Impact of Invasion: A case study on the ecological and socioeconomic impact of *Lantana camara* (L.) in Abay Millennium Park (AMP), Bahir Dar, Ethiopia

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Lantana camara (L.), a highly aggressive exotic environmental weed in many countries, has significant adverse effects on biodiversity. It forms dense thickets, suppressing native vegetation and seedlings through shading, nutrient competition, smothering and allelopathy. This study was carried out to quantify ecological distribution, abundance and effects of L. camara on different land uses, and to assess the perception of the local community concerning its impacts on environment and biodiversity of the study area, Abay Millennium Park, Bahir Dar. To do so, 20 m x 20 m (trees) and inside which 5m x 5m nest plots (shrubs and saplings), 2mx2m (seedlings) were laid. Vegetation data were collected using purposive sampling technique with quantitative measurements (DBH, density, seedling and sapling count). Furthermore, semi-structured questionnaire was used to collect data about socio-economic and ecological impacts of the plant. Results revealed that L. camara has shown highest invasion (82.1%, grassland) and least invasion (34.6%, riverine forest), cultivated land being intermediate (57.5%). Plant species density was high at the lower class (<6 cm DBH, covering 83.94% of total plants sampled, showing the area was dominated by shrubs (1821 individuals/ha). At species level, L. camara exhibited an inverted J-shaped frequency distribution (62.21%, < 2 cm DBH), screening its greater regeneration potential. Also, there was high diversity and species richness (excluding L. camara) with H'=2.6980 & S=45, natural riverside forest, H'= 1.8173 & S=28 cultivated land, and H'=0.3446 & S=14, grassland. The socio-economic and ecological impact study as well, revealed L. camara was perceived as more disadvantageous (90% of the respondents), and therefore, they highly recommend, if possible, for its complete removal from the area.

Key words: *L. camara*, ecological distribution, AMP, land use, socioeconomic and ecological impact

INTRODUCTION

The deliberate or accidental introduction of non-indigenous species to new habitats has become an increasingly important aspect of global environmental change (Pimentel *et al.*, 2000; Mack *et al.*, 2000; Andersen *et al.*, 2004; Malik and Husain, 2007) and can cause important economic, environmental and social losses (Goulson and Derwent, 2004). Many research works have shown that invasive plant species have broad distribution throughout the world and can directly or indirectly affect the food security of local residents by destroying natural pasture, displace native trees, crops, and reduce grazing potential of rangelands and set limitations for economic development (Manchester and Bullock, 2000; Stohlgren *et al.*, 2001; Pauchard and Alaback, 2004; Anderson, 2005; Dogra *et al.,* 2009). Invasion is considered as the second most widespread threat to global biodiversity next to habitat destruction (Sharma *et.al.,* 2005) of natural ecosystems worldwide (Hayson and Murphy, 2003; IUCN/SSC/ISSG, 2004; Sala *et al.*, 2005;; CBD, 2005, Sharma and Raghubanshi, 2009). Once an invasive species becomes firmly established, its control often becomes difficult and eradication is usually impossible (Primental.et el., 2000).Therefore, exotic species will forever be common components of every ecosystem on Earth.

The impacts of alien species are enormous. They cause alteration in ecosystem processes and community structure, decline in abundance and richness of native flora (Sander, 1998; Stohlgren *et al.*, 2001) and many more. Globally, the extent of damage caused by invasive species has been estimated to be £1.5 trillion per year, close to 5% of global GDP. In developing countries, where agriculture accounts for a higher proportion of GDP, the negative impact of invasive species on food security, they exacerbate poverty as well as on economic performance can be even greater (Pimentel *et al.*, 2000; Manchester and Bullock, 2000; IBC, 2009). Due to its strong allelopathic properties, aggressiveness and its dense impenetrable thorny thickets, *Lantana camara* has the potential to interrupt the health and regeneration process of other species by decreasing germination, growth of seedlings and biomass production which in turn increases mortality and decline of plant species, pasture and crops (Gentle and Duggin, 1998; Catherine and Russell, 2005; Sharma *et al*., 2005 and Sharma and Raghubanshi, 2006).

A native of Central and South America (Spies and Duplessis, 1987; Day *et al.*, 2003), *Lantana camara* (as coined by Carlous Linnaeus in 1753; Swarbrick et al. 1995), contains approximately 270 species and subspecific taxa of woody shrubs (Mendez-Santos, 2002; Bhakta and Ganjewala, 2009). The genus Lantana ranked among the 100 worlds worst invasive alien species (Day, 2003; GISP, 2006). The diverse and broad geographic distributions of the species beyond its native range are the reflection of its wide ecological tolerance, ability to conquer diverse habitats and its success on a variety of soil types (Day *et al.*, 2003; ECZ, 2004). It is now a cosmopolitan weed and has been declared as a noxious weed in many parts of the world (Benggeli *et al.*, 1998; Goulson and Derwent, 2004). It is particularly a weed of the tropics and sub-tropics of the worldwide becoming naturalized in approximately 60 countries (Day *et al*. 2003).

The spread of invasive plant species in Ethiopia is a growing concern in national parks, lakes, rivers, power dams, and urban green spaces - causing huge economic and ecological losses (Hailu *et al.,* 2004, Kassahun *et al.,* 2004). In Ethiopia, invasive plant species have become major threats to biodiversity loss and socio-economic welfare of the people. The prominent ones include *Parthenium hysterophorus*, *Prosopis juliflora*, *Eichhornia crassipes*, *Lantana camara* Acacia species (*A. drepanolobium and A. melifera)* and declared the need for their control and eradication (Taye *et al.* 2007; Mckee, 2007). *L. camara* was introduced into Ethiopia as an ornamental plant due to its beautiful aromatic flowers (Binggeli and Desalegn, 2002). However, because of prolific seed production and easy dispersal, it escaped cultivation and become a pest social, ecological and economic concerns. Presently, it has spreaded almost all over the country, but still it is not much perceived as a chronic environmental problem, except in few parts of Ethiopia, such as Oromia and Somali regions (Binggeli and Desalegn, 2002). Currently, there is little information available on spatial distribution of *Lantana camara* invasion and its potential geographic spread.

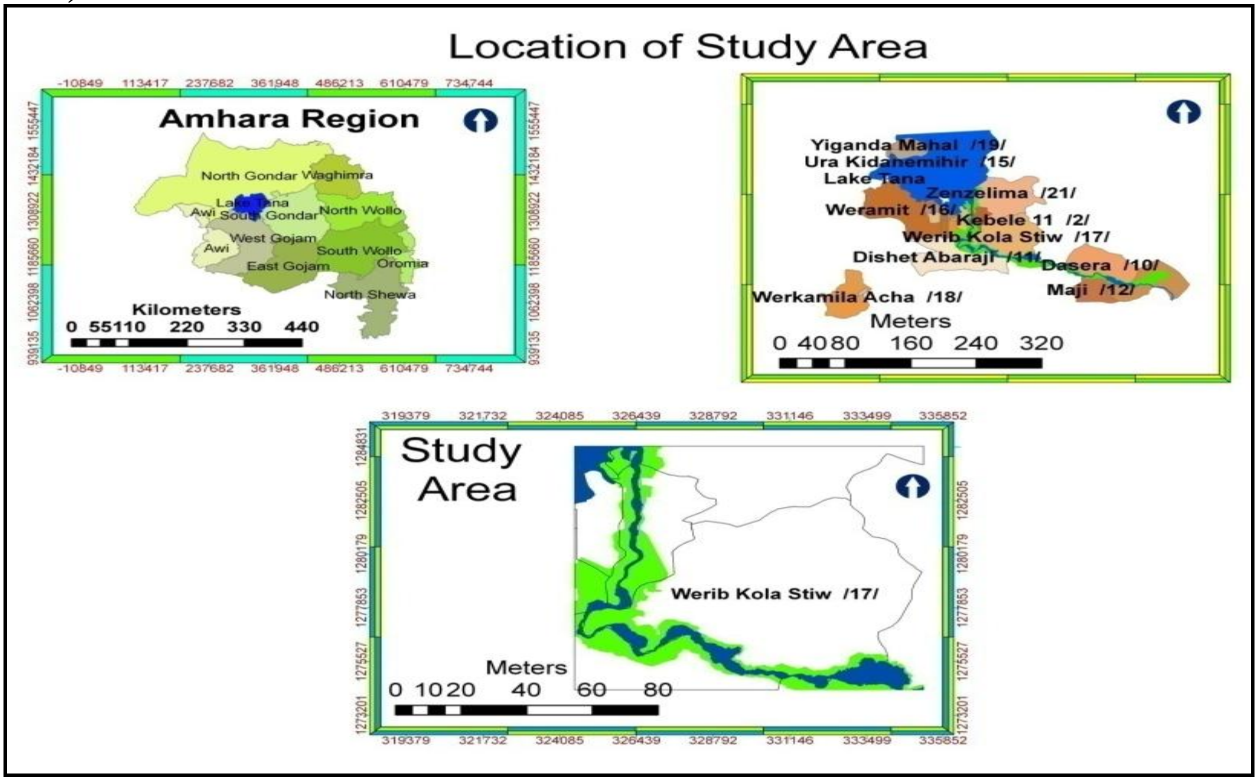
Lantana was brought from Addis Ababa by Ato Alubel Kassa in 1985, the local administrator of Bezawit Palace at that time, and planted as one of the ornament species in and around the natural forest patch. Within 25 years of introduction, it has covered about 60 hectare of the park area, Abay Millennium Park (AMP) and currently it is highly spreading and destroying the forage and habitats of animals and other native plant species in the park. While having vast horizons of both ecological and environmental significance in the park, so far due attention is not yet given by the concerned body. Moreover, there is no paramount ecological investigation, which is done to either indicate the status or the extent of this invasive weed distribution and economic disadvantages in the study area. Therefore, goal of this study is to carry out an ecological investigation on the distribution, invasion impact on different land uses and associated plant species of *L. camara* and to assess the perception of the local community concerning its impacts on the biodiversity of AMP.

MATRIALS AND METHODS

Study area

The study was carried out at Bezawit in AMP, Bahir Dar zuria woreda, Ethiopia. The topography of the park is characterised by gentile undulating plateau with meandering river course and slow flow of water. The vegetation structure is composed of evergreen, moist riverine forest with scattered islands of dense forests. This largely protected riverian park covers 4680 ha (Abraham, 2009) and extends up to 39 km along the course of Abay River (Berhanu *et al*, 2007). This park is located at 11^0 28' to 11^0 38' N and 37^0 23' to 37^0 36 E (Berhanu *et al*, 2007). Bezawit, the present study site (Fig. 3) covers an area of about 60 hectares, and is found under Worebkolasion Kebele, adjacent to Abay (Berhanu *et al*., 2007).This area has very high diversity of woody plant species (Abraham, 2009).

Figure 1 Map of the study area [(Source: ANRS, BoFED, 2007).



Data source and material

In this study, to investigate the relative ecological distribution, socio-economic and ecological impacts of *L. camara*, both primary and secondary data sources were collected. Primary data were generated from preliminary survey, field work and the responses of the local people, agricultural experts and park managers who involved directly or indirectly with the plant using questionnaire and interview. On the other hand, secondary data were obtained from Bahir Dar city master plan, published materials including books, journals, research articles and census reports.

Field data collection

A reconnaissance survey and group discussion was carried out with the residents of Bezawit kebele. This was conducted in Oct 16-20, 2010 to collect base line information, observe vegetation distribution and to determine the number of transect lines and plots that would be laid. Subsequently, field survey was carried out from Oct. 21 to Nov. 15, 2010 to determine whether there was a gradient in indigenous plant diversity at different land uses caused by of Lcamara invasion and to identify plant species threatened. The length and the width of the plots were measured using tape measure and ropes. Total count of each plant species along transect was recorded. The variation of habitats with respect to altitude was measured with GPS.

Sampling technique

Data on vegetation were collected using systematic sampling techniques to include as much vegetation as possible that can represent the vegetation of the study area. To analyze the spatial distribution and effect of *L. camera* on neighboring plants (woody plants and shrubs), starting from 50 m away from the primary plantation of Lantana around the Palace, three transect lines were laid down to the hill of Bezawit along three directions or land uses of natural forest (South-East or towards Abay River), cultivated (South and South-East) and grassland (North-East). Within 50m interval, 12 plots per land use (a total of 36 plots) with 20m x 20m were taken for sampling of trees (Gyansharma and Raghubanshi, 2007) and within each sample plot nested plots, 5m x 5m (saplings and shrubs) of each tree species and, 2mx2m (seedlings) were used (ECZ, 2004).

The collected specimens were identified by expert and rarely by comparing with already identified ones from the herbarium and authenticated using Flora of Ethiopia and Eritrea (Hedberg and Edwards, 1989 & 1995, Azene *et al.*, 1993). Moreover, diameter at breast height (DBH) was measured at 1.3m above the ground for trees (DBH > 5.00 cm and height > 3.00 m) and 0.3m for seedlings (DBH < 2 cm and 0.5m height) saplings and shrubs (6 cm < DBH >2cm and 0.50 m to 3.00 m height) (Tefera Mengistu *et al.*, 2005) to estimate the regeneration status of the forest in comparison with the regeneration potential of *L. camara.*

Socio-economic survey

The socio economic data was collected from Nov. 20 to 30, 2010. This was done to assess the perception and awareness of the local people towards the species, and the data was collected through semi-structured questionnaires and participatory rural appraisal (PRA) interview (Martin, 1995). A total of 60 households, 55 people from local residents who have faced problems against Lantana invasion and 5 people from agro-forestry and park development experts of the area were selected to be representative using purposive sampling technique. Households (Both male and female) who were absent during data collection were replaced with the proceeding households. headed households were included in the sampling.

Data analysis

Both descriptive and inferential statistics were used for data presentation and analysis. MS-Excel was used for data organization, density, relative abundance and list of species. The quantitative structure analysis was made using data from density, abundance, and frequency of distribution of each species in the study sites.

Shannon Wiener's diversity index (H')

Species diversity indices were analyzed using software PAST (Hammer *et al*., 2001). Shannon diversity index accounts for both diversity and evenness of the species present in a community. This means, due consideration was given to the species richness (composition) and evenness (equitability) within the given land or community.

H' = - [Σ (Pi) (lnpi)] Where,

H' = Shannon-Wiener index

Pi = n/N is the proportion of individuals or the abundance of i^{th} species expressed as a proportional of total cover in the sample (ranges 0 to 1)

n= no of individuals of a given species; **N**= total no of individuals found

ln = natural log (i.e. base 2.718)

Σ = Summation symbol; and ln = log bases (natural logarithms).

Equitability or evenness index was calculated from the ratio of observed diversity to maximum diversity using the equation;

E = H'/ln (S) =H'/Hmax

Where: E = Evenness; H' = Shannon-Wiener Diversity Index; H'max = lnS; S = total number of species in the sample.

DBH and regeneration status

For population structural analysis, diameter class distribution for each species was done to investigate the regeneration status of the forest (Peters, 1996). Population structure bar graphs (density versus DBH class) were used to discuss the different patterns of population structure in relation to the distribution of *L. camara* so that total number of individuals was grouped into different arbitrary diameter classes.

Density- is referred to as the total number of plants per hectare, and it is useful for evaluating areal coverage of each species.

Frequency- It is calculated by a number of quadrates in which a particular species occurred divided by the total number of quadrates.

RESULT AND DISCUSSION

Bezawit forest patch

This upland riverside mixed forest patch, whose center is the palace of Emperor Hailesillasie, which was built in the early1960s, is found south of Gudegude and north of Burefesese, extended down to Abay River in the west direction (Abraham, 2009). The Bezawit hilltop offers a spectacular view of Bahir Dar city, the islands of Lake Tana, and the Abay River leaving the

Lake. Observation from the hilltop occasionally enables to see hippopotamus and some beautiful water birds at the underling river (Berhanu *et al*., 2007). Although this forest patch has been highly threatened by the invasion of *L. camara* in the past, there are still many recorded native species of shrubs and trees. The result of the study showed that the area was locally dominated by *L. camara* (1379 individuals/ha), followed by the second highly spreading and threatening plant species; *Agave sisalana* (159 ind/ha). Other relatively abundant plants with more than 50 ind/ha includes: *Securinea virosa* (114 ind/ha), *Calpurnia aurea* (93 ind/ha), and *Argemone mexicana* (75 ind/ha) (Table 4).

Although this forest patch is highly affected by the invasion of *L. camara* in the study aea, the compositions of vegetation are relatively intact and are much more diverse (with H=3.9215) and dense with 1898 ind/ha (Abraham, 2009) when compared to the other forest patches of the park. In the northeast direction of the study area; towards the grassland, there has been modification by re-vegetation with indigenous tree species mainly *Syzygium guineese*, *Milleia ferruginea*, *Cordia africana*, *Acacia abyssinica*, *Croton macrostachyus* and *Olea europea subspp capsidata* by the government and private sectors of the city during the Ethiopian millennium celebration. As the respondents replied, this natural vegetation was intensively deforested previously and left with partly grasslands as result of illegal cutting of trees for construction, firewood and expansion of farmlands. This indicates there was high past disturbance of the area which created more access or open spaces for the fast invasion of Lantana, corresponding with the colonizing nature of the species where disturbances are very common (Gentle and Duggin, 1997; Goodland, 1998; Day *et al*., 2003; Stock, 2005). Moreover, the absence of shade effects is believed to accelerate the intensity of Lantana invasion and severely damage the land uses of the study area.

Floristic composition

A total of 55 species of woody plants (i.e. trees, shrubs and climbers) representing 38 families were recorded including *L. camara,* from Bezawit forest patch of AMP. All the specimens were found sparsely intermingled with the dense stand of Lantana thickets, and of the 55 sampled plants, 49 were used in floristic and structural analysis (Table 3). Since they were collected from the spaces outside the selected sampling quadrates (still within the study area), the six ones were not considered in the analysis, but they were, indeed, taken into account in the total specimens in order to make the complete floristic list of all land uses.

From all species collected and identified, 24, 22 and 3 were trees, shrubs and climbers, respectively (Table 1). Thus, Fabaceae was the most diverse family in species number that comprised seven species; *Maytenus arbustifolia, Milletia ferruginea, Piliostigma thonningii, Albizia malacophylla, Carissa edulis, Pterollopum stellatum,* and *Calpurnia aurea* (18.42%) followed by family Euphorbiaceae which includes four species; *Securinega virosa, Clutia abyssinica, Croton macrostachyus, and Sapium ellipticum* (10.52%).

Table 1 Proportion and density of plant life forms

No.	Life form	No. of species	Density/ha
1	Shrubs (with *L. camara*)	22 (44.89%)	1821
2	Trees	24 (48.98%)	361
3	Climbers	3 (6.13%)	35
Total		49 (100%)	2217

Species diversity, richness and equitability

The output of computation (Shannon-Wiener diversity index) of vegetation data collected in comparison with *L. camara* is shown in Table 2 bellow. The mean diversity index of woody plants across three land uses was H'=1.6199 with the maximum H'=2.6980 was at the natural forest and the minimum H'='0.3446 was at the grass land in which the intermediate H'=1.8173 being at cultivated. These values were obtained by subtracting the index of *L. camara* (these values within parentheses) from the total diversity index, including *L. camara* (those values without parentheses).

Table 2 Comparisons of diversity indices of woody plant species on different land uses versus *L. camara* distribution

Habitats	Species Richness (S)	Diversity index (H')	H'max	Evenness (H'/H'max)
Natural forest (NF)	46 (1)	3.0652 (0.3672)	3.5786 (0.5134)	0.8802 (0.7152)
Cultivated land (CL)	29 (1)	2.1256 (0.3183)	2.5906 (0.5134)	1.4949 (0.6200)
Grassland (GL)	15 (1)	0.5066 (0.1620)	0.8224 (0.2158)	1.3309 (0.7507)
Mean	30	1.9024 (0.2825)	3.1256 (1.2426)	1.5171 (0.6953)

(x) Values of *L. camara*, indicating its contribution (influence) for each diversity index (*i.e.*, the values without parentheses minus values within parentheses results values of other plant species)

Based on the standardized values of Wiener diversity index, in table 2 there was medium diversity of plant species (excluding *L. camara*) with H'= 2.6980 (2<H'<3) in the NF followed by low diversity, H'= 1.8173 (1<H<2) in the CL and very low species diversity (H<1) in the GL with H = 0.3446, indicating adverse effect of *L. camara* in disruption of succession, which aggressively reduced the indigenous plant diversities in which H' in NF > CL > GL. A low value of evenness indicates that the dominance of an environment by one or a few species, while others are present with few individuals (Zerihun *et al.*, 1999).

Thus, in our current study, species evenness of woody plants of the GL (E=0.6802) is lower than that of the CL (E=0.8749) and the maximum one is recorded from the NF forest (E=0.8802), indicating there was high dominancy and effect of *L. camara* in the GL followed by CL. Species richness (S), equitability (E) and diversity (H') are also positively correlated (Krebs, 1999), with the ratio of mean diversity and evenness indexes of Lantana to other woody plants

(0.2825/1.6199 and 0.6953/0.8118), respectively (Table 2). This revealed that there was better diversity of woody plants compared to the distribution and low diversity of *L. camara*, and the relatively high equitability in the study area. Considering species richness as one measures of diversity (Tivy, 1993), the NF has high species richness (S=45) followed by the disturbed site (S=28) and the GL which left with the poorest species abundance (S=14). This reveals that threatened and subsequent extinction of species in the grassland are very common due to the negative effect of the weed (Csurhes & Edwards, 1998; Daehler, 1998; Humphries *et al.*, 1991).

Density, frequency and abundance of woody plants

The total density of tree and shrub species excluding *L. camara* in NF, CL and GL is 1,457, 513 and 543 individuals/ha, respectively. However, the density of *A. sisalana* (*i.e.* the second devastating species of plants in the area), were 42 ind/ha in CL but 435 ind/ha in GL and totally absent in the NF (Table 3). Therefore, the total density of other woody plants excluding these two species (*A. sisalana* and *L. camara*) becomes 471 ind/ha in the CL and and 109 ind/ha in the GL. Consequently, density ratio of *L. camara* to other affected woody plant species in the NF, CL and GL was found to be 773/1457, 698/471 and 2665/109 ind/ha of the sampled area. This revealed that the effect of Lantana is still remained more severe towards the GL than the other habitats.

Analysis of the mean density of other woody plants was done for comparison of the land uses under the influence of *L. camara*, and were turned to be 30.35, 10.69 and 11.31 ind/ha in NF, CL and GL, respectively (Table 3), corresponding to the total density recorded in the same area by taking into account the influence of *A. sisalana* in GL. Moreover, the mean density of Lantana in all habitats (1379 individuals/ha) was found to be about 46 times greater than the mean density of woody plants in the NF and 125 times greater than the rest land use types.

Table 3 List of woody species including *L. camara* recorded from three land uses with their densities and frequencies

Species name	Habit	Density/ha			Mean Density/ha	Frequency (%)			Mean frequency (%)
		NF	CL	GL		NF	CL	GL	
Lantana camara	**S**	**773**	**698**	**2665**	**1379**	**100**	**100**	**100**	**100**
Acanthus eminens	S	35	4	0	13	50	17	42	69.4
Acokanthera scmiperi	S	100	8	0	36	66.7	17	0	16.67
Adanosonia digitata	T	13	0	13	9	33.3	0	33	77.8
Agave sisalana	T	0	42	435	159	0	33	58	33.33
Albizia malacophylla	T	4	0	0	1	16.7	0	0	27.77
Albizia schimperiana	T	8	0	0	3	25	0	0	5.57

Argemone mexicana	T	142	8	0	75	100	25	0	11.1
Buddleja polystachya	S	15	15	6	12	33.3	25	25	33.33
Calpurnia aurea	S	179	60	40	93	100	75	75	22.2
Capparis tomentosa	C	19	19	0	10	50	42	0	8.33
Carissa edulis	S	54	4	10	23	66.7	8.3	25	13.87
Cassia siemea	S	0	2	0	1	0	8.3	0	25
Celtis africana	T	54	29	0	8	66.7	58	0	33.33
Clausena anisata	S	8	0	0	3	16.7	0	0	83.33
Clutia abyssinica	S	23	0	0	8	41.7	0	0	41.67
Combretum spp.	T	17	0	0	6	25	0	0	22.23
Commiphora africana	T	10	0	0	3	16.7	0	0	13.9
Cordia africana	T	10	2	4	5	25	8.3	8.3	8.33
Croton macrostachyus	T	65	56	19	47	100	92	42	8.33
Cussonia holstii	T	8	0	0	3	25	0	0	8.33
Dodonaea viscose	S	4	4	0	3	16.7	17	0	13.9
Dombeya torrid	S	6	0	0	2	16.7	0	0	8.33
Erythrina abssinica	T	6	0	0	2	16.7	0	0	11.1
Eulea racemosa	S	50	6	0	19	83.3	17	0	5.57
Gardenia termifolia	T	10	0	2	4	25	0	8.3	38.9
Grewia terruginea	T	6	8	0	5	16.7	17	0	30.57
Hibiscus ludwigil	S	8	0	0	3	16.7	0	0	11.13
Jasminium abyssinicum	S	0	4	0	1	0	8.3	0	5.57
Jasminium grandifeorum	*C*	33	4	0	12	50	8.3	0	36.13
Lannea scimperi	T	19	6	2	9	25	17	8.3	8.33
Matenus gracilips	S	0	10	0	3	0	17	0	11.13
Maytenus arbutifolia	S	31	31	2	21	41.7	50	8.3	5.57
Milletia ferruginea	T	8	0	0	3	25	0	0	30.53
Mumusops kmmel	T	15	0	0	5	25	0	0	19.43
Ocimum lamiifolium	S	17	35	0	17	16.7	58	0	41.67
Osyris guadriparitita	T	15	0	0	3	33.3	0	0	47.23
Piliostigma thonningii	T	13	0	0	4	25	0	0	5.57
Pittosporum viridifokium	T	35	0	0	12	66.7	0	0	11.1
Premna schimperi	S	19	2	0	7	33.3	8.3	0	27.8
Pterollobium	C	31	8	0	13	75	25	42	8.33

stellatum									
Rhus glutinosa	T	21	13	0	11	33.3	25	0	19.43
Rhus vulgaris	S	21	0	0	7	25	0	0	2.77
Rumex nervosus	S	4	4	0	3	16.7	8.3	0	8.33
Sapium ellipticum	T	13	0	6	6	25	0	8.3	5.57
Securinega virosa	S	246	92	4	114	100	100	8.3	2.77
Senna singueana	S	42	31	0	24	66.7	50	0	5.57
Streeospermum kunthianum	T	10	6	0	5	25	25	0	16.67
Syzygom quineense	T	10	0	0	3	41.7	0	0	8.33
Mean without *L. camara*		30.35	10.69	11.31	17.45	37.5	17.9	8.2	21.06
Total density without *L. camara*		1457	513	543	839				
Total density with *L. camara*		2230	1211	3208	2217				

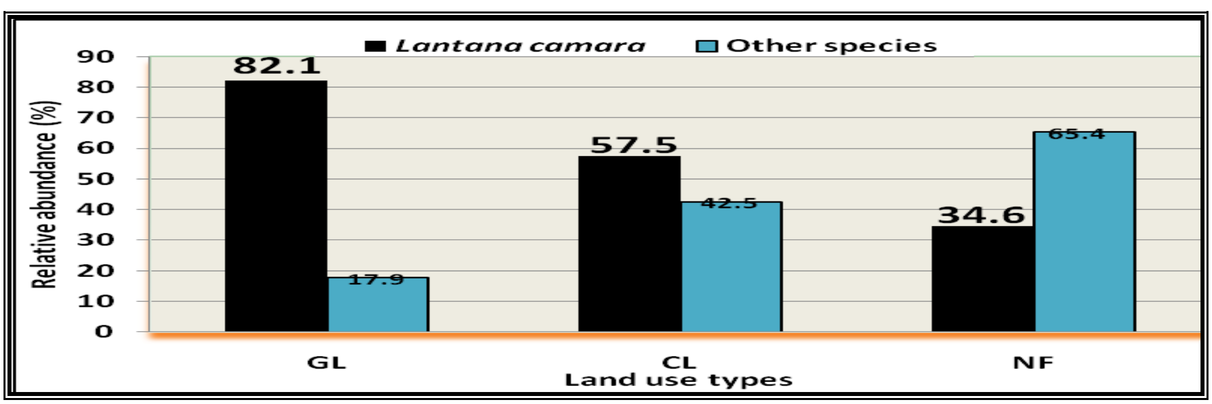
[NF] natural forest, [CL] cultivated land, [GL] grassland, [S] shrub, [T] tree

The frequency of *L. camara* in all land uses or its mean frequency was found to be 100% which means that it has distributed and found in all plots of sampled area. Nevertheless, the mean frequency of other woody plant species was 37.51% in NF, 17.90% in the CL and 8.16% in GL.

Distribution of *L. camara* on different land uses

Although the density of Lantana towards the FL was to some extent greater than its density towards the cultivated or disturbed site (Table 3), its relative abundance and rigorous effect still remained in the CL (Fig. 4). However, compared to other land use types, there was high dense stand of Lantana in the GL (2665 ind/ha) due to may be, the presence of intense tree canopy in the NF, imposing heavy shade effect on Lantana and there preventing sun light, an essential factor for the hasty growth of Lantana, from reaching to this species (Reader and Bricker, 1994; Goodland, 1998; Gentle and Duggin, 1997; Stock, 2005 and ARMCANZ & NZ ECCFM, 2000).

Figure 4 The relative abundance of *L. camara* on difffernt habitats



On the other hand, as the research work of Gentle and Duggin (1998) and (Prieur-Richard and Lavorel, 2000), the presence of enough nutrients and the absence of shade effect on the open and/or disturbed sites, greatly favor *L. camara* to flourish and widely distribute. Accordingly, as the competition of resources with Latana in such field is very severe for them, the native species in the area would be declined progressively from time to time (Swarbrick *et al.*, 1995; ARMCANZ & NZECCFM, 2000). Equivalently, our current finding indicated that the relative abundance and invasion pattern of *L. camara* showed an inverted "J" shape distribution, where 82.1% of the GL was invaded followed by 57.5% of the CL and lastly 34.6% of the FL habitat (Fig. 4). Since the suppression and deleterious effect of the species is much more severe on the GL, there would be a serious fodder problem to the society practicing mixed farming due to the modification of the habitats and the overall ecosystem of the area (Csurhes and Edwards, 1998; Daehler, 1998; Mack *et al*., 2000).

Population structure and regeneration status

The entire analysis of population structure of all tree species resulted in three different patterns (Fig. 5a-c), except *Melia azedarch* which occurred singly, only in one plot. The first pattern is represented by *L. camara* (Fig. 5a), and all species in this group have high density in the lower DBH class and gradually decreases with increasing DBH (positively skewed). They show inverted "J" curve pattern which further indicates good reproduction and recruitment. Other species included in this group are *Securinega virosa*, *Calpurnia aurea, Carissa sapinarum, Acanthus eminus, Jaminiuum grandifeorum, Matenus arbutifolia*, *Pterollobium stellatum, Argemone mexicana, Osris guadriparitita*, *Celtis africana and Pittostigma thonningii.*

The second pattern is represented by *Croton macrostachus* (Fig. 5b). The density of all species in this group increases with increasing DBH up to some points and then decreases with increasing DBH afterwards (shows Gaussean curve). Tree species in this group are, *Ackanthera schmiperi, Sennaea singunea, Ecluea racemosa, Ocium lamifolium, Pottosporum vividifolia, Clutia abyssinica and combretum* species.

Figure 5 Population structure of some representative woody plant species (Fig. 5a *L. camra*, Fig. 5b *C. macrostachyus* and Fig. 5c *S. elipticum*

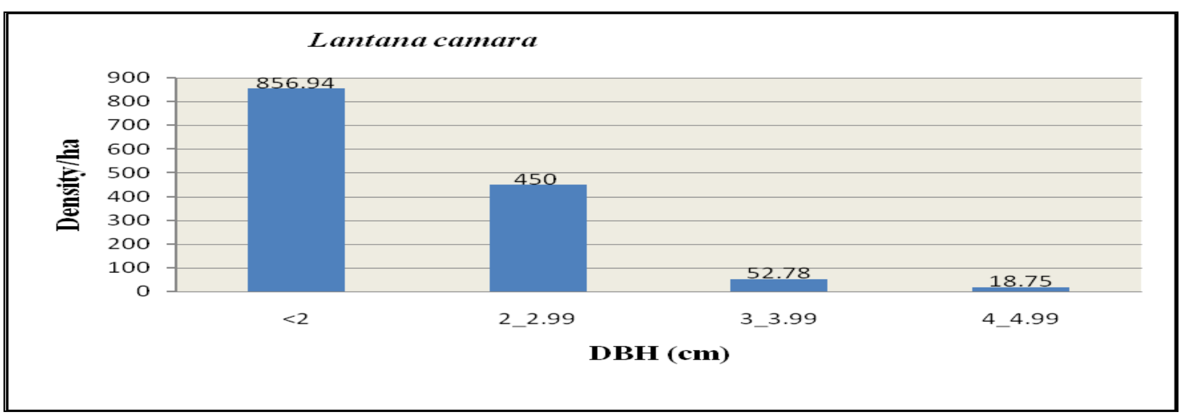
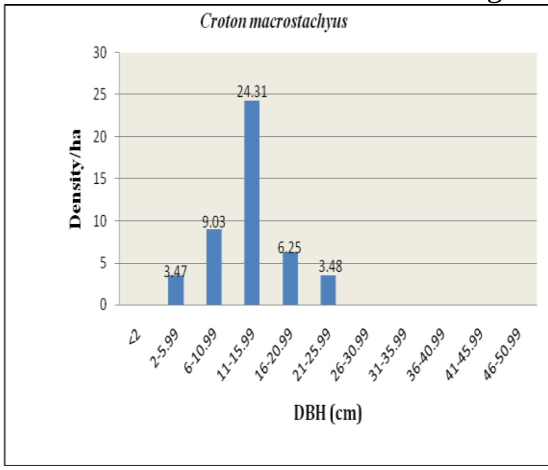


Fig.5a



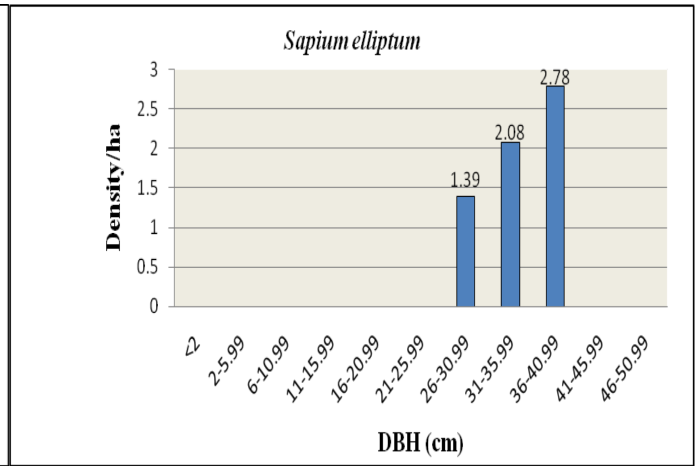


Fig.5b

Fig.5c

The third pattern is represented by *Sapium elliptum (*Fig. 5c). Species included in this pattern are *Cussonia holisti, Dombeya torrid, Rhus vulgaris, Capparis tomentosa, Lannea schimperi, Gordonia termifolia, Cordia africana, and Milletia ferruginea*. The number of individual trees in each species increases with increasing DBH and most of the remaining species were found to be included in this pattern, except the recorded data of a few species which showed decreasing pattern at the beginning and then increase up to some limits and then decrease.

Population structure or distribution of individuals of each species in arbitrarily diameter size classes enables to provide the overall regeneration profile of the study species (Simon and Girma, 2004) and it is used to predict the trend of the population of that particular species (Peters, 1996). For that reason, composition and density of seedlings and saplings of each threatened tree species recorded from Bezawit forest were included in this study so as to compare the regeneration status of the forest against the seedling recruitment capacity of *L. camara*. To do so, all tree species in the study area were categorized into three arbitrary diameter classes, seedlings (< 2cm DBH), saplings plus shrubs (2 cm < DBH < 6 cm) and trees (> 6 cm).

In this investigation, 1216.6 of seedlings, 746.52 of saplings plus shrubs and 268.61 trees of individuals per hectare were recorded from the total sampled plants. As a whole, when the diameter classes of all woody species were analyzed together, the forest patch showed somewhat an inverted J-shaped frequency distribution with abundant individuals at the lower diameter classes more by seedlings (49.69%) and then by shrubs and saplings with (33.25%) showing decrement in number of individuals as the diameter classes increased, thereby suggesting good regeneration status of the forest. Nevertheless, when considering the proportion of seedlings, more than 70.44% (856.94 seedlings/ha) of the total seedling count were contributed by *L. camara*, screening its greatest regeneration ability (Fig. 5a) and its effect on the decline of species diversity and regeneration (Murali and Siddapa, 2001; Sharma *et al.*, 2005; Sharma and Raghubanshi, 2006). Thus, the results obviously indicate the threatened status of the forest community in the park.

Socio-ecological impact

For additional data organization and documentation on socio-economic and ecological impacts of Lantana, a questionnaire was administered to key informants in that to test their perception and suggest actions that would be thought effective to control its further distribution. Therefore, selected respondents from the local community and from some concerned governmental bodies for interview, based on their level of education and age, category were used.

Benefits of *L. camara*

The socio economic survey identified the following uses of *L. camara* in the specified area.

Table 5 Economical and ecological use values of *L. camara*

Economic benefits	Respondents	Ecological benefits	Respondents
Source of fodder & nectar	15 (25%)	Combat desertification	22 (36.67%)
Hedge (live & dead)	21 (35%)	Decrease soil erosion	48 (80%)
Fire wood	8 (3.33%)	Reduce wind speed	41 (68.33%)
Medicinal vale	__	Shelter for wild life	15 (25%)
Ornamental	10 (16.67%)	Shade tree	5 (8.33%)
Construction	6 (10%)		

The above table (Table 5) implies that the economic value of the weed was generally low or its negative effect is more perceived by the local people (Table 6 and 7) rather than its use in any case. The utilization of the plant as a live fence/hedge around the villages and farm lands in the study area was also mentioned most frequently (35%), corresponding to reports from other part of the world (ARMCAN and ANECCFM, 2000; Binggeli, 2003; Day *et al*, 2003). Leaf of *L. camara* for animal fodder and the varieties of its flowers was the second advantage of the plant. While the livestock are forced to eat the leaves where there is no an alternative feed around, particularly during drought seasons. The local people used to cut the stand of Lantana from the field in a way to remove and manage its invasion, but not purposely for fuel. It was also common to observe bees collecting nectar from flowers.

Although extensively used in the overseas (Bhakta and Ganjewala, 2009), none of the respondents acknowledged the medicinal value of the plant in their localities. This may be due to lack of knowledge and experience in the traditional use plants in the study area. Lantana can also make the area, in which it is planted, very attractive and interesting because of its year around varietal flowers (Holm *et al.*, 1991; Swarbrick *et al.*, 1995), but here the economic value of the plant as ornamental was placed in the third rank. In this particular study, the ecological benefits of the weed were found to be better (Table 6), and therefore, the main advantage of the plant in the study area was highly recommended for its significant role in reducing soil erosion (80% of the respondents), followed by its importance in reducing wind speed and compacting desertification. Likewise, the local people benefited from the plant as shade tree when it appears especially in single stumps.

Harms of *L. camara*

In highly invaded areas, towards the GL, 91.67% of the respondents (Table 6) noted that the most severe problems appeared to be in the reduction of grasses and herbs under its canopy. Many respondents (75%) also acknowledged secondly that the negative effect of Lantana was great in decreasing the biodiversity of neighboring plants (Plate 4) by computing resources, mechanical suppression and aggressiveness (Gentle and Duggin, 1998).

Table 7 Adverse impacts of *L. camara*

Adverse Impacts	Respondents
Decrease woodlands and farm lands	58.33%
Injure and poison animals	25%
Discourage growth of grasses under its canopy	91.67%
Decrease crop productivity	38.33%
Decrease plant diversity	75%

Furthermore, they (58.33% of the respondents) added that the plant narrowed the size of their farm lands and create difficulties in cultivation of crops. The prickly impenetrable thickets of Lantana, not only completely hinders movement of their animals, prevents them in searching of food, but also punctures their skins and cause injury (Table 7).

Perception and attitude of the local people

Raising public awareness is absolutely crucial for successful AIS prevention and management (Goodland, 1998; Binggeli, 2003). The socio-economic survey revealed that different respondents have similar view about how (it was purposely introduced), why (it was believed to be used as ornamental/hedge), and where (it was planted around the palace) the species was established to the study area. About 90% of the local people (farmers and agropastoralists) have negative attitude towards the species (Table 7) and they are highly intended for its total removal, while some governmental employees (park development and agroforestry experts) did not support its complete eradication, and have mixed attitude towards the species. They elaborated their reasons in that the plant has its own advantage (being its more terrible effect kept), for example, such species are ecologically successful and important in conserving genetical resources in the environment.

Table 7 People perception and attitude against the impact of *L. camara*

Perception	Respondents
Disadvantage	54 (90.00%)
Advantage	6 (10%)
Should completely removed (agreed)	49 (81.67%)
Should proper management adopted (disagreed)	11 (18.33%)

Management and control options

Even if there is not any action that yet taken by the regional government to control its invasion, the community is aware of the problem, and has substantial interest to control and manage the plant. Lantana is difficult to control (ECZ, 2004), as it will coppice and form denser thickets if it is simply slashed, not uprooted. The edible pods, mostly by birds, also contribute for its long range dispersal mechanisms (Gentle and Duggin, 1997; Binggeli and Desalegn Desissa, 2002). At broad scale, there are basically three methods of prevention and management options (*i.e.*, mechanical, chemical and biological control), all of which can be used together within an integrated management programme (Williams and West, 2000). In this study however, the local people (91.67%) (Table 8) have tried to use only physical methods (hand grubbing, uprooting, and cutting). These physical and mechanical (stickraking, bulldozing, ploughing) techniques are in fact effective and mainly suited to medium sized infestations Thinning and pruning methods of control were also frequently used, especially following the street of the palace.

Table 8 Methods used to control invasion of *L. camara* in the study area

Methods	Respondents (%)
physically	91.67
Thinning and pruning	8.33
Biological	—
Chemical	—
Burning	—

Nevertheless, in the assessment of the study area, no longer biological and chemical control methods were used (Table 8). However, a study conducted in South Africa proved that biocontrol agents including *Teleonemia scrupulosa* (Hemiptera), *Octotoma scabripennis* (Coleoptera), *Uroplata girardi* (Coleoptera) and *Ophiomyia lantanae* (Diptera) were partially successful in controlling Lantana invasion (Cilliers and Neser, 1991; Broughton, 2000).

Furthermore, a number of herbicides are registered for control of Lantana. If carefully managed, fire has also been proved to bring effective control, particularly well-suited to dense infestations (ARMCAN and ANECCFM, 2000).

CONCLUSION

The result of this study indicated that *L. camara* has not equally distributed on each land use types. The plant was highly abundant and distributed in the grass, agricultural and forest lands of the study area, respectively, due to absence of shade effect on the grassland and frequent disturbance in the former land uses. *L. camara* occupied 62.20% (1379 individuals/ha) of area coverage in the sampled study area (1.44 ha), with high proportion of its seedlings (60.20%). This implies that the greater regeneration capacity and potential threat of the weed on the environment. On the other hand, Lantana has at most the following advantages, usually as ornamental or hedge plant, avoidance of soil erosion and in some cases, it may provide animal fodder. However, at the current situation, the disadvantages massively outweighed the advantages. Consequently, nearly every one of the respondents in the study area agreed for its comprehensive removal, except a few of them from governmental employees that did not agree.

RECOMMENDATION

Based on the results obtained from the study, tools proposed by the respondents and the researcher for the long term and sustainable control of Lantana include the following: The dilemma on the benefits and adverse impact of *L. camara* could be solved by enhancing the profits and improving/implementing all proper management options. The principles underpinning for strategic control need collective action including all levels of governments, NGOs and community groups. On the other hand, creation of community awareness about the impacts of Lantana would optimize control success and utilization options. Thinning and pruning of the plant should be adopted. The more promising areas for future research are the modeling and mapping invasion risk potential. Integration of such techniques is likely to result in improved control and mitigation strategies.

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