is situated in a basin like flat land surrounded by ridges and hills in the west, south and east. There is no permanent river, which endangers settlement in the town. However its basin like position discourages the peripheral areas of the town for settlement due to the flood generated from the hills and ridges. Inspite of the presence of channels to discharge water, most areas along the north western ridge are not favoured for settlement because of the presence of direct run off. Flood from the southern ridge and southeastern hills gathered in the southeastern depression create swamp, which become mosquito breeding sites. The topography of Bishofitu area is greatly altered by the geologic formation of crater lakes.

4.2 Field sampling

4.2.1 Biophysical Data Sampling

Fifty-four 5m x 5m plots were systematically established based on homogeneity and representativeness in the study areas. The number of plots were distributed equally for the three study sites; Aroge adama, Soloqe, and Bisihoftu. Quadrats were laid across three transects laid 50m from the left side of the main road. In order to reduce the effects of human interference, the sites selected were, as much as possible, far away from the main road and human settlement.

Wittenberg *et al*., (2000), suggested that pairing data has the theoretical effect of reducing measurement variability (i.e. variance), which increases the accuracy of statistical conclusion. More over two treatments should be laid side by side in the field in order to avoid unnecessary differences in soil, moisture, temperature, etc. Two plots next to each other usually respond more alike than those at a distance. Non-invaded sample plots should be chosen as close as possible to invaded plots to represent primary communities where invasions have taken place (Pimentel *et al*., 2000). If the habitats were not identical the assessment may partly introduce different habitat parameters (i.e. the invasive may not be growing in some of the plots due to variation in certain characteristics). Considering the suggestions given them in the three study sites invaded patches and surrounding *Lantana* free vegetations in the same habitat type were sampled as releve' pairs. The releve' pairs chosen have the same plot size.

Individuals of each plant species in each releve's (quadrat) with 5mx5m were counted. Individuals having their canopy with in the plots and that were rooted outside were not included in the count. Plant specimens in each plot were collected and pressed for identification at the National herbarium of the Addis Ababa University; vernacular names were recorded in the field.

Altitude and GPS records were taken for the 54 releve's using GPS. Disturbance were recorded as reflected by the actual presence of animals, their trails and droppings, the removal of plant material and soil due to animal grazing, browsing and movement among others.

The levels of disturbance recorded were assessed using a subjective scale of 0-3, detailed as follows:
(0)-nil ;(1)-low ;(2)-moderate ;(3)-heavy (Kumilachew Yeshitila and Taye Bekele, 2003).

4.2.2 Socioeconomic Data

Socio-economic information on condition of introduction, status, use value and impact, and management (means to reduce its adverse impacts and methods to make the species beneficial) and attitude data were collected using semi-structured interview. A total of 54 key informants were interviewed. All of them are farmers.

4.3 Data Analysis

4.3.1 Biophysical Data Analysis

The indigenous species in the sample pairs; in the invaded and non-invaded releve's were compared using Shannon diversity index to investigate the variation in species diversity and richness (determined using Shannon diversity index) and t-test.

The diversity and richness of species in the three study sites was determined using Fortran Computer Program for Shannon-Weiner index.

ANOVA is used for the analysis of the variation in species diversity in the invaded and non-invaded releve's in all the study sites.

To establish the level by which the diversity and abundance/density of indigenous species were vulnerable to invasion, Spearman's rank correlation coefficients, r_s (rho), for altitude, disturbance, and density of *Lantana* were determined.

4.3.2 Socioeconomic Data Analysis

The data collected using semi-structured interviews on 54 key informants on the introduction, use value, impact and management (means to reduce its adverse impact) and attitude towards it was analyzed using SPSS program**.**

5. Results

5.1 Species Diversity

Table 1 Shannon-Weiner diversity and spesies richness values for the three study sites.

	Site1(ArogeAdama)	Site 2(Soloqe)	Site3 (Bishofitu)
Spp.diversity (H')	2.79	3.14	2.74
Spp. richness (N)	24	31	20

Table 2. Shannon –Weiner diversity values for Invaded and Non- invaded releve's for the three study sites

	Sites					
	1(Aroge Adama)		2(Soloqe)		3(Bishofitu)	
	Invaded	Non-inv	Invaded	Non-inv	Invaded	Non-inv
Spp. diversity (H’)	2.48	2.65	2.85	2.91	1.26	1.69

The results of Shannon –Wiener diversity index showed that site 2 (Soloqe) has relatively the highest species diversity and richness, while site 3 (Bishofitu) has the lowest species diversity and richness site 1 (Aroge Adama) being of higher in species diversity and richness.

Results of Shannon-Weiner diversity index in invaded and non-invaded plots showed that the vegetation invaded by *Lantana* has lower species diversity compared to the non invaded *Lantana* free vegetation.

The independent t–test, comparing the Shannon index in invaded and non-invaded releve’s in the three sites showed significance difference (Table 3).

Table 3: P-value for independent sample t-test for the three study sites (Site 1: Aroge Adama; Site 2: Soloque; Site 3: Bishofitu)

	Site 1	Site 2	Site 3
P-value	0.00	0.021	0.000758

The results of one-way ANOVA test considering H’ in the invaded plots (Pvalue: 0.004) and non-invaded plots (Pvalue: 0.000) in the three sites showed significant difference in species diversity in the three invaded sites

5.2 Sources of Disturbance

All the plots sampled were trampled. Grazing occurred in 24 plots, 17 plots were browsed. While the combined effects of browsing and grazing occurred in 9 plots. Stone removal occurred in 4 invaded releve’s of Bishofitu.

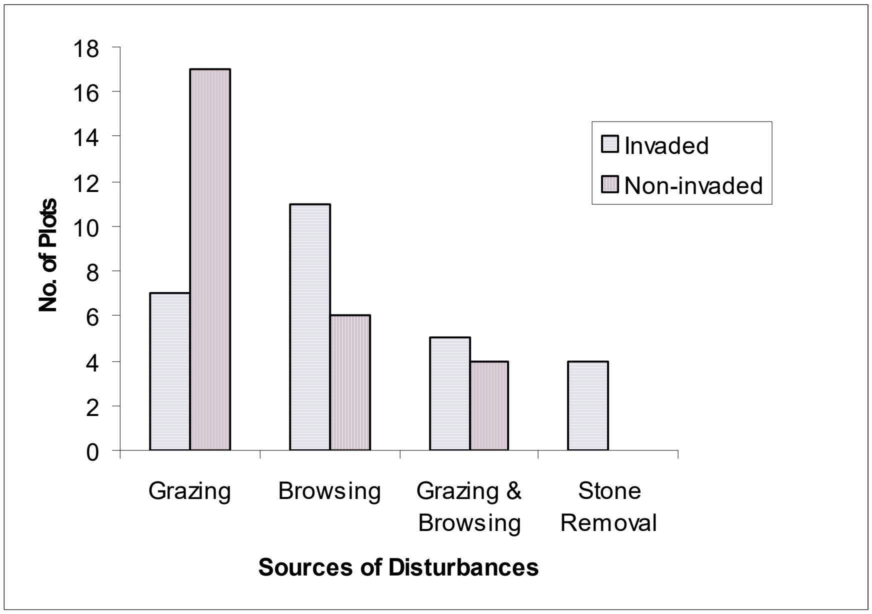


Fig.3 Sources of Disturbances in the Plots Sampled in Invaded and Non-invaded releve's in all the three Study Sites

5.3 Levels of Disturbance

All the plots sampled were disturbed. In the invaded areas 15 plots were highly disturbed, 8 moderately and low level of disturbance affected 4 plots. In the non-invaded areas 4 plots were highly disturbed, 14 moderately and 4 at low level.

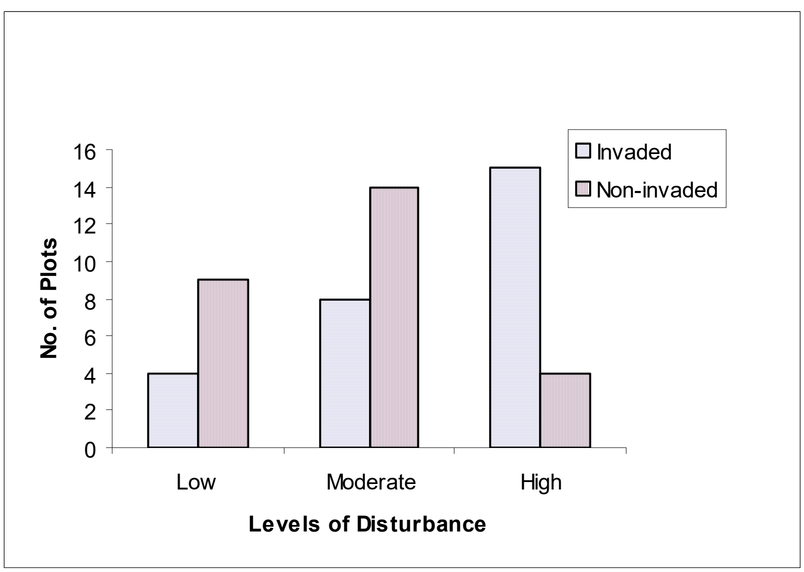
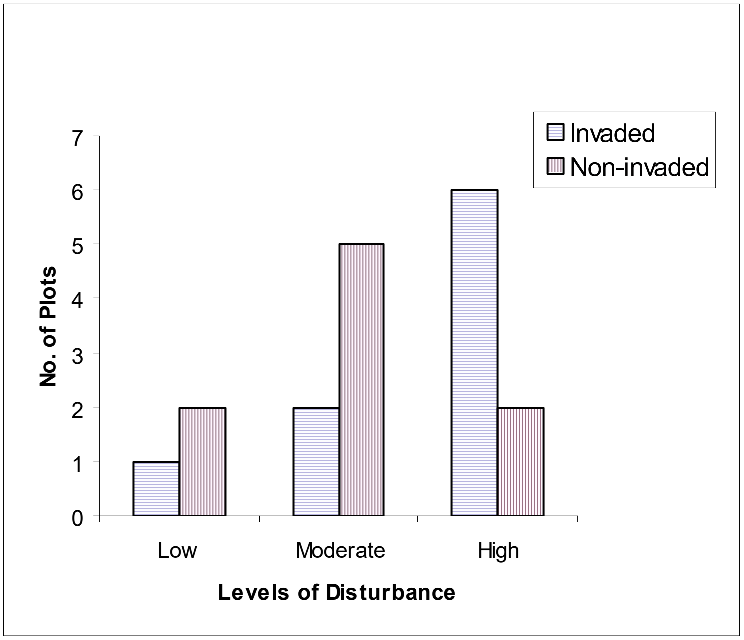
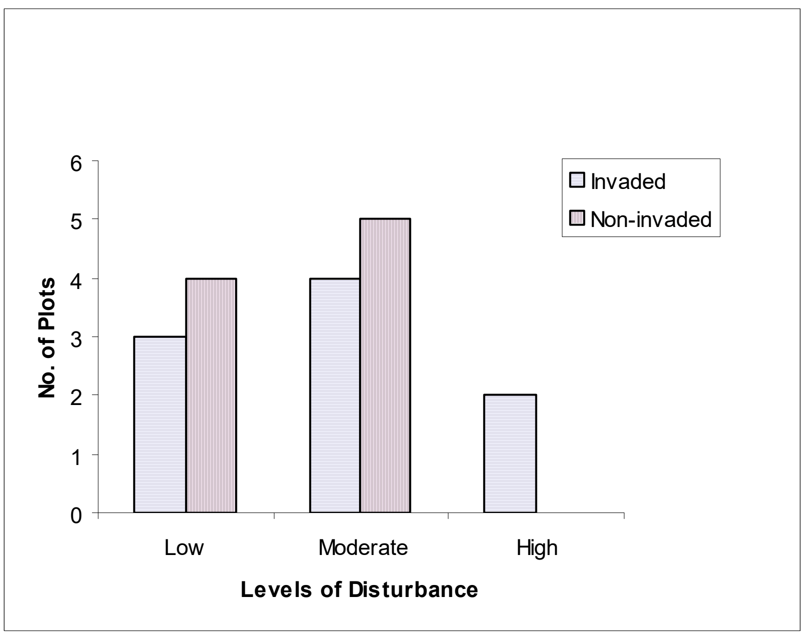


Fig 4.Levels of Disturbances in all the Plots Sampled in Invaded and Non-invaded releve's



(a)



(b)

(c)

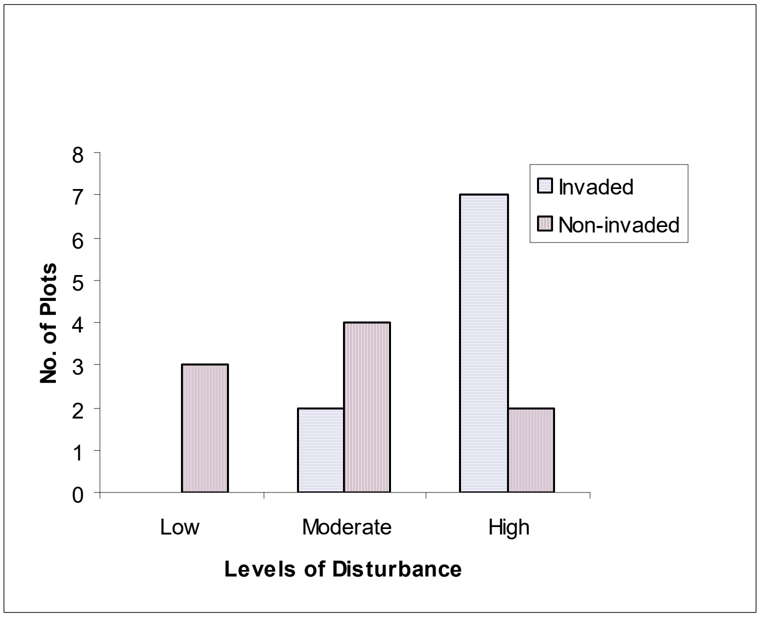


Fig.5 Levels of Disturbance (Invaded and Non-invaded) releve's in (a) Aroge Adama (b) Soloque (c) Bishofitu

Types and levels of disturbances were variable for all the sites. Out of 18 releve's sampled in Aroge Adama; six were highly disturbed mainly by browsing and trampling in invaded releve's. In the non-invaded releve's, moderate levels of disturbance were recorded in most plots (Fig 5a).

In Soloque (Fig 5b), invaded releve's 2 plots had high level of disturbance. In the non-invaded releve's the disturbance level decreased, 4 releve's had low level of disturbance while 5 moderate.

In Bishofitu (Fig 5c), in the invaded releve's 7 plots had high level of disturbance. In the non-invaded releve's 3 plots had low and 4 moderate level of disturbance.

(a)

(b) 

Fig 6. Photos Showing Invaded Patches in (a) Aroge Adama (b) Soloque

5.4 The Relationship between Species Diversity and Environmental Variables

To establish the relationship between diversity of native species and environmental factors spearman rank correlation coefficients r_s (rho) were determined.

Table 4 a & b summarizes the results for Aroge Adama. In the invaded releve's, vegetation diversity is highly negatively correlated with disturbance (r:-0. 839) and density of *Lantana* (r:-0. 835). While *Lantana* density and disturbance were highly positively correlated (r: 0.840). In the non-invaded releve's (Table 4b) vegetation diversity is highly negatively correlated with disturbance level (r:-0. 948) (at $P \leq 0.001$).

Table 4a Spearman r_s (rho) Correlation for the Invaded releve's of Aroge Adama

			Alt.	Dist. lev	H'	D/NPLs	D/La
Spearman's rho	Alt.	Correlation Coefficient	1.000	-.279	.199	.113	-.159
		Sig. (2-tailed)	.	.467	.607	.772	.683
		N	9	9	9	9	9
	Dist. lev	Correlation Coefficient	-.279	1.000	-.839**	.052	.840**
		Sig. (2-tailed)	.467	.	.005	.894	.005
		N	9	9	9	9	9
	H'	Correlation Coefficient	.199	-.839**	1.000	.005	-.835**
		Sig. (2-tailed)	.607	.005	.	.991	.005
		N	9	9	9	9	9
	D/NPLs	Correlation Coefficient	.113	.052	.005	1.000	.315
		Sig. (2-tailed)	.772	.894	.991	.	.410
		N	9	9	9	9	9
	D/La	Correlation Coefficient	-.159	.840**	-.835**	.315	1.000
		Sig. (2-tailed)	.683	.005	.005	.410	.
		N	9	9	9	9	9

**. Correlation is significant at the .01 level (2-tailed).

Alt.: Altitude in meters; Dist.lev: disturbance level; H': Shannon-Weiner diversity index

D/NPLs: Density of native plants; D/La: Density of *Lantana*

Table 4b Spearman Correlation r_s (rho) for Non-invade releve's of ArogeAdama

			Alt.	Dist. lev	H'	D/NPLs
Spearman's rho	Alt.	Correlation Coefficient	1.000	-.292	.162	.352
		Sig. (2-tailed)	.	.446	.676	.353
		N	9	9	9	9
	Dist. lev	Correlation Coefficient	-.292	1.000	-.948**	.034
		Sig. (2-tailed)	.446	.	.000	.930
		N	9	9	9	9
	H'	Correlation Coefficient	.162	-.948**	1.000	-.056
		Sig. (2-tailed)	.676	.000	.	.887
		N	9	9	9	9
	D/NPLs	Correlation Coefficient	.352	.034	-.056	1.000
		Sig. (2-tailed)	.353	.930	.887	.
		N	9	9	9	9

**. Correlation is significant at the .01 level (2-tailed).

In Soloqe invaded releve's (Table 5a), vegetation diversity is highly negatively correlated with disturbance (r:-0. 977) and density of *Lantana* (r:-0. 950). While *Lantana* density and disturbance were highly positively correlated (r:0. 943). In the non-invaded releve's diversity is highly negatively correlated with disturbance (r:-0. 968) (at P<0.01)

Table 5a Spearman correlation r_s (rho) for non-invade releve's of Soloque

			Alt.	Dist. lev	H'	D/NPLs	D/La
Spearman's rho	Alt.	Correlation Coefficient	1.000	.036	-.120	-.518	.094
		Sig. (2-tailed)	.	.926	.758	.153	.809
		N	9	9	9	9	9
	Dist. lev	Correlation Coefficient	.036	1.000	-.977**	.088	.943**
		Sig. (2-tailed)	.926	.	.000	.822	.000
		N	9	9	9	9	9
	H'	Correlation Coefficient	-.120	-.977**	1.000	.005	-.957**
		Sig. (2-tailed)	.758	.000	.	.991	.000
		N	9	9	9	9	9
	D/NPLs	Correlation Coefficient	-.518	.088	.005	1.000	-.109
		Sig. (2-tailed)	.153	.822	.991	.	.780
		N	9	9	9	9	9
	D/La	Correlation Coefficient	.094	.943**	-.957**	-.109	1.000
		Sig. (2-tailed)	.809	.000	.000	.780	.
		N	9	9	9	9	9

**. Correlation is significant at the .01 level (2-tailed).

Table 5b Spearman Correlation r_s (rho) for Non-invade releve's of Soloque

			Alt.	Dist. lev	H'	D/NPLs
Spearman's rho	Alt.	Correlation Coefficient	1.000	-.174	.299	-.018
		Sig. (2-tailed)	.	.654	.434	.964
		N	9	9	9	9
	Dist. lev	Correlation Coefficient	-.174	1.000	-.968**	.045
		Sig. (2-tailed)	.654	.	.000	.908
		N	9	9	9	9
	H'	Correlation Coefficient	.299	-.968**	1.000	.117
		Sig. (2-tailed)	.434	.000	.	.764
		N	9	9	9	9
	D/NPLs	Correlation Coefficient	-.018	.045	.117	1.000
		Sig. (2-tailed)	.964	.908	.764	.
		N	9	9	9	9

**. Correlation is significant at the .01 level (2-tailed).

In Bisihofitu, in the invaded releve's, (Table 6a), diversity and density of native plants is negatively correlated with disturbance(r:-0. 753). *Lantana* density is positively correlated with disturbance (r: 0. 731) and negatively with diversity and density of native plants(r:-0. 734). For the non-invaded releve's (Table 6b), diversity and native pant density is negatively correlated with disturbance (r:-0. 787) (at P≤0.05)

Table 6a Spearman correlation r_s (rho) for invade releve's of Bisihofitu

			ALT	dist	H	D NPL	D LC
Spearman's rho	ALT	Correlation Coefficient	1.000	-.104	.383	.383	-.118
		Sig. (2-tailed)	.	.790	.309	.309	.762
		N	9	9	9	9	9
	dist	Correlation Coefficient	-.104	1.000	-.753*	-.753*	.731*
		Sig. (2-tailed)	.790	.	.019	.019	.025
		N	9	9	9	9	9
	H.	Correlation Coefficient	.383	-.753*	1.000	1.000**	-.734*
		Sig. (2-tailed)	.309	.019	.	.	.024
		N	9	9	9	9	9
	D NPL	Correlation Coefficient	.383	-.753*	1.000**	1.000	-.734*
		Sig. (2-tailed)	.309	.019	.	.	.024
		N	9	9	9	9	9
	D LC	Correlation Coefficient	-.118	.731*	-.734*	-.734*	1.000
		Sig. (2-tailed)	.762	.025	.024	.024	.
		N	9	9	9	9	9

*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

Table 6b Spearman Correlation r_s (rho) for Non-invade releve's of Bisihofitu

			Alt.	Dist. lev	H'	D/NPLs
Spearman's rho	Alt.	Correlation Coefficient	1.000	-.267	.346	-.267
		Sig. (2-tailed)	.	.487	.361	.487
		N	9	9	9	9
	Dist. lev	Correlation Coefficient	-.267	1.000	-.787*	1.000**
		Sig. (2-tailed)	.487	.	.012	.
		N	9	9	9	9
	H'	Correlation Coefficient	.346	-.787*	1.000	-.787*
		Sig. (2-tailed)	.361	.012	.	.012
		N	9	9	9	9
	D/NPLs	Correlation Coefficient	-.267	1.000**	-.787*	1.000
		Sig. (2-tailed)	.487	.	.012	.
		N	9	9	9	9

*. Correlation is significant at the .05 level (2-tailed).

**. Correlation is significant at the .01 level (2-tailed).

Analysis of variance was performed to detect variation in the invaded and non-invaded releve's in the three study sites with respect to disturbance, altitude and density of *Lantana.* The result showed that in the invaded releve's (Table7a) in the three sites altitude, disturbance and *Lantana* density showed significant difference at $P \leq 0.025$. In the non-invaded releve's (Table 7b), altitude showed significant difference while disturbance showed no significant difference (at $P \leq 0.000$)

Table 7a ANOVA results of Invaded releve's for Environmental Factors

		Sum of Squares	df	Mean Square	F	Sig.
ALTITUDE	Between Groups	396941.6	2	198470.778	1327.399	.000
	Within Groups	3588.444	24	149.519		
	Total	400530.0	26			
disturbance leve	Between Groups	3.852	2	1.926	4.333	.025
	Within Groups	10.667	24	.444		
	Total	14.519	26			
SHANNONE	Between Groups	1.425	2	.712	6.867	.004
	Within Groups	2.490	24	.104		
	Total	3.915	26			
DENPL	Between Groups	41.407	2	20.704	6.944	.004
	Within Groups	71.556	24	2.981		
	Total	112.963	26			
DENLC	Between Groups	1166.519	2	583.259	15.666	.000
	Within Groups	893.556	24	37.231		
	Total	2060.074	26			

Table 7b ANOVA results of Non-invaded releve's for Environmental Factors

		Sum of Squares	df	Mean Square	F	Sig.
ALTITUDE	Between Groups	393179.6	2	196589.815	481.586	.000
	Within Groups	9797.111	24	408.213		
	Total	402976.7	26			
disturbance level	Between Groups	.963	2	.481	1.040	.369
	Within Groups	11.111	24	.463		
	Total	12.074	26			
SHANNONE	Between Groups	1.175	2	.587	28.814	.000
	Within Groups	.489	24	2.038E-02		
	Total	1.664	26			
DENPL	Between Groups	266.000	2	133.000	78.492	.000
	Within Groups	40.667	24	1.694		
	Total	306.667	26			

5.5 Socioeconomic Importance and Impacts

The respondents have different views on the introduction of *Lantana* and its current status in Ethiopia. About fifty six percent of the respondents agree that it is introduced deliberately as an ornamental plant, while forty four percent of them agree on its accidental introduction. All respondents claim that the species is currently infesting large areas (aided by wind, running water and excretion of animals) and has created problems by displacing indigenous species through competition for resource and shedding. Preventing movement of livestock and humans by forming dense thickets. Serving as host for rats, porcupines and hyenas, which attack their cattle and crops. Encroaches on agricultural land. Decreasing the carrying capacity of pastures. Eighty five percent of the respondents reported seed production as its major means of encroachment.

Hundred percent of the key informants admitted, as there are species which can outcompete it by shedding and competition for resource (for example, *Grevillea robusta*, *Tarenna graveolens*, *Acacia saligna*, *Acacia seyal*, *Asparagus africanus*, *Acacia nilotica*). Eighty three percent of the respondents associate the impact to crop production, through encroachment on farmlands and increasing the labor cost of production. The informants reported that in every sowing season they pay considerable amount of money for daily laborers for clearing *Lantana* from their farmlands.

Livestock production is also affected by the species. Due to its thicket forming nature it inhibits livestock and causes wounding in cattle, goats and sheep. Most of the respondents concluded that the species has more disadvantages than advantages and stressed that they are looking for knowledge/expierience/technology that can assist them in either controlling or eradication of the especies.

About 26%of the respondents have the opinion that no benefits are derived from the species while 74% of the informants admitted that, even if its disadvantage outweigh the advantage, the local people are benefitting from *Lantana*. Based on the respondents response *Lantana* can be used to control erosion; increase soil fertility (Sixty percent of the key informants reported that the soil fertility improves after removing *Lantana*; useful as shedding; fuel wood; medicinal; hedge; food for cattle, monkey, porcupines, rats, birds, etc.

Thirty seven percent of the key informants reported, as there are methods to minimize the detrimental effects of the species and use it in ways that improve biophysical and socioeconomic conditions of the area.

Accordingly:

- Allowing it to grow in highly eroded and flood prone areas rehabilitates the areas and decreases the rate and extent of erosion.
- Planting it around farmlands prevents soil erosion of agricultural lands.
- Planting those species of plants, which can compete or destroy it.
- Using it as ornamental and boundary hedge.
- Cultivating the area.
- Use of herbicides.

Even if *Lantana* offers direct and indirect benefits the attitude of the local people and governm ent and non-government organization is negative.

6. Discussion

6.1 Impacts of Invasion on Species Diversity

In this study, lower diversity indices were recorded in the non-invaded releve's in all the three sites. According to (Barnes, 1997), invaded and non-invaded communities are distinct. Invaded communities have low diversity because invasive plants alter the invaded ecosystem and species composition to such an extent that they threaten native flora and fauna. Thus, the high value of Shannon-Weiner diversity index in the non-invaded plots/releve's and its significant difference ($P<0.005$) in independent t-test in invaded and non-invaded releve's suggests that *Lantana* has impact on the indigenous species composition through decrease in species diversity. This concurs in many studies conducted in different parts and vegetation types of the world (Binggli *et al*., 1998; Morton, 1994; Sharma *et al*., 1988; Hailu, 2002; Kassahun, 1999; Annon, 2003), which have reported that in natural areas the shrub has series deleterious effect on some endemic animals and plant species and is known to displace natural scrub communities as well as prevent natural regeneration of some tree species. Invasive species utilize soil, water and space of the more desired crops of agriculture, forestry and protected areas. They replace natural vegetation and threaten its natural landscape, upsetting ecosystem composition, processs and productivity.

The variation in Shannon-Weiner species diversity index and richness value in the three sites and also one-way ANOVA test for Shannon index in the invaded and non-invaded releve's in the three sites showed significant difference. This may be due to variation in *Lantana* impact brought bydifference in disturbance level. In this study high disturbance level is recorded in site1 (Aroge Adama) and site 3 (Bishofitu) while moderate level in site 2 (Soloqe). Acccording to (Roxana *et al*., 2003), most invasive species thrive on disturbed sites, they could change its disturbance regime (type, frequency and /or intensity). For example, according to (Drake *et al*., 1997), most woody invadedrs (space occupiers) take advantage of disturbance, which over time may develop adverse conditions (velnerability) that the local plants can't tolerate. These suggests that the relatively low diversity in site 1(Aroge Adama) and site 3(Soloqe) to be due to favourable conditions created by high disturbance for the invasive success. However the relatively high diversity in site 2 (Soloqe) suggests low impact of *Lantana* due to the moderate level of disturbance. This is in agreement with (Crawely, 1997), moderate level of disturbance prevent dominance of few species in favour of a higher number of potential colonists.

6.2 Relationship between Vegetation Diversity and Environmental Factors

Disturbance is one of the main factors determining patterns of species diversity. The high disturbance levels experienced in the invaded releve's are assumed to bring decrease in diversity of species. Independent t-test revealed significant difference. Hobbs (1989), found that diversity is related to the level of disturbance. When disturbance is frequent and high, species may not have enough time to properly establish themselves. Thus few species can persist or repeatedly colonize after disturbance, which also results in low diversity. According to (Wilkinson, 1999), diversity declines when local extinction of grazing and trampling sensitive species exceedes the establishment of new grazing and trampling tolerant species. In this study in the non-invaded releve's, disturbances are relatively lower; correspondingly, species diversity was high for all sites.

When disturbance is less intense or less frequent, then a greater number of species are given the opportunity to establish themselves. According to the intermediate disturbance hypothesis (IDH), both high and low levels of disturbances reduce diversity while intermediate levels promote higher diversity. Hobbs (1989), also stated that peak diversity should occur at intermediate frequencies and intensities of disturbances. In this study the high species diversity in site 2 (Soloqe) (Table 1) is due to moderate level of disturbance experienced.

6.3 Correlation between *Lantana camara* Density and Environmental factors

In the study high density of *Lantana* is recorded in site 1 (Aroge Adama) and site 2 (Bishofitu). Hobbes (1989), found that disturbance enhanced the invasion of exotic species by increasing the availability of limiting resources such as light, water or neutrients. Thus the high level of disturbance in site1 (Aroge Adama) and Site 3 (Bishofitu) and the strong positive correlation between disturbance and density of *Lantana* suggests suitability of conditions for *Lantana* invasion due to disturbance. This is also in agreement with (Barnes, 1997), ecologically open and disturbed forest sites offer establishment of introduced organisms.

The strong negative correlation between density of the invasive species and diversity suggests the availability of conducive conditions due to high disturbance for the invasive species success in competition. Barnes (1997), found that disturbance selectively destroys biota and initiates changes in mutualistic and competitive relations, among organisms. It also destroys forest organisms and changes Species composition and site conditions (on parental material, soil, and hydrology) throught shift in the available resource. Their direct effect, cause ecosystem change of which alteration in species composition is one part.

6.4 Socioeconomic Impacts and Importance

The socioeconomic survey made showed that *Lantana* has both direct and indirect advantages and disadvantages to the local people .As a result the local people have different opinion about the plant. The majority of respondents (Seventy four percent) admitted the importance of the species, but maintained that disadvantage out-weighs the advantage.

According to some local people there was high rate/extent of erosion in the form of gullies affecting their farmland before the introduction of *Lantana* to the area but after its introduction the extent and rate of impact of erosion has greatly reduced and the land has become productive. Using *Lantana* as live fence around their farmlands has reduced the effect of erosion. When they cultivate their land after clearing *Lantana* the land becomes highly productive. This is in agreement with (Swarbrick *et al*., 1995*)*, *Lantana* is used as a facilitator of secondary succession, by providing both the humus and shade necessary for successful germination and seedling establishment It is capable of reforesting laterite soils in the humid regions of Madagascar. Hailu (2002), found that Prosopis has changed the harsh conditions of microclimates by revegetation of deteriorated lands and fighting toxicity in the Afar region of Ethiopia. *Lantana* is also useful in providing numerous socioeconomic benefits in Madagascar, domestic hens and, butterflies use it for food (Binggli, 2002).

Despite these facts, the people in the study areas claim that it is affecting crop and livestock production, and indigenous species. This claim may be due to lack of awareness of the ways to use it to improve their socioeconomic and biophysical environment. There for it invites, future studies to adjust the positive and negative impacts of the species to control and eradicate if possible from where it is undesirable and to derive the services it gives where it is desirable when there is no option.

7. Conclusions and Recommendations

The results of the study has indicated that the invasive species *Lantana camara* has impact on indigenous species composition through decreasing species diversity. Disturbance in the form of herbivory was found to be the major factor facilitating the invasion and encroachment of *Lantana*.

Decrease in livestock market and crop production through encroachment on grazing and farmlands is found to be the negative socioeconomic impact. While reclaiming degraded lands, preventing erosion prone areas from erosion, increasing soil fertility and use as a live fence were found the positive socio-economic impacts.

Based on the results the following recommendations are forwarded:

- The society should be awared not to use the land for grazing or browsing more than its carrring capacity, as disturbance in the form of herbivory is found to be the major factor facilitating invasion and encroachment of the species.
- Provision of training on how to use the species to improve biophysical and socio-economic environment. For example; planting it on eroded areas for rehabilitation of the areas, and in erosion prone areas to prevent erosion and to use it for live fence around farmsteads and home gardens.
- Removing it before seed production for seed production is the major means of encroachment to uninvaded areas.
- Planting those species of plants, which can outcompete it.
- Determination of the threshold level for decline in biodiversity and the identification of "management barriers" to invasion.

8. References

Amare Getahun (1976). Some Common Medicinal and Poisness Plants Used in Ethiopian Folk Medicine, A.A.U., Ethiopia.

Anonymous (2003). Invasion Rates and Risks. Online: [www.aliens.csir.co.za]

Anonymous (2003). Guide lines for Mapping Invading Plants. Online:[http://www. Fred.esir.co.za.20/01/2003.

Anonymous (2004). Invasive Alien Plants.Online: [http://www. Plants.USADA.gov. 02/05/2004.

Baars, J.R., and Neser, S (1999). Past and Present Initiatives on the Biological Control of *Lantana camara* (Verbeneceae) in South African Entomology 7:21-33.

Barnes, B.V.and Hopkins, S.B. (1997). Forest Ecology.

Binggeli P.and Desalegn Dessisa (2002). *Lantana camara*. The Invasive that Threaten to Drive People out of their Land. Newsletter of the Ethiopian Wildlife and Natural History Society.

Binggeli, P., Hall, J.B., and Healy, J.R. (1998). An Overview of Invasive Woody Plants in the Tropics. School of Agricultural and Forest Science Publication No.13.University of Wales, Bangor.

BirdLife International (2000). Threatened Birds of the world. Lynx Editions and BirdLife International, Barcelona and Cambridge, UK, 852pp

Craige, W. (2005). *Lantana camara* (shrub): Global Invasive Species Database. Department of Natural Resource, Queens Land, Australia.

Cronk, Q.C.B., and Fuller, J.L. (1995). Plant Invaders, London: Chapman and Hall.

Crawley, M.J. (ed.)(1997). Plant Ecology 2nd edn. Blackwell Science, Cambridge, U.K.

D'Antonio, C.M. (2000). Fire, Plant Invasions and Global Changes. In Mooney, H.A.and H.A.Hobbs (eds). Invasive Species in a Changing World. Island Press. Washington D.C.

Davis, M.A., Grime, J.P.and Thjompson, K. (2000). Fluctuating Resources in Plant Communities: a General Theory of Invisibility. Journal of Ecology88: pp.528-534.

Day, M.D., Wiley, C.J., Playford, J. and Zalucki, M.P. (2003). *Lantana*: Current Management Status and Future Prospects. Austrian Center for International Agricultural Research (ACIAR), Canberra, Australia.

Deka, M.K. (1978). Antifeedant and Repellent Effects of Pongam (*Pongamia pinnata*) and Wild Sage (*Lantana camara*) on Tea Mosquito Pug *(Melopeltis theivora*). Indian J, Agric, Sci.68 (5); 274-276.

Dessalegn Dessisa and Binggeli, P. (2003). Ethiopian Plants.Online:[http://members.lycos.co.uk].

Di casri, F. (1989). Hisiory of Biological Invasions With Special Emphasis on the Old World. John Wiley, New York.

EARO. (1996). IAS (invasive alien species). Removing the Barriers to Invasive Species Management. On line [http://www.undp.org/gef/index.htm/

Edwards, S., Mesfin Tadesse and Hedberg, I. (eds.)(1995). Flora of Ethiopia and Eritrea, Vol.2: Cancellaceae to Euphorbiaceae, Addis Ababa and Uppsala.

Edwards, S., Sebsebe Demissew and Hedberg, I. (eds.)(1997). Flora of Ethiopia and Eritrea, Vol.6: Hydrocharitaceae to Arecaceae, Addis Ababa and Uppsala.

Edwards, S., Sebsebe Demissew and Hedberg, I. (eds.)(2000).Flora of Ethiopia and Eritrea, Vol.2 part 1:Magnoliaceae to Flacourtiaceae, Addis Ababa and Uppsala.

Gentle, C.B., and Duggin, J.A. (1997). *Lantana camara* L.Invasions in Dry Rain Forest-Open Forest Ecotones. The Role of Disturbances Associated with Fire and Cattle Grazing. *Australian Journal of Ecology* 22; 298-306.

Ghorden, D.R. (1998). Effects of Invasive, Non-indigenous Plant Species on Ecosystem Processes: Lesssons from Florida. Ecological Applications (4), pp.975-989.

Greathead, D.J. (1971). A Review of Biological Control in the Ethiopian Region. Technical Communication. Common Wealth Institute of Biological Control 5:1-162.

Hailu Shferaw.(2002).Some Biological Characteristics that Foster the Invasion of *Prosopis juliflora* (sw.) DC.at Middle Awash Rift Valley Area, Northeastern Ethiopia. Maters Thesis, Addis Ababa University.

Hedberg, I.and Edwards, S. (eds.)(1989). Flora of Ethiopia and Eritrea, Vol.3; Pittosporaceae to Araliaceae.Addis Ababa, Asmara and Uppsala 660 pp

Hedberg, I.and Edwards, S. (eds.)(1997). Flora of Ethiopia and Eritrea, Vol.7; Poaceae (Graminae). Araliaceae.Addis Ababa and Uppsala 420 pp

Hedberg, I.and Edwards, S. and Sileshi Nemomissa (eds.)(2003). Flora of Ethiopia and Eritrea, Vol.4; part 1:Apiaceae to Dipsacaceae.Addis Ababa and and Uppsala 420 pp

Henderson, L. (2001). Alien Weeds and Invasive Plants .A Complete Guide to Declared Weeds and Invaders in South Africa. Plant Protection Research Institute Handbook No12.

Heywood, V.H.; Gardner.A.K. (eds.). (1995). Global Biodiversity Assesment.UNEP, Cambridge University Press.

Hobbs, R.J. (1989). The Nature and Effects of Disturbance Relative to Invasions. A Global Perspective.Drake, J.A., Mooney, K.A, DiCastri, F. (eds). Wiley.Chichester, UK.pp.389- 405.

Hobbs, R.J. (2000). Land Use Changes and Invasions. In Mooney, H.A.and H.A.Hobbs (eds). Invasive Species in a Changing World. Island press. Washington D.C.

Kassahun Zewdie. (1999). *Prosopis* (*Prosopis juliflora*) in Ethiopia (Fassil Reda, Tanner, D.G., (eds.) Arem 5,96-102.Ethiopian Weed Science Society, Addis Ababa, Ethiopia.

Katerina, B; Bohumil, M and Ivana, K. (2004). How Does Reynoutria Invasion Fit the Various Theories of Invisibility? Journal of Vegetation Science 15:495- 504.IAVS: Opulus Press Uppsala.

Keeley, J.E. (2001). Fire and Invasive Plants in Mediterranean-climate Ecosystems of California. In: Galley K.E.M, and Wilson, T.P. (eds), Proceedings of the Invasive Species Workshop: the Role of Fire in the Control and Spread of Invasive Species. Fire Conference. Tall Timbers Research Station, Tallahassee, FL.

Kingston, N and Waldren, S. (2003). The Plant Communities and Environmental Gradients of Pitcairn Islands: The Significance of Invasive Species and the Needs for Conservation Management. Annuals of Botany 92:31- 40.

Kowarik, I. (2003). Biological Invasions: Neophyten und Neozoen in Mitteleuropa.Verlag Eugen Ulmer, Stuttgart, Germany, 380pp

Kumelachew Yeshitela and Taye Bekele. (2003). The Woody Species Composition and Structure of Masha-Anderacha Forest, Southwestern Ethiopia, *Ethiop.J.Biol.Sc*. 2(1): 31- 48.

Lyons, E.E and Miller, S.E. (1999). Invasive Species in East Africa: Proceedings of the Workshop Held at ICIPE.ICIPE Science Press, Nairobi, Kenya.

Mack.M.C. and D'Antonio. C.M. (1998). Impacts of Biological Invasions on Disturbance Regimes. Tree vol.13, no 5, pp195-198.

Mack.R.N. (2000). Assessing the Extent, Status and Dynamism of Plant Invasions: Current and Emerging Approaches. In Mooney, H.A.and Hobbs, H.A. (eds). Invasive Species in a Changing World. Island press. Washington D.C.

Mailu, A.M. (2001). Preliminiary Assessment of the Social, Economic, and Environmental Impacts of Water Hyacinth in the Lake Victoria Basin and the Status of Control. In: Julien, M.H and Integrated, Hill, M.P.Center, T.D. and Ding Jianqing (eds) Biological Control of Water Hyacinth, *Eichhornia crassipes*. ACIAR proceedings 102.

McNeely, J.A., Mooney, H.A., Neville, L.E., Schei, P. and Waage, J.K. (eds) (2001).A Global Strategy on Invasive Alien Species. IUCN, Gland, Switzerland and Cambridge, UK in Collaboration with the Global Invasive Species Program.

McNeely, J.A. (2000). The Future of Alien Invasive Species: Changing Social Views. In Mooney, H.A.and Hobbs, H.A. (eds). Invasive Species in a Changing World. Island Press.Washington D.C.

McNeely, J.A. (2001). The Great Reshuffling. Human Dimensions of Invasive Alien Species. IUCN, Gland and Cambridge, 242pp.

Mooney, H. A.and Hobbs, R.J. (eds). (2000). Invasive Species in a Changing World. Island Press, Washington, D.C.

Morton, J.F.(1994).*Lantana*, or a Red Sage (*Lantana camera* L., (Verbeneceae), Notorious weed and Popular Garden Flower; Some Cases of Poisoning in Florida. Economic Botany 48:259-270.

Perrings, C., Williamson, M., and Dalmazzone, S. (eds). (2000). The Economics of Biological Invasions. Edward Elgar, Cheltenham.

Pimental, D., Lach, L., Zuniga, R. and Morrison, D. (2000). Environmental and Economic Costs of Nonindigenous Species in the United States. Bioscience 50,53-56.

Richardson, D.M.., Pysek, P., Rejmanek, M., Barbour, M.G., Panetta, F, D. and West C, j. (2000). Naturalization and Invasion of Alien Plants: Concepts and Definitions. Diversity and Distributions 6:93-107.

Roothaert, R.L. (2000). The Potential of Indigenous and Naturalized Fodder Trees and Shrubs for Intensive Use in Central Kenya.

Roxana, A and Msnuel, M.J.(2003).Species Composition and Invasion in NW Argentinian Secondary Forests: Effects of Land use History, Environment and Landscape. *Journal of Vegetation Science* 14:195-204.IAVS: Upulus Press Uppsala.

Segretain, B; Helene and Arnauld, E. (2004). Experiments on Ggrowth Interactions Between two Invasive Macrophyte Species. *Journal of Vegetation Science* 15:109- 114.IAVS: Opulus Press Uppsala.

Sharma, O.P., Makkar, H.P.S.and Dawra, R.K. (1988). A Review of the Noxious Plant *Lantana camara*. Toxicon 26; 957-987.

Sharman, R.R.(1974).*Lantana camara*; Its Introduction, Dispersal and Impact on Islands of the Tropical Pacific Ocean. Micronesica 10:17-39.

Sutherst, Robert W.(2000).Climate Change and Invasive Species. A Conceptual Framework. In Mooney, H.A.and Hobbs, H.A. (eds). Invasive Species in a Changing World. Island press. Washington D.C.

Swarbrick, J.J., Willson, B.W., and Hannan, J M.A. (1995). The Biology of Australian Weeds. 25.*Lantana camara L*. Plant Protection Quarterly 10:82-95.

Syed, Z.Guerin, P.M. (2004). Tsetse Flies are Attracted to the Invasive Plant *Lantana camar*. A Journal of Insect Phisiology 50, 43-50.Instituts of Zoology, University of Neuchatel, Switzerland.

Thakur, M.L., Ahmad, M and Thakur, R.K. (1992), *Lantana* Weed (*Lantana camara Var.aculeate* linn). And its Possible Management Through Natural Insect Pest in India. Indian Forester 118(7): 466-485.

UNEP, (2000b). Decisions Adopted by the Conference of the Parties to the Convention on Biological Diversity at Its Fifth Meeting, UNEP, Nairiobi.

UNEP, (2000c). Policy Recommendation: Alien Species that Threaten Ecosystem<UNEP, Nairobi.

U.S. Congress. (1993). Harmful Non-indigenous Species in the United States. Office of Technology Assessment. OTA- F-565.US. Congress Government Printing Office, Washington DC, USA.

VanWilgen, B.W., Little, P.R., Chapman, R.A., Gorgens, A.H.M., Willems, T.and Marais, C.(1997). The Sustainable Development of Water Resources: History, Financial Costs, and Benefits of Alien Plant Control Programs. *South African Journal of Science* 93, 404-411.

Vitousek, P.M. (1996). Biotic Invasions as Global Environmental Change. American Scientist.

Walter, H. (1975). Vegetation of the Earth and Ecological Systems of the Geosphere.3rd ed.SpringerVerlag.Berlin.318pp

Weber, E. (2003). Invasive Plant Species of the World. A Reference Guide to Environmental Weeds.Cabi Publishing, Oxford, England.

Whittaker, R.H. (1975). Communities and Ecosystems 2nd(edn) Gollier Macmillan publishers, London.

Wilkinson, D.M (1999). The Disturbance History of Intermediate Disturbance. Oikos 84(1) pp.145-147.

William, K. (2003). *Lantana (Lantana camara*): Weeds of National Significance: Weed Management Guide. Department of Environment and Heritage and the CRC for Australian Weed.

Williamson, M. (1996). Biological Invasions. Chapman and Hall, London, 244pp

Wittenberg, R. and. Cock, M.J.W. (2000). Invasive Alien Species: a Toolkit of Best Prevention and Management Practices. Global Invasive Species Programmme, CAB Intenational, Willigford, Oxon, UK.

World Bank (2000). World Development Report.Oxford University Press, Oxford.

World Resource Institute (1994). World Resource: 1994-95.Oxford Universtiy Press, New York.

Appendices

Appendix 1. Species List from the Study Areas.

Scientific Name	Vernacular name	Habit	Family
Acacia albida Del.	Gerbi (Oro.)	T	Fabaceae
Acacia etbaica Schweinf.	Dere (Amh.)	T	Fabaceae
Acacia polycantha willid.	Nechi Kontir (Am) Sebekisa (Or)	T	Fabaceae
Acacia nilotica (L.) willid.ex Del.	Kesele (Am)	T	Fabaceae
Acacia saligna (Labill.) Wendl.	Kacha (Am)	T	Fabaceae
Acacia seyal Del.	Wacho (Or)	T	Fabaceae
Acokanthera schmperi (A.Dc.)	Keraro (Oro)	T/S	Apocynace

	Merenz (Am)		
Allophyllus alnifolius (Bak.) Radlk.	Chakima	T	Sapindacea
Aloe citrina Carter&Brand hm	Ret (Am)	H	Aloaceae
Alternanthera nodiflora R.Br.	Yeset milas (AM)	H	Amaranthacea
Anthospermum herbaceum Lf.	Dergu (Am)	H	Rubiaceae
Argemone mexicana L.	Koshesile (Or) Nechi Lebash (Am	H	Papaveraceae
Aristida adscensions L.	Asendabo (Or)Yewisha Sindedo (Am)	G	Poaceae
Asparagus africanus Lam.	Serite(Or)Kesentic(Or)	S	Asparagacea
Balanites glabra Midbr.And Schlechf.	Bedena(Or)Gemo(Am)	T	Balanitaceae
Bromus pectinatus Thunb	Gomech	G	Poaceae

Appendix 1 cont'ed

Calpurnia aurea (Ait.) Benth	Digita (Am)	S/T	Fabaceae
Carissa edulis Wahl.	Agam (Am)	S	Apocynacea
Chioris gayana Kunth.	Grass	G	Poaceae
Croton macrostachyus Del.	Bisana (Am)	T	Euphorbiacea
Cymbopogon commutatus (Steuid*)*	Sennbelet (Am)	G	Poaceae
*Cynodon dactylon(L.)*pers	Serdo(Am)	G	Poaceae
Datura stramonium L.	Atse faris (Am)	H	Solanaceae

Dichrostachys cinerea(L.) Wight &Arn	Ader (Am)	S	Fabaceae
Dipsacus pinnatifidus A.Rich.	Abadabo (Am)Raskimir(Am)	H	Dipsacacea
Dodenea angustifolia L.f.	Kitikita (Am)	T/S	Sapindacea
Echinops macrochaetus. Fresen	Yahiya joro (Am)	H	Asteraceae
Euclea divinorum Hiern	Dedeho (Am)	S	Ebenaceae
Euphorbia cyparissiodes pax	Anterfa (Am)		Euphorbiacea.
Grevillea robusta R.Br.	Saligna	T	Proteaceae
Grewea ferruginea Hochst.	Teye (Am)	S	Tiliaceae
Harpachne schimperi A.Rich	Grass	G	Poaceae
Helinus mystacinus (Ait.) E.mey.ex steuid.	Kechachilo (Or)	S	Rhamnaceae

Appendix 1 cont'ed

Hibiscus micranthus L.fil	Chfirig (Am)	S	Malvaceae
Jasminium abyssinicum Ho Chst.ex Dc	Tembelel (Am)	W cli.	Oleaceae
Lantan camara L	Yewef kollo (Am) Tikure (Am)	S	Verbeneceae
Lithania somnifera	Gizawa (Am)	S	Amaranthaceae
Ocimum forkaolei Benth	Damakessie	S	Lamiaceae
Opuntia ficus- indica (L) Millert	Kulkual (Am)	H	Euphorbiaceae

Parthenium hystrophorus L.	Akenchira	H	Asteraceae
Rumex nervousus vahl.	Embuwachow	S	Polygonaceae
Senna didymobotrya (Fresen.) Irwin &Barneby	Sue sue (Am)	S	Fabaceae
Senna septemtrionalis (viv.) Irwin&Barnbey	Kelteme (Am)	T	Fabaceae
Tagetes minuta L	Gimie (Am)	H	Asteraceae
Tarenna graveolens (S.moore) Bremek	Bunit (Or) Wenehe (Am)	S/T	Rubiaceae
Zizipus spinachristi (L.) Desf.	Kurkura (Am)	T	Rhamnacae

T: tree; S: shrub; H: herb; W. cl.; woody climber; G: grass.

Am-Amhric;Or-oromiffa

Identification was done flora of Ethiopia: volume 1-4,6&7

Appendix ii Semi-structured Interview

Name of the Informant---Age--------Sex------

Occupation-----------------Vernacular Name of the Species----------------------.

1.How do you think the species is introduced?

A) intentional B) marketing C) accidental D) trade

E) aid shipment F) others

2.How is mechanism of encroachment or invasion?

A) seed production B) root system C) other mechanism

3.In which is the species dominant?

A) cultivated land B) home garden C) grazing fields D) others

4.In which community does the species bring greatest impact?

A) grazing land B) crop field C) agro forestry D) plantations

E) others

5.How is it effect?

A) allelopathy B) shedding C) consumption of resources/ nutrients, water

6.Which species is/are flourishing after the invasion by the species?

7.What reason do you think for the favour?

8.What is the beneficial aspect/economic importance of the species?

A) market value B) shading C) construction D) fuel wood/charcoal

E) Forage/grazing value F) medicinal G) food F) others

9.Is there change in socioeconomic and biophysical environment in the area due to the species?

A) Water use capacity B) livestock market (Agro economics) C) on erosion

D) Salinity E) on movement of human beings F) others

10.How do you minimize the detrimental effects of the species? (Method employed to be beneficial)

11.How is the species used sustainably and in environmentally friendly way in the improvement of socioeconomic condition?

12.Is there indigenous knowledge to wipe out the species? YES or NO.

13.Is there help from NGOS and GOS to wipe out the species? YES or NO

Appendix ii cont'ed

14.Does it have effect on livestock?

15.What impact does the species brings

16.What type of health effect on human beings?

17.Does it produce poisness chemical?

18. What is the status of the species in the area?

Appendix iii: Summary of Environmental Factors Assesed for all Study Sites Invaded and Non-invaded releve's.

Code	Alti.(m)	Dist. Level	Type of Dist	Shannon index	No. of Native Spp	Abund. of Lantana
1	1650	3	BT	1.39	3	25
2	1621	3	BT	1.39	6	26
3	1670	3	BT	1.61	6	23
4	1645	2	BT	1.79	6	15
5	1653	2	BT	1.79	11	10
6	1673	3	BT	1.1	10	31
7	1636	3	BT	1.39	6	26
8	1655	3	BT	1.61	8	30
9	1677	1	BT	1.79	4	9
10	1678	2	GT	1.95	10	0
11	1685	2	GT	1.95	8	0
12	1686	1	GT	2.3	12	0
13	1681	3	GBT	1.79	9	0
14	1676	2	BT	1.95	10	0
15	1673	2	GBT	1.95	8	0
16	1660	3	GBT	1.79	10	0
17	1658	2	GT	2.08	8	0
18	1676	1	GT	2.2	8	0
19	1607	3	GBT	1.1	4	20
20	1611	2	GT	1.79	4	9
21	1607	2	BT	1.79	5	10
22	1589	2	GT	1.79	6	9
23	1595	1	GT	2.4	6	7
24	1595	1	BT	2.3	3	8
25	1595	2	GT	1.79	4	11
26	1596	1	Gt	2.08	5	8
27	1594	3	GBT	1.39	6	17
28	1611	1	GT	2.3	7	0
29	1614	2	GT	2.08	7	0
30	1620	1	GT	2.48	11	0
31	1615	2	GT	2.08	6	0
32	1611	1	GT	2.3	7	0
33	1607	2	BT	2.08	7	0
34	1604	1	GT	2.3	6	0
35	1605	2	GT	2.08	8	0
36	1601	2	BT	2.08	9	0

37	1884	2	GT	1.609	5	20
38	1879	3	BGT	1.099	3	31

Appendix iii cont'ed

39	1876	3	RT	1.386	4	28
40	1873	3	RT	0.693	2	30
41	1874	2	GT	1.609	5	18
42	1868	3	GBT	1.099	3	25
43	1895	3	GBT	1.386	4	31
44	1882	3	RT	1.099	3	28
45	1879	3	RT	1.386	4	30
46	1881	3	GBT	1.609	3	0
47	1880	1	GT	1.792	1	0
48	1885	1	GT	1.792	1	0
49	1890	2	GT	1.609	2	0
50	1922	1	BT	1.792	1	0
51	1930	2	BT	1.609	2	0
52	1834	3	BT	1.609	3	0
53	1938	2	GT	1.792	2	0
54	1868	2	GT	1.609	2	0

GB: grazing &browsing; GT: grazing &trampling; BT: browsing &trampling;

GBT: grazing browsing&trampling; RT: stone removal &trampling

Declaration

I the undersigned, declare that this thesis is my original work and has not been presented for the award of a degree in any university and all the resources of materials used for this thesis have been duly acknowledged.

Name --------------------------

Signature --------------------

Date and place of Submission: Environmental Science Program Addis Ababa University

June 2005.