

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

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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 Bishofitu 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 mainroad. There 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-four percent of the key informants admitted the benefits obtained from it even though they maintained the disadvantage outweighs its advantages. Thirty seven percent of the key informants responded as there are methods to minimize the detrimental effects & use it to improve biophysical & socio economic condition of the areas.

Keywords: *Lantana camara*, Invasive species, Indigenous species, invaded.

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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 literature on invasive species such as Williamson (1999); McNeely (2000); Wittenberg et al., (2000); McNeely (2001), among others. (The 1996 UN conference on invasive species ranked these species second only to habitat destruction 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, 2000; Hobbs, 2000), 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 alternative genetic diversity, transmit exotic genetic

diseases to native species, and further jeopardize 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 (Takur et al, 1992; Dessalegn, 2003; EARO). *Lantana* tolerates a wide range of climates and is found anywhere 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^o 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 wide spread Ethiopian Agricultural Research 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, ethno botanists, 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. Material and Methods

2.1. Description of Study Area

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^o30'N latitude and 39^o 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 favourable 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. The mean annual temperature and rainfall of Adama is 20.194^oC and 741.43mm respectively. Its mean maximum temperature reaches 30.8^oC in May, whereas the mean minimum temperature is 12^oC in December. Its wettest season is between July (219.282mm) and September (104.455mm) of rainfall, but the mean maximum and minimum rainfall are 223.45 mm and 13.8 mm in August and February respectively.

Bishofitu lies at latitude 8^o44'N and longitude 38^o58'E, with an average altitude of 1,850masl. 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. The mean annual temperature and rainfall of Bishofitu is 18. 8^oC and 711.84mm respectively. Its mean maximum temperature reaches 29.5^oC in May whereas the mean

minimum temperature is 9°C 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.

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. In spite 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 south eastern hills gathered in the south eastern depression create swamp, which become mosquito breeding sites. The topography of Bisihofitu area is greatly altered by the geologic formation of crater lakes.

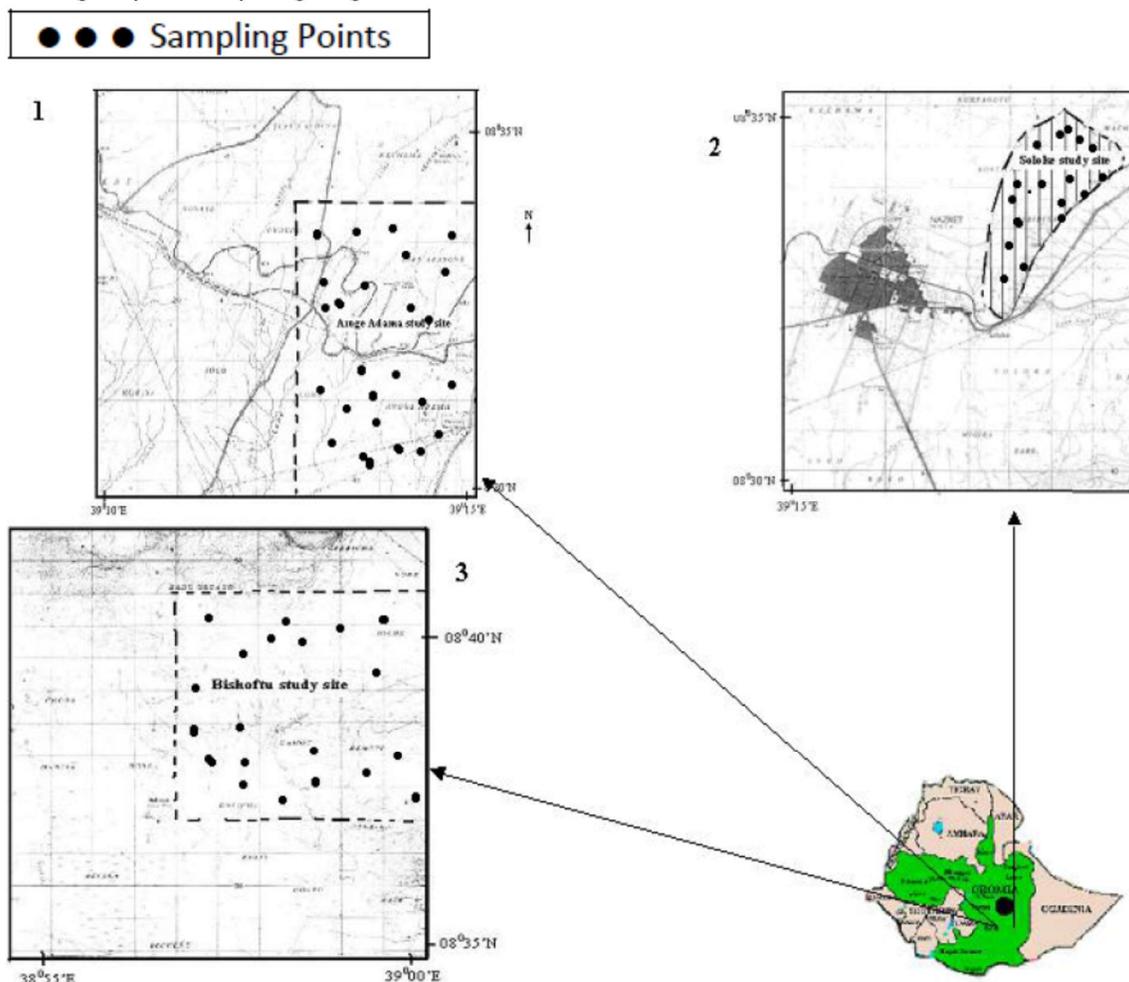


Fig 1 Map of the Study Sites: (1). Aroge Adama (2). Soloqe (3). Bishofitu Source Ethiopian Mapping Authority.

2.2. Data Collection

2.2.1 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 Bishofitu. 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, 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 within 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 and Taye, 2003).

2.2.2 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.

2.3 Data Analysis

2.3.1 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 (ρ), for altitude, disturbance, and density of Lantana were determined

2.3.2 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 analysed using SPSS program.

3. Results

3.1 Species Diversity

Table1 Shannon-Weiner diversity and species 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)	
	Invade	Non-inv	Invaded	Non-inv	Invaded	Non-inv
d						
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 site1 (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 (Table3).

Table 3: P-value for independent sample t-test for the three study sites (Site 1: Aroge Adama; Site 2: Soloque; Site3: 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

3.2 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.

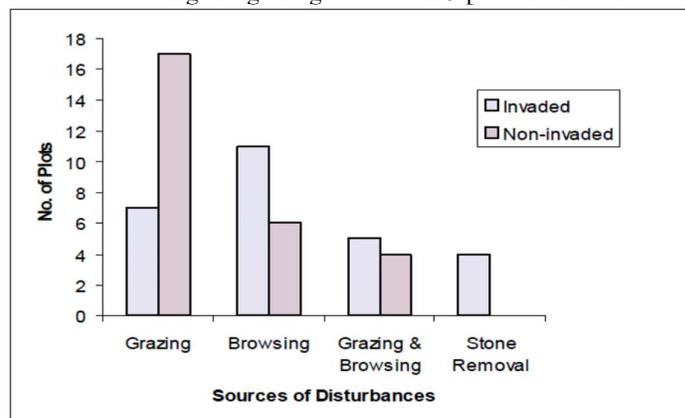


Fig.3 Sources of Disturbances in the Plots Sampled in Invaded and Non-invaded releve's in all the three Study Sites

3.3 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.

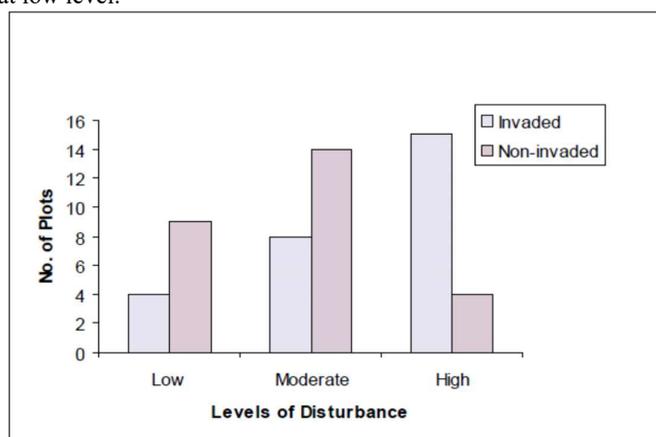
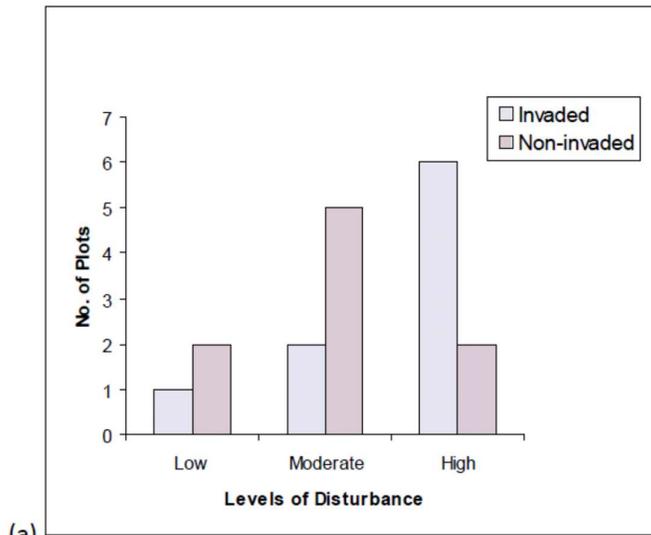
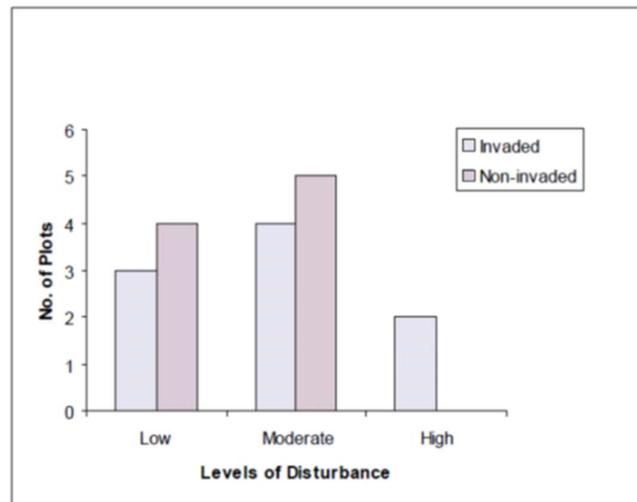


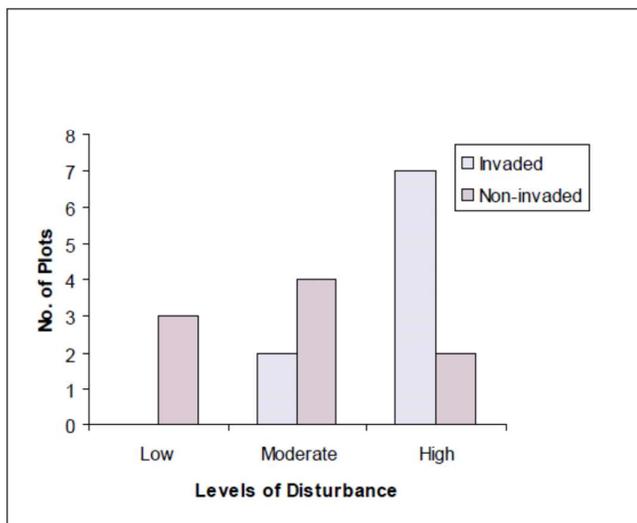
Fig 4. Levels of Disturbances in all the Plots Sampled in Invaded and Non-invaded releve's



(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 (Fig5a).

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

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

**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 rs(rho) for Non-invade releve's of Aroge Adama

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

Table5a Spearman correlation rs (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	Dist. lev	Correlation Coefficient	.036	1.000	-.977**	.088	.943**
		Sig. (2-tailed)	.926	.	.000	.822	.000
		N	9	9	9	9	9
H'	H'	Correlation Coefficient	-.120	-.977**	1.000	.005	-.957**
		Sig. (2-tailed)	.758	.000	.	.991	.000
		N	9	9	9	9	9
D/NPLs	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	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 rs (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	Dist. lev	Correlation Coefficient	-.174	1.000	-.968**	.045
		Sig. (2-tailed)	.654	.	.000	.908
		N	9	9	9	9
H'	H'	Correlation Coefficient	.299	-.968**	1.000	.117
		Sig. (2-tailed)	.434	.000	.	.764
		N	9	9	9	9
D/NPLs	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 plant density is negatively correlated with disturbance (r: 0.787) (at $P \leq 0.05$)

Table 6a Spearman correlation rs (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	dist	Correlation Coefficient	-.104	1.000	-.753*	-.753*	.731*
		Sig. (2-tailed)	.790	.	.019	.019	.025
		N	9	9	9	9	9
H.	H.	Correlation Coefficient	.383	-.753*	1.000	1.000**	-.734*
		Sig. (2-tailed)	.309	.019	.	.	.024
		N	9	9	9	9	9
D NPL	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	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 rs (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	Dist. lev	Correlation Coefficient	-.267	1.000	-.787*	1.000**
		Sig. (2-tailed)	.487	.	.012	.
		N	9	9	9	9
H'	H'	Correlation Coefficient	.346	-.787*	1.000	-.787*
		Sig. (2-tailed)	.361	.012	.	.012
		N	9	9	9	9
D/NPLs	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 (Table 7a) 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			

3.5 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/experience/technology that can assist them in either controlling or eradication of the species.

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 farm lands 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 government and non-government organization is negative.

4. Discussion

4.1 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 & Dessalegn 2002; 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 land scape, upsetting ecosystem composition, process 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 by difference 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). According 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 invaders (space occupiers) take advantage of disturbance, which over time may develop adverse conditions (vulnerability) 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 favorable 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 favor of a higher number of potential colonists.

4.2 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 exceeds 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) (Table1) is due to moderate level of disturbance experienced.

4.3 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 nutrients. 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) through shift in the available resource. Their direct effect, cause ecosystem change of which alteration in species composition is one part.

4.4 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 micro climates 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.

5. 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 aware not to use the land for grazing or browsing more than its carrying 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 farm steads 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.

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