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Impact of *Lantana camara* L. on Plant Diversity and Soil Physicochemical Characteristics in Wollo Floristic Region, Ethiopia

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ABSTRACT

Degraded forestland in the Wollo floristic region areas are highly invaded with *Lantana camara* L. species due to the invasive nature of the species and less consent of resource manager. This study was intended to assess the effects of *Lantana camara* L. on plant diversity and selected soil parameters. Thus, the study forests were stratified into three categories such as highly invaded, moderately invaded and un-invaded forest. In those sites, a total 30 sample plots, for tree and shrub assessment (main plot size of 20 m × 20 m), seedling and sapling (two subplots of 2 m × 5 m), and herbaceous species and soil sampling (five 1 m × 1 m subplots) within each main plot were used. All plant species in all plots were recorded; trees and shrubs Height and Diameter at Breast Height were measured. The data was then analyzed using R-Software. In the study sites, species abundance and basal area decreased with increasing invasion of *Lantana camara* L. from highly invaded, moderately invaded to an un-invaded site in that order. The invaded site had the least Shannon Weiner (H') value, while the highest value was in the un-invaded site. Phosphorus and organic carbon were highest in the invaded site, followed by the moderately invaded site, and lowest in the un-invaded site. In conclusion, the species result in changing species composition and horizontal structure, then, it is recommended that local communities and policymakers should formulate effective controlling strategies to protect further expansion.

Keywords: Basal area, Forest soil, *Lantana camara* L., Plant diversity, Vegetation structure.

INTRODUCTION

The idea that biological invasions are one of the major causes of ecosystem degradation is currently under debate (Gaertner, et al., 2012). Many authors consider biological invasions to be important drivers of ecosystem degradation, whereas others suggest that they are just‘ passengers’ – capitalizing on other anthropogenic disturbances. Introduced species that become invasive can become a major concern as they can cause significant ecological damage. Biodiversity in forest ecosystems is under threat worldwide (Michanek et al., 2018). Invasive alien species modify local-scale microclimatic conditions in forest under stories. It plays a key role in shaping the composition, diversity, and function of the forest (Jucker et al., 2018). It reduces diversity while diverse ecosystems can be more productive, stable, and produce more goods and services than simple ecosystems. Diverse forest ecosystem scan return to their original state following a perturbation (Thompson et al., 2009). For a system to have resilience, the state of interest (e.g., the mature forest type) must be stable over a certain period. Considerable research has explored the concept that species diversity enhances stability. Dynamic responses in diverse ecosystems that maintain stability to environmental change over time may occur at genetic, species, or population levels. There appears to be low variability among ecosystem properties in response to change in diverse systems compared to those systems with low diversity, where higher variance is observed (Loreau & Mazoncourt, 2013). Ecosystem stability and the response of ecosystems to disturbance are of crucial importance for conservation management, especially when the object is to maintain and/or to restore early succession communities.

Management of invaded ecosystems is an increasingly complex problem worldwide. The processes and mechanisms underlying impacts of alien invasion are numerous and complex, including the displacement of resident plants, the inhibition of native plant establishment, and the modification of physical and chemical resources (e.g. water and nutrient availability) and native ecosystem processes (i.e. changes to fire regimes and nutrient cycling) (Gaertner et al., 2012). After passing such complex issues, measures to control

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alien invasive species have helped several species to move to a lower extinction risk category (Secretariat of the Convention on Biological Diversity, 2006). It is imperative that countries also seek out all available technologies to manage this insidious threat, which includes biological control, long considered as one of the most effective ways of managing invasive species. A comprehensive solution for dealing with invasive alien species as part of forest restoration needs fundamental and applied research, at local, national, and global levels. The establishment of a new plant species often changes the structure and functioning of an ecosystem. Restoration ecology studies often focus on the consequences of invasions for populations and communities (i.e. changes in community composition or changes in species richness). Hence, underlying processes and mechanisms are much less frequently addressed (Gaertner et al., 2012).

Lantana camara L. (*L. camara*) is among the top ten invasive weeds on our earth. Research on the impact of this species on plant diversity and soil parameters is scarce, except on documentation of the species occurrence in Wollo floristic region (Ayalew, et al., 2006), hence studies on its impacts on biodiversity are not yet determined locally. The results of this study are important for the forest enterprise, local communities, and policymakers to formulate effective containment strategies. Therefore, this study was attempting to assess its impact on the native plant communities and selected soil parameter.

MATERIALS AND METHODS

Study area:

This study was conducted in Wollo Floristic Region (WU). The naming of the WU regions does not bear any relation to the current administrative boundary (Friis et al, 2010). However, Wollo floristic region includes three administrative zones as North Wollo, South Wollo, and Oromia in Amhara region, Ethiopia. It is situated between the Eastern highland plateaus of the region and the North-Eastern highland plateaus of Ethiopia (Fig. 1).

Bimodal rainfall patterns were experienced in the study area. The long rainy season extends from

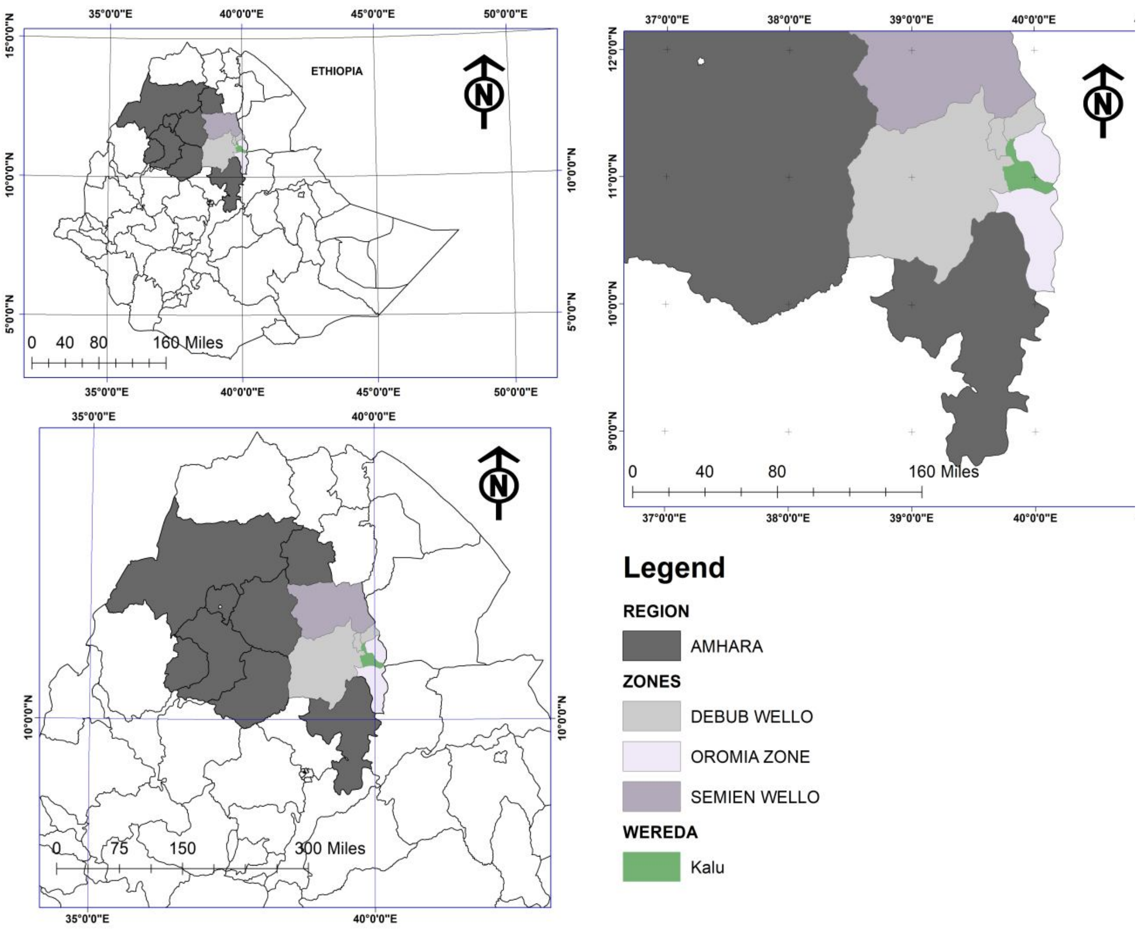

Fig. 1: Map of the study area, Wollo Floristic Region, Ethiopia.

June to September, which supports the major crop production. The shorter rainy season comes in March and April and allows minor crop production. Mean annual temperature of 19.6°C and annual rainfall of 1017 mm have been recorded over the years (1984-2015) at Kombolcha Meteorological Station (Ethiopia National Meteorological Services Agency, 2016). The annual minimum and maximum temperatures of the area are 8.8 ^{0}C and 30.6^{0}C, respectively.

Biology and ecological requirement of *L. camara:*

L. camara one of the world's worst invasive species is a perennial woody shrub, belonging to the family Verbeneceae. *L camara* is one of the many invasive species that severely affects the properties of the ecosystems in which it inhabits. It can grow in compact clumps, dense thickets is heavily branched and evergreen shrub. The stems have a square cross-section and a diameter of 24 mm when they are young. Leaves opposite, green and scabrid above, pale green and pubescent below; blade ovate, 3.5-9 x 25 cm, apex rounded to acute, base cuneate, margin crenate-serrate; petiole 4-17 mm long (Hedberg, et al., 2006). Inflorescence solitary; lower floral bracts linear or linear-lanceolate, 4-7 x 1-1.5 mm; peduncle 2-10 cm long. Flowers in corymb-like heads, 1-2 cm wide. Drupe 3-5 mm across, dark purple turning black at maturity (Hedberg et al., 2006). After its introduction in cultivation, the species has become naturalized in many parts of the tropics. It is common as an ornamental in all parts of the Flora area and is naturalized in some open disturbed areas; 500-2500 m (Hedberg et al., 2006). The diversity and broad geographical distribution of *L. camara* is a reflection of its wide ecological tolerance. It occurs in diverse habitats in a variety of soil types, soil range of mostly sandy, to clay and loam, water range from semi-arid to normal.

Vegetation sampling:

Reconnaissance of the survey was made before the formal survey. The local forests were stratified into three depending on the magnitude of infestation level such as highly invaded (*L. camara* cover> = 50 %), moderately invaded (0%<*L. camara* cover <50%), and un-invaded (no *L. camara* cover) following Chatanga, et al., (2008). After local stratification, three-study sites namely *Adis mender, Aba bishane, and Harbu Mikayile* were selected among the forests patches of Wollo floristic region.

Vegetation data were collected using the sampled plot of 20 m × 20 m (400 m^2), equal numbers of plots were taken from the three categories, 30 sample plots were used. For tree and shrub assessment, the 400 m^{2}sample plot was used. For seedling and sapling, inventory two subplots of 2 m × 5 m (10 m^2) were used. For herbaceous species five 1 m × 1 m (1m^2) subplots within each 400m^2 plot four at the corner and one at the center were used.

All plant species in all plots were recorded. The cover-abundance of all vascular plants in each plot was estimated using visual eye judgment. For all trees and shrubs Height and Diameter at Breast Height (DBH) were recorded. In all plots, additional trees and shrubs outside the plot boundaries but within 10−15 m were collected and notes as a present. Herbaceous species encountered outside the subplots were collected and notes as a present. Species were identified at the national herbarium in Addis Ababa.

Soil sampling:

The effect of *L. camara* on soil physical and chemical properties was studied using standardized soil sampling procedures. To study the impact of the species on soil physical and chemical property, composited soil sample was taken from five 1 m × 1 m sub-plots within each 400m^2 plot using the hand auger to remove a soil sample from the top 30 cm of the soil horizon. An equal number of soil samples were taken from the three sites. From each soil sample plot at least 120g in weight and free of litter and roots was used. Soil from the hand auger was carefully added to a plastic bag. A permanent marker was used to label the sample bag with the appropriate site ID, sample ID, date, and weight (g.). Then the samples were kept using standardized soil despatching procedures to Holeta Agricultural Research Centre for subsequent soil analysis.

Data analysis:

Effect of L. camara on woody species diversity:

For each site, the alpha (α, average species richness per plot), beta (ß, total richness/average richness) and gamma (ɣ, total species) richness, Shannon's diversity (H') and evenness (J) indices were calculated (Simpson, 1949; Shannon & Weiner, 1963).

Effect of L. camara on horizontal structure:

Horizontal structural characteristics such as the proportion of plots in which a species occurs in sampled plots, abundance (the number of individual species per plot), and basal area were computed independently for both sites. Basal area of tree species with >2 cm DBH was calculated as Basal area= $\Sigma\ \pi D^2/4$. The effect of *L. camara* was determined using appropriate pacing in R software, check for significance level at alpha =0.05.

Soil data analysis:

Laboratory analyses were conducted at Holeta Agricultural Research Centre, Ethiopia using the following standard methods. Soil particle size distribution was determined by the hydrometer method (Pansu & Gautheyrou, 2006). Soil organic carbon was determined by the Walkley-Black (Walkley, & Black, 1934). Available phosphors (ppm) were determined using Olsen method. Soil pH was determined by measuring the hydrogen ion activity in an aqueous solution. A glass electrode, calibrated against a pH standard is used to do this some 20 g of soil was weighed into a numbered conical flask and 50 ml of distilled water was added to the soil. The suspension was thoroughly mixed and left to settle for 10 minutes. The pH was measured using a digital pH meter in the supernatant suspension of 1:2.5 soil to liquid ratio as detailed in the handbook of soil analysis (Pansu & Gautheyrou, 2006).

RESULTS

Effect of *L. camara* invasion on woody species composition, abundance and diversity:

A total of 58 plant species were recorded in the sampled plots from a site that was not invaded by *L. camara*, while the number was 47 in the highly invaded forest site (Table 1).

Table 1: List of plant species recorded in different infestation level identified during the study in Wollo floristic region.

Species name	Family name	Highly invaded	Moderately invaded	Un-invaded
Acacia abyssinica Hochst. ex Benth	Fabaceae		✓	✓
Acacia asak (Forssk.) Willd.	Fabaceae	✓	✓	✓
Acacia brevispica Harms	Fabaceae	✓		✓
Acacia etbaica Schweinf	Fabaceae	✓	✓	✓
Acacia laha Steud. & Hochst. er Benth.	Fabaceae	✓	✓	✓
Acacia nilotica (L.) Willd. ex Del	Fabaceae	✓	✓	✓
Acacia seyal Del.	Fabaceae	✓	✓	✓
Acacia sieberiana DC.	Fabaceae	✓	✓	✓
Achyranthes aspera L.	Amaranthaceae	✓		
Andropogon abyssinicus R.Br. ex Fresen.	Poaceae		✓	✓
Arthraxon prionodes (Steud.) Dandy	Poaceae			✓
Asparagus africanus Lam.	Asparagaceae		✓	✓
Blepharis maderaspatensis (L.) Roth.	Acanthaceae.	✓		✓
Calotropis procera (Ait.) Ait. F.	Asclepiadaceae			✓
Calpurnia aurea (Ait.) Benth.	Fabaceae	✓	✓	✓
Canthium lactescens Hiern	Rubiaceae	✓	✓	✓
Capparis tomentosa Lam.	Capparidaceae		✓	✓
Carissa spinarum L.	Apocynaceae		✓	✓
Clematis simensis Fresen.	Ranunculaceae			✓
Combretum molle R. Br. ex G. Don	Combretaceae		✓	✓
Commelina africana L.	Commelinaceae	✓		
Corchorus olitorius L.	Tiliaceae	✓	✓	
Cordia africana Lam.	Boraginaceae		✓	✓
Cordia monoica Roxb.	Boraginaceae	✓		✓
Cotula abyssinica Sch. Bip. ex A. Rich	Asteraceae		✓	✓
Crotalaria pycnostachya Benth.	Fabaceae	✓	✓	✓
Crotalaria spinosa Hochst. ex Benth.	Fabaceae	✓	✓	✓
Cynodon dactylon (L.) Pers.	Poaceae		✓	✓
Datura stramonium L.	Solanaceae	✓		
Dichrostachys cinerea (L.) Wight & Arn.	Fabaceae	✓	✓	

Species name	**Family name**	**Highly invaded**	**Moderately invaded**	**Un-invaded**
Dodonaea angustifolia L.f.	Sapindaceae	✓	✓	✓
Eculea racemosa Murr.	Ebenaceae		✓	✓
Eucalyptus camaldulensis Dehnh	Myrtaceae	✓		
Fluggea virosa (Willd.) Voigt.	Euphorbiaceae		✓	✓
Gerbera piloselloides (L.) Cassa.	Asteraceae	✓	✓	✓
Grevillea robusta A. Cunn. ex R. Br.	Proteaceae		✓	
Grewia bicolor Juss.	Tiliaceae	✓	✓	✓
Grewia trichocarpa Hochst. ex A. Rich.	Tiliaceae	✓	✓	✓
Grewia villosa Willd.	Tiliaceae	✓	✓	✓
Harpachne schimperi (Sch. Bip.) Beauv.	Poaceae	✓	✓	✓
Hibiscus macranthus Hochst. ex A. Rich.	Malvaceae	✓	✓	✓
Hibiscus ovalifolius (Forssk.) Vah.	Malvaceae	✓	✓	✓
Hyparrhenia anthistirioides (Hochst. ex A. Rich.) Andersson ex Stapf.	Poaceae		✓	✓
Hyparrhenia coieotricha (Steud.) W. D.	Poaceae		✓	✓
Hyparrhenia hirta (L.) Stapf	Poaceae		✓	✓
Hyparrhenia variabilis Stapf	Poaceae		✓	✓
Hypoestes forskaolii (Vahl) R. Br.	Acanthaceae	✓		✓
Hypoestes triflora (Forssk.) Roem. & Schult.	Acanthaceae	✓		✓
Indigofera amorphoides Jaub. & Spach.	Fabaceae	✓		✓
Indigofera arrecta Hochst. ex A. Rich.	Fabaceae	✓	✓	
Indigofera suaveolens Jaub. & Spach	Fabaceae	✓		✓
Jasminum grandiflorum L.	Oleaceae	✓	✓	✓
Justicia ladanoides Lam.	Acanthaceae	✓	✓	
Kalanchoe petitlana A. Rich	Crassulaceae	✓	✓	
Kalanchoe marmorata Baker.	Crassulaceae		✓	✓
Lantana camara L.	Verbenaceae	✓	✓	
Launaea intybacea (Jacq.) Beauv.	Asteraceae	✓		✓
Lippia adoensis Hochst. ex Walp.	Verbenaceae		✓	✓
*Monechma debile (*Forssk.*)* Nees.	Acanthaceae	✓		
Parthenium hysterophorus L.	Asteraceae	✓		
Peristrophe paniculata (Forssk.) Brummitt	Acanthaceae	✓		
Pithecellobium dulce (Roxb.) Benth.	Fabaceae		✓	✓
Rhus natalensis Krauss	Anacardiaceae		✓	✓
Rumex nervosus Vahl.	Polygonaceae		✓	✓
Sida rhombifolia L.	Malvaceae		✓	✓
Sida schimperiana Hochst. ex A. Rich.	Malvaceae	✓	✓	✓
Solanum marginatum L .f.	Solanaceae	✓		✓
Stephania abyssinica (Dillon & A. Rich.) Walp.	Menispermaceae	✓		✓
Vernonia leopoldi (Sch.Bip. ex Walp.) Vatke	Asteraceae	✓	✓	✓
Xanthium spinosum L.	Asteraceae	✓		
Ziziphus mucronata Willd.	Rhamnaceae	✓	✓	✓
Ziziphus spina-christi (L.) Desf.	Rhamnaceae	✓	✓	✓

Table 2: Richness, Shannon Weiner values for the heavily invaded, moderately invaded and non-invaded sites

Particulars	Richness	Simpson	Shannon Evenness	Simpson Evenness
Highly invaded site	47	19.32	0.88	0.39
Moderately invaded site	51	22.18	0.90	0.43
Un-invaded site	58	33.62	0.92	0.56

Table 3: ANOVA table shows significant Effect of infestation level on Basal area

Groups	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	70.65	2	35.32	25.62	0.00
Within Groups	37.23	27	1.38		
Total	107.88	29			

Table 4: Multiple Comparisons of mean difference of Basal area on the three infestations categories

(I) LEVEL		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Highly invaded site	Moderately invaded site	-2.39*	0.53	0.00	-3.47	-1.31
	Un-invaded site	-3.70*	0.53	0.00	-4.79	-2.63
Moderately invaded site	Highly invaded site	2.39*	0.53	0.00	1.31	3.47
	Un-invaded site	-1.32*	0.53	0.02	-2.40	-0.24
Un-invaded site	Highly invaded site	3.70*	0.53	0.00	2.63	4.79
	Moderately invaded site	1.32*	0.53	0.02	0.24	2.39

*The mean difference is significant at the 0.05 level.

Table 5: Means and standard deviation of the soil variables in the different intensities of *L. camara* in Wollo floristic region

Soil parameters	Level of infestation	Min	Max.	Mean	Standard deviation (n-1)
	High	6.3	6.9	6.6	0.2
pH	Medium	6.5	7.0	6.8	0.2
	None	6.6	7.2	6.9	0.2
	High	4.0	48.0	18.7	17.7
AvP (ppm)	Medium	7.8	35.4	17.1	10.4
	None	3.9	58.4	17.0	18.4
	High	1.3	2.9	2.0	0.5
OC (%)	Medium	1.0	2.9	2.0	0.6
	None	0.9	3.0	1.7	0.6
	High	11.3	68.8	37.9	17.3
Clay (%)	Medium	2.9	53.8	26.9	17.0
	None	15.0	40.0	25.5	8.6
	High	6.3	71.3	27.4	18.0
Silt (%)	Medium	27.5	69.7	41.4	12.3
	None	27.5	37.5	31.8	3.7
	High	17.5	47.5	34.8	10.5
Sand (%)	Medium	17.5	52.5	31.8	12.6
	None	22.5	52.5	42.8	10.8

Table 6: Multiple comparison means and standard deviation of the soil variables in the different intensities of *L. camara* in Wollo floristic region

Multiple Comparisons							
Dependent Variable			**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
						Lower Bound	**Upper Bound**
pH	Highly invaded site	Moderately invaded site	-0.24	0.08	0.01	-0.41	-0.07
		Un-invaded site	-0.38	0.08	0.00	-0.56	-0.22
	Moderately invaded site	Highly invaded site	0.24*	0.08	0.01	0.07	0.41
			-0.14	0.08	0.09	-0.32	0.02
	Un-invaded site	Highly invaded site	0.38*	0.08	0.00	0.22	0.56
		Moderately invaded site	0.14	0.08	0.09	-0.02	0.32
AvP (ppm)	Highly invaded site	Moderately invaded site	1.61	7.12	0.82	-13.00	16.21
		un invaded site	1.74	7.12	0.81	-12.86	16.35
	Moderately invaded site	Highly invaded site	-1.65	7.12	0.82	-16.21	13.00
		un invaded site	0.13	7.12	0.99	-14.47	14.74
	Un-invaded site	Highly invaded site	-1.74	7.12	0.81	-16.35	12.86
		Moderately invaded site	-0.13	7.12	0.99	-14.74	14.47
OC (%)	Highly invaded site	Moderately invaded site	-0.07	0.26	0.78	-0.62	0.46
		un invaded site	0.21	0.26	0.42	-0.32	0.76
	Moderately invaded site	Highly invaded site	0.07	0.26	0.78	-0.46	0.62
		un invaded site	0.29	0.26	0.28	-0.25	0.83
	Un-invaded site	Highly invaded site	-0.22	0.26	0.42	-0.76	0.32
		Moderately invaded site	-0.29	0.26	0.28	-0.83	0.25
Clay(%)	Highly invaded site	Moderately invaded site	10.97	6.65	0.11	-2.69	24.62
		un invaded site	12.38	6.65	0.07	-1.28	26.03
	Moderately invaded site	Highly invaded site	-10.97	6.65	0.11	-24.62	2.69
		un invaded site	1.41	6.65	0.83	-12.24	15.06
	Un-invaded site	Highly invaded site	-12.38	6.65	0.07	-26.03	1.28
		Moderately invaded site	-1.41	6.65	0.83	-15.06	12.24
Silt(%)	Highly invaded site	Moderately invaded site	-13.99	5.72	0.02	-25.72	-2.26
		un invaded site	-4.38	5.72	0.45	-16.10	7.35
	Moderately invaded site	Highly invaded site	13.9*	5.72	0.02	2.26	25.72
		un invaded site	9.62	5.72	0.10	-2.11	21.34
	Un-invaded site	Highly invaded site	4.38	5.72	0.45	-7.35	16.10
		Moderately invaded site	-9.62	5.72	0.10	-21.34	2.11

Multiple Comparisons							
Dependent Variable			Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Sand(%)	Highly invaded site	Moderately invaded site	3.00	5.08	0.56	-7.43	13.43
		un invaded site	-8.00	5.08	0.13	-18.43	2.43
	Moderately invaded site	Highly invaded site	-3.00	5.08	0.56	-13.43	7.43
		un invaded site	-11.00	5.08	0.04	-21.43	-0.57
	Un-invaded site	Highly invaded site	8.00	5.08	0.13	-2.43	18.43
		Moderately invaded site	11.00*	5.08	0.04	0.57	21.428

The un-invaded site had the highest species diversity (H'= 3.78) followed by the moderately invaded site the managed site (H'= 3.54). The invaded site had the lowest species diversity (H'= 3.41) (Table 2).

Effect of infestation level infestation on horizontal structure basal area:

Table 3 shows the sum of squares and significant differences in woody vegetation basal area among the three *L. camara* infestation categories (F=25.61, $p<0.05$). Table 4 shows the mean and standard deviation of the basal area obtained from the three infestations such as on highly invaded, moderately invaded, and uninvaded forest sites.

Effects of *L. camara* infestation level on some selected soil parameters:

Soil physicochemical parameters on *L. camara* highly invaded, moderately and an un-invaded forest site is presented in Table 5. The site highly invaded by *L. camara* had a mean pH value of 6.55 (sd=0.18). The moderately invaded-invaded site had a mean pH of 6.79 (0.20), while the site where *L. camara* was invaded recorded a mean pH value of 6.94 (sd=0.17). Means, standard deviation, and significance test of the soil variables in the three categories of forest sites in Wollo floristic region were presented (Table 6).

DISCUSSION

Several reports have shown that invasive alien plants can transform ecosystems by changing species composition, ecosystem structure, and ecosystem functioning (Mostert et al., 2017). The current study found that *L. camara* had reduced both species diversity and composition. Likely, the vigorous growth of the species, the extensive and dense root system of *L. camara* plays a role in the competitive exclusion of other species from invaded communities.

Species abundance decreased with increasing invasion of *L. camara* from invaded, moderately invaded to un-invaded site in that order. The invaded site had the least Shannon Weiner (H') value, while the highest Shannon Weiner (H') value was recorded in the un-invaded site. These results support (Aravindhan & Rajendran, 2014) findings in Vegetation of Velliangiri Hills, India

Low biodiversity recorded in the invaded site could attributed to the fact that *L. camara* produces and releases phenolic acids, flavonoids, terpenes, and terpenoids, some of which are known to inhibit the growth of other plants. Tadele, (2014) argued that leaf chemicals have different effects on different species.

There were significant differences in woody vegetation basal area among the three *L. camara* infestation categories (F=25.61, $p<0.05$). The uninvaded forest site recorded the highest mean basal area followed by the moderately invaded and the highly invaded recorded the least mean basal area. Basal area decreased with increased *L. camara* intensity (Chatanga et al., 2008), *L. camara* has the potential to disrupt the succession cycle, displacing native biota resulting in decreased biodiversity. Its infestations alter the structural and floral composition of native communities, as the density of *L. camara* in forest increases, allelopathic interactions increase, and hence there is a decline in species richness (Priyanka & Joshi, 2013; Sharma, et al., 2005). Similarly, it can replace already established species in a community; prevent the establishment of new individuals or both (Gaertner et al., 2012).

L. camara affects the dynamics and composition of the soil and has some impact on ecosystem functioning, especially soil nutrient cycling (Priyanka & Joshi, 2013). Some selected soil properties were higher across sites, highest in the invaded site, followed by the moderately invaded site, and lowest in the un-invaded site except for soil moisture content. The higher soil pH levels recorded in *L. camara* infested soils are similar to those reported in India (Sharma et al., 2005). A possible explanation for this might be that the invasive species prefer higher pH environments. However, further investigation, including the contribution of its biomass and associated chemical exudates.

Phosphorus and organic carbon were highest in the invaded site, followed by the moderately invaded site, and lowest in the un-invaded site. Sites invaded by *L. camara* were recorded as being richer in nutrients (Sharma et al., 2005). *L. camara* architecture promotes the accumulation of litter under the shrub, resulting in the build-up of nutrients, including nitrogen (Sharma et al., 2005). The increase inorganic carbon and phosphorous levels in the *L. camara* infested site is attributed to a decrease in nutrient sequestration following native species displacement as a consequence of *L. camara* invasion. Displacement of already established plants can occur through competition for resources changes in physical or chemical soil properties, an alteration of soil microbial feedbacks, or allelopathic effects (Gaertner et al., 2012).

In conclusion, this study has provided evidence that *L. camara* invasion is reducing biodiversity levels and negatively affecting other ecosystem processes in the study area. *L. camara* poses a significant threat to biodiversity and physiochemical property in the study area. Soil pH, P, and organic carbon have increased in the invaded site. *L. camara* has the potential to colonize most of the vegetation types in the study area, which will result in changing species composition and ecosystem structure. However, more studies are required to investigate the threshold level resulting degradation of local species in the area, and then, the results from this study it can be recommended that forest enterprises, local communities, and policymakers should formulate an effective controlling strategy to protect further expansion.

COMPETING INTERESTS

The authors have declared that they have no competing interest.

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