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Effects of *Lantana camara* and *Psidium guajava* on the Chemical Properties of the Soil in Eswatini–A Case of Ngudzeni Area

[1]H.S. Mamba and [2]S.S. Singwane

[1]Free Evangelical Assembles High School, P.O. Box 487, Nhlangano, Swaziland
[2]Department of Geography, University of Eswatini, Environmental Science and Planning Private Bag 4, Kwaluseni, Swaziland

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Corresponding Author:
S.S. Singwane,
Department of Geography,
University of Eswatini,
Environmental Science and Planning
Private Bag 4, Kwaluseni, Swaziland

ABSTRACT

This study investigated the effects of *Lantana camara* and *Psidium guajava* which are invasive plants on the native species and chemical properties of the soil at Ngudzeni area. In carrying out this study, direct observation was used in the field to ascertain the effects of the invasive species had on the native plants. A field survey was undertaken in eight (8) transects and sixteen (16) quadrats, eight (8) in the experimental and eight (8) in the control sites. In each quadrat, the species types were identified and counted to determine their numbers. Soil samples were taken at 15 and 30 cm depths. Acid digestion (aqua regia method) and analysis using Atomic Absorption Spectrophotometer (AAS) was used to determine the levels of the chemical elements in the soil. The results of this study reveal that the magnitude and direction of the effects varied both within and between the types of the effects. On average, abundance and diversity of the native species decreased in the invaded sites. Furthermore, the analyses of this study reveal that although the presence of the invasive species had negative effects on some of the elements of the soil, in some others still no marked effect was observed. Overall, invasive species effects are heterogeneous and not unidirectional even within particular effects types.

Key words: *Lantana camara*, *Psidium guajava*, Ngudzeni, native species, invasive species

INTRODUCTION

An invasive plant species has been defined as any species that is likely to spread into native flora or managed plant systems, develops a self-sustaining population and becomes dominant or disruptive to those native plants[1]. An invasive plant has the capability to flourish and spread belligerently outside its natural range. Generally, a naturally belligerent plant may be principally invasive when it is introduced to a new habitat. Alien invasive plants are a serious threat to biodiversity and they have the largest effect on plant biodiversity in many parts of the world second only to habitat loss[2]. They also have many adverse effects on ecosystem services, agriculture and forestry, the economy and human welfare[3].

Invasive plants disrupt many natural habitats. They are most threatening in ecosystems such as wetlands, sand dunes, fire prone areas and serpentine barrens where rare native plants are found. In addition to their negative effects, some invasive species may have positive traits. For example, the Himalayan blackberry produces edible berries that are relished by wildlife and people alike. Similarly, though it now threatens to crowd out native plants and increase fire danger, scotch broom, with its bright yellow flowers, was originally plant for beautification and landscaping purposes. Any positive effect an invasive species might have in an ecosystem can easily be outweighed by the damage it causes. Therefore, the threat of alien plants is enormous and awareness of what they are and what they do is just the start, but a vital part of the battle[4].

Invasion of terrestrial plants causes: a decline in species diversity (biodiversity). Many alien plants are capable of creating monospecific stands over large areas. Alien plant invasion has been observed to cause changes in the resident fauna of the affected area. Many of our indigenous birds, insects and other animals are not adapted to feed on or nest in alien plants and consequently they leave the area[4]. Local and even total extinction of indigenous species (loss of genetic pool), for example: *Pinus* spp., *Acacia* spp. and *Hakea* spp. have already caused the total extinction of several Fynbos species. The alien species induce an ecological imbalance and therefore an increased risk of catastrophic events (for example, fire risk, flooding). They increase fire hazard since some aliens are very flammable, (for example the *Acacia* spp. and *Chromolaena odorata*) enhancing the chance of runaway fires and increasing the fuel load, thereby creating hotter fires, which can sterilize the soil and kill deep growing roots[4,5]. Inhibitors of Apoptosis (IAPs) also have the potential of prevention of access. Thorny or spiny aliens (for example, *Opuntia* spp., *Pereskia aculeata*) can form impenetrable barriers, thereby preventing access to streams, pastures, shade trees or plantations whether by game, stock or workers. Their presence results in a decreased productivity of rangeland and a reduced value of the land. Unpalatable or poisonous species will be promoted by selective grazing (for example, *Nassella trichotoma*). These species can then cause suffering and even the death of stock. They can also contaminate and damage the coats, feet and mouths of the animals[4, 5].

Alternatively, soil erosion and the consequent siltation of dams and rivers are prone to occur in invaded areas. Alien trees (for example, *Sesbania* spp. and *Acacia* spp.) are easily ribbed out during floods, exposing bare soil. The dislodged trees can then block the watercourse, thereby causing even more flood damage[4,5]. Depletion of water resources has also been noted in invaded areas. Invasive alien plants usually use more water than the plants they replace. Gums and wattles in catchment areas are often implicated in the drying up of rivers and the lowering of the water table[4]. The presence of alien plants in an area may result in increased agricultural input costs. Many aliens interfere with agricultural activities such as crop production and in pastures. The costs incurred in controlling them increase the overall costs of production[4].

The Kingdom of Swaziland, like many other countries, is invaded by a variety of invasive alien plants and in recent time these have also caused widespread degradation of rangelands, water resources and crop lands culminating in their declaration as a national disaster[6]. Therefore it is imperative that alien invasive plant invasions be controlled[7]. There are about 340 invasive plant species that are listed in Swaziland's alien plant database. Four of the most problematic ones in Swaziland were identified as *Chromolaena odorata* (Sandanezwe), *Solanum mauritianum*, (Gwayana) and *Psidium guajava* (Umgwava). *Parthenium* species has also been shown to be troublesome and causing immeasurable ecological devastation in ranches and game reserves in addition to the other invasive species[1]. Among these alien species, the most disruptive invasive weed in Swaziland is *Chromolaena odorata*[1].

Psidium guajava is listed as a category 2 species and is also listed as the third most invasive alien plant species in the moist Savannah biome after *Lantana camara* and *Chromoloena odorata* (Triffid weed)[8]. It is widely spread throughout Swaziland in almost all habitat types, occurring mostly in the upper and lower Middleveld in medium to high rainfall areas (650-1000 mm per annum)[9]. According to a survey that was conducted in June to September 2009 by the Agriculture Research Council institute for soil, climate and water in South Africa, the worst infestations by *Psidium guajava* were in the frost-free areas of the Middleveld and distribution was strongly correlated to areas of high human population density and old cultivated fields[10]. The fast spread rate of *Psidium guajava* is ascribed to it being a nutritious fruit, easily spread by human and wildlife dispersal and also aided through vegetative redevelopment by suckering[11].

Psidium guajava seems unselective to soil as it thrives on soils of all textures derived from most parent materials. Doing equally well on heavy clay, marl, light sand, gravel bars near streams, or on limestone; and tolerating a pH ranging from 4.5 to 9.4. It is somewhat salt-resistant[12]. Good drainage is recommended but *Psidium guajava* trees are seen growing spontaneously on poorly drained land with a high water table–too wet for most other fruit trees. Mildly salty soils and soils both rich and poor in basic cations are tolerated.

On the other hand, *Lantana camara* grows best in open un-shaded areas such as wastelands, rainforest edges and forest recovering from fire or logging. It is also favored by disturbed areas such as road sides, railway tracks and canals.

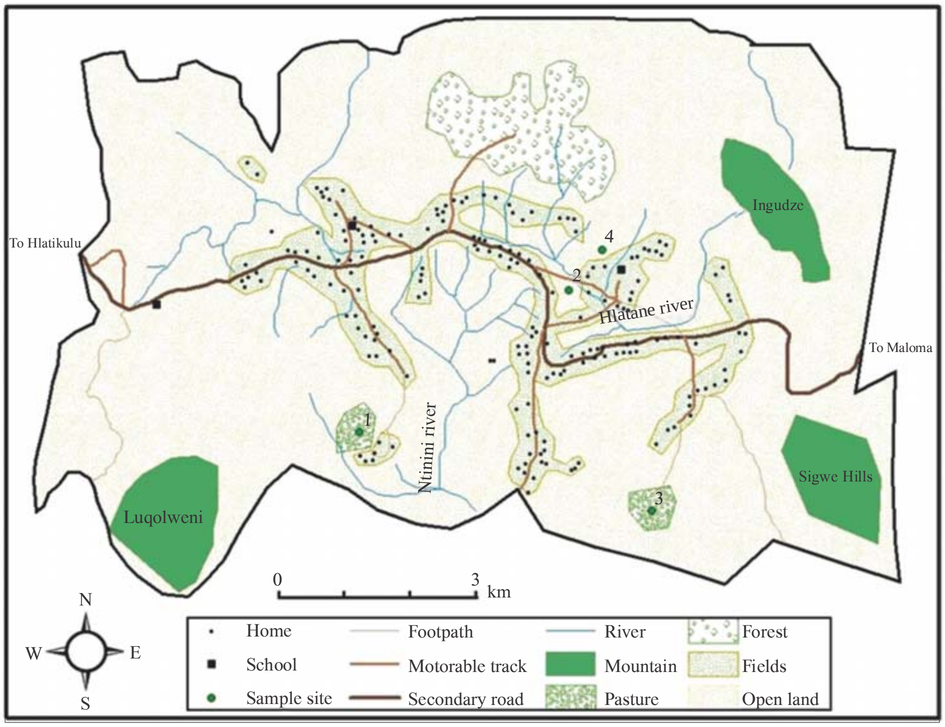

Fig. 1: Ngudzeni area, Source-ArcGIS

It has benefited from the destructive foraging activities of introduced vertebrates such as pigs, cattle, goats, horses, sheep and deer. *Lantana* has also invaded areas with high moisture levels[13]. *Lantana* is considered a weed of international significance[14] because of its widespread distribution in temperate, subtropical and tropical climates[15] and effects on primary production and biodiversity[14].

Lantana has formed dense, impenetrable thickets that have taken over the native bush land in the Ngudzeni area, displacing more desirable species and thereby decreasing biodiversity. Its allelopathic qualities have reduced vigour of plant species nearby, thus reducing on productivity. *Lantana* is steadily altering the structure of the vegetation around the area. It is thus affecting the flora as well as the fauna of the area. The capacity of the soil to absorb rain is lower than under good grass cover, thus potentially increasing the amount of runoff and the subsequent risk of soil erosion.

This study was carried out at Ngudzeni area in the Shiselweni district and Middleveld region of Swaziland. The name Ngudzeni is derived from Ingudze Mountain which is the North-east border the area (Fig. 1).

The chemical parameters of interest in this study were: Cation Exchange Capacity (CEC), Electrical Conductivity (EC), pH, Potassium, Calcium, Sodium, Magnesium, Zinc and Manganese. Plant nutrients can broadly be divided into two categories namely: those that are essential and those that are beneficial to the plant. A nutrient is essential (for example K) to the plant if it aids and supports the plant to complete its lifecycle, it has a specific role to play in the physiological processes of the plant and its role is irreplaceable and finally it has a direct function or role in the plants' metabolism. Beneficial nutrients on the other hand, are non-toxic and do not disturb the proper functioning and the lifecycle of the plant even in their absence (for example, Zn). For this study, the parameters of interest were selected because they are essential and key to the sustainable growth of plants. Also CEC, EC and pH which are soil properties that enable the availability of these essential nutrients to the plant were studied because even if the essential nutrients can be in abundance, if these three parameters are not conducive then the plant will not survive.

Plant invasions do not result in consistent changes in soil properties even for the same invasive species. Available data suggests a number of trends with respect to soil nutrients and plant invasions. Invasions have been associated with increases[16], decreases[17], or no change in soil nitrogen[18]. Moreover, research has shown that soil mineralization and nitrification rates were strongly related to the degree of invasion[19]. Nutrient dynamics may also become altered as a result of changes in the physical properties of the soil caused by the introduction of new species.

Alien plants alter soil nutrient dynamics by differing from native species in biomass and productivity, tissue chemistry, symbiotic associates, plant morphology and phenology. Available data suggest that alien invasive plant species frequently increase biomass and net primary productivity, alter nutrient availability and produce litter with higher decomposition rates than co-occurring native species[20]. Differences in litter mass or the litter decomposition is often, but not always, accompanied by changes in organic matter. For example, there was no difference in soil organic matter content in *Phragmites*-invaded compared to non-invaded *Spartina patens* marshes, despite having large differences in standing crop biomass and litter dynamics[21]. *Fallopia*, an invasive plant, tends to conserve nitrogen in the ecosystem. The decomposition of its litter is slow and immobilizes a large amount of inorganic N, reducing its availability in soil[22]. *Fallopia* is also able to decrease N losses from the ecosystem by decreasing nitrification and denitrification intensity in sites with high nitrification potential.

Effects on biological properties include the threatening of native habitats by outcompeting indigenous vegetation for water, nitrogen and organic materials, replacing grass communities[23]. For example, *Acacia mearnsii* reduces native biodiversity and increases occurrences of water loss from riparian zones[24]. Invaded ecosystems often have altered species composition and community structure[25].

Studies on *Acacia melanoxylon* indicated that residues from the *Acacia* tree produce a strong inhibitory effect that is toxic and affects germination at the initial phases and the greatest effects are on the growth of a plant[23]. The tree releases phenolic compounds into the soil that inhibit growth and development of vegetation. The soils sampled from the *Acacia* invaded site showed strong toxic effects on radicle growth and germination of indigenous vegetation[23].

Invasive alien plants threaten native species and habitats by competing for critical and often limited resources like sunlight, water, nutrients, soil and space. They succeed through vigorous growth, prolific reproductive capabilities and by causing changes that favor their growth and spread, they cause genetic changes in native plant relatives through hybridization and some serve as agents for the transmission of harmful plant pathogens. Invasive plant species displace and disrupt native plant communities, impede forest regeneration and natural succession, change soil chemistry, alter hydrologic conditions and alter fire regimes[26].

For example, various invasive plants are known to decrease local plant species diversity[27], increase ecosystem productivity and alter the rate of nutrient cycling[28] and hence impact upon ecosystem services and human well-being[29]. However, while there are growing numbers of studies reporting effects of alien plants, we still lack broad quantitative syntheses of how the effects vary depending on the attributes of recipient ecosystems and of the invaders themselves[30].

In Swaziland a significant portion of the population derives its livelihood from agricultural practices, mainly crop farming and livestock rearing. Therefore, anything that tempers with the soil productivity definitely has negative effects on the socio-economic and physical status of the people. The decline in soil productivity means that the people will not be able to grow sufficient food to sustain their families until the next growing season. This may consequently perpetuate deficiency diseases which if not well monitored might claim numerous lives, thus a sudden increase in the mortality rate of the country.

Alien plants are a major problem of the entire world but there is a shortage of accurate and informative data on their effects on the soil chemical properties, hence the need to investigate. On the other hand, the mechanisms by which alien invasions cause declines in native plants are not clearly understood[30]. Thus, there is a need to investigate the effects of alien invasive plants on native plant species.

The hypotheses of the study were:

- H_0: Invasive alien species have no effect on chemical properties (CEC, EC, pH, Calcium, Sodium, Magnesium, Potassium, Zinc and Manganese) of the soil
- H_1: Invasive alien species have an effect on soil chemical properties (CEC, EC, pH, Calcium, Sodium, Magnesium, Potassium, Zinc and Manganese) of the soil

The main objective was to investigate the effects of Lantana camara and Psidium guajava on the chemical properties of the soils at Ngudzeni area.

The specific objectives were:

- To determine the effects of alien invasive plants on chemical properties of soil
- To determine the effects of alien invasive plants on native plant species

MATERIALS AND METHODS

Research design: The study employed the experimental design, which permitted the making of fairly safe inferences about the relationship between the soil chemical properties and the invasion by the two alien plant species[31]. This design allowed the determination of cause-and-effect relationships.

Sampling: For the site selection, purposive sampling technique was used since it allowed the selection in accordance with the specific requirements of the study. For each species two (2) experimental and control sites were selected in ecosystems with contrasting resident vegetation structure, soil types and composition, in an attempt to sample the range of habitat colonized by the species under study. In all the selected sites, vegetation structure was profoundly affected by invasion, with alien species generally forming pure stands (Fig. 1).

The sites fulfilled the following conditions: had well established and still expanding population of the target species surrounded by native un-invaded vegetation, had sufficient homogenous soil, site selection was aimed at minimizing the probability differences existing prior to the invasion event. To that end, invaded and control (un-invaded) plots within a site were in the same topographic situation and had the same soil texture. Moreover, the (un-invaded) control plots were located as close as possible nearby the invaded plots. Therefore, systematic differences between invaded and un-invaded soils are reasonable ascribed to the contrasted plant cover.

A field survey was undertaken where transects were laid and along each (two) 2 quadrats were demarcated and carefully studied to understand the distribution of the vegetation in the sites. Therefore, there were 8 transects and 16 quadrats in all.

Information required: Parameters which were assessed on each soil sample are: Cation Exchange Capacity (CEC), Electrical Conductivity (EC), Soil pH, Calcium (Ca), Sodium (Na), Potassium (K), Magnesium (Mg), Zinc (Zn) and Manganese (Mn) content of the soil. The distribution of plant species on the site was noted and with this information on the tree species distribution, the frequency of species and species diversity (richness and equitability) were calculated.

Methods of data collection: After the site had been selected through purposive sampling, eight (8) 100 m transects were laid. In the site invaded by *Psidium guajava* there were (two) 2 experimental sites and two (2) control sites. The same principle was applied in the site invaded by *Lantana camara*. Hence all in all there were eight (8) transects (four (4) experimental and four (4) control sites Gutubane (site 1), Hlatane (site 2), Lachachacha (site 3) and School (site 4), two (2) for each species) (Fig. 1). Along each transect two (2) 15 m by 15 m quadrats at intervals of 50 m were demarcated using a measuring wheel, pegs and some strings.

Plant data: Within each quadrat a survey was undertaken where the type of plant species and number of individuals belonging to each species were identified, counted and recorded. The data collected from the field survey was quantitatively recorded and calculations were made for the frequency of species, species richness and equitability.

Soil data: Within each quadrat soil samples were taken at two depths (15 and 30 cm, after removal of litter) following an M pattern. The two depths were used since there is always a potential of leaching of the elements so the 30 cm depth allowed a recapture of leached elements from the 15 cm depth. Therefore, the five soil cores taken in each quadrat at the same depth were mixed, to make a composite sample and tested for the properties of interest. There were thirty two (32) samples in total. After sampling had been completed, samples were air dried to constant weight, ground using a mortar and pestle and then sieved to separate the soil (particles with diameter <2 mm) from gravel and stone (particles with diameters <2 mm) after which they were stored in air tight containers. Samples were then frozen to avoid the loss of volatile nutrient elements like Nitrogen. Furthermore, an effort was made to maintain the redox condition of the samples at the time of collection in order to avoid distortion of results obtained from the laboratory analysis. Preserved soil samples were then taken to the laboratory for the assessment of the parameters of interest: CEC, EC, soil pH, Calcium (Ca), Sodium (Na), Potassium (K), Magnesium (Mg), Zinc (Zn) and Manganese (Mn). A method was developed for the sequential determination of essential nutrients in soil using Analyst 800 atomic absorption spectrophotometer (AAS).

For identification purposes, the study sites are called Gutubane, Hlatane, Lachachacha and School, respectively.

Description of the study sites: Gutubane (site 1), was a *Psidium guajava* invaded site located within a fenced pasture. The site is on a gently sloping ground with sandy soil, light brown in colour. *Psidium guajava* trees formed pure stands on the site with very few native vegetation under story, mainly small herbs; as a result, the ground beneath the *Psidium guajava* trees was bare (Fig. 2). Nearby the site was a perennial small stream. The control site was on the same site, 30 m away from the experimental site and had the same topography and soil as the experimental site the main difference being that it was not invaded by *Psidium guajava* trees and had grass as its main vegetation cover (Fig. 2).

Hlatane (site 2), was a *Lantana camara* in vaded site located by the road-side. Nearby this site were cultivated fields and a small perennial stream. The site is on a very gently sloping ground with loamy soil, red in colour. The *Lantana camara* formed very thick, continuous and impenetrable thickets (Fig. 3). Very few native species were seen growing in

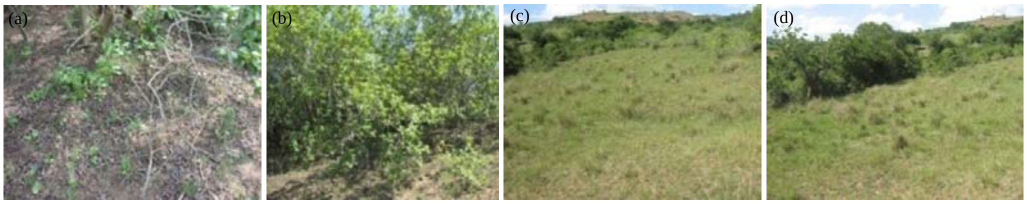

Fig. 2: Gutubane experimental and control site, (a-d) Experimental site dominated by *Psidium guajava* control site dominated by grass

Fig. 3: Hlatane experimental and control site, (a-b) Hlatane experimental site infested with *Lantana camara*, (c) Hlatane control site dominated by grass

Fig. 4: Lachachacha experimental and control site, (a-b) Lachachacha experimental site infected with *Psidium guajava* (c) Lachachacha control site

association with *Lantana camara.* This is mainly because native species were overcrowded by *Lantana camara* which made it difficult for them to grow freely and spread. The control site was 5 m away from the experimental site, across the road where *Lantana camara* had not yet invaded. The control site had all other conditions similar to the experimental site with the only difference being that the control site was not invaded (Fig. 3).

Lachachacha (site 3), was a *Psidium guajava* invaded site located within a fenced pasture. Nearby the site there is a perennial stream. The site is on a rugged terrain with dark grey-black clayey soil. In this site, the *Psidium guajava* formed prominent stands with grass as an understory (Fig 4) and some native species between the *Psidium guajava* trees. The control site was located 3 m away from the experimental site and it was covered by a number of native trees with the ground underneath them bare (Fig. 4).

School (site 4), was a *Lantana camara* invaded site located by the roadside. It was on a level ground with silt soil, dark brown in colour. In this site, the *Lantana camara* formed dense impenetrable thickets with grass as an understory (Fig. 5). A few native species were observed on site. The control site was located 5 m away from the experimental site and it had grass as it main ground cover (Fig. 5).

Properties of the soil favorable to invasive alien plant species: Common characteristics of ecosystems that may have increased susceptibility to alien plants include land that is disturbed by fire, human activities and overgrazing among amongst other things. This observation has been proved by this study to be true since the study sites were either pastures or they were by the roadside and hence all of them were disturbed sites and this explains why they were invaded and are still being invaded by the *Lantana camara* and the *Psidium guajava* species (Fig. 6).

Effects of IAPS on the native plants: With reference to the effects of the alien species on the native plants, there was

Fig. 5: The School experimental site infested with *Lantana camara*, (a-b) School experimental site infested with *Lantana camara* (c-d) School control site with grass

Fig. 6: A pasture invaded by *Psidium guajava* and a roadside invaded by *Lantana camara*, (a-b) A pasture invaded by *Psidiumguajava*, (c-d) A roadside invaded by *Lantana camara*

evidence of competitive exclusion of some of the native species. This was discovered when the species that were growing on the experimental sites were compared to those of the control sites, some of the species that were identified in the control sites were not found in the adjacent experimental site. Since all other conditions were kept uniform (in terms of topography and soil type), the only reason we can ascribe to their absence is the presence of the alien plant species in the experimental sites.

Statistical analysis: Student t-test was used to analyze the data.

RESULTS

The results reflect that in Hlatane and Lachachacha sites there were more species in the control sites than in the experimental sites. This is indicative of the significance of the impact of invasive plant species on native plants. On the other hand, in Gutubane and the School sites the trend was not clear, since the number of species varied such that they were sometimes more in either the control or experimental sites (Table 1). Regarding the number of individuals in the quadrats, the results indicate that in Gutubane, Hlatane and Lachachacha there were more plants in the control site than in the experimental sites. Again this reflects that in the control site there is no or minimal invasion by the alien plant species. However, in the School site there were more species in the experimental site than in the control site. Nonetheless, this also stems from the high number of species in the experimental sites than in the control site (Table 1).

In terms of species diversity (richness and equitability) the calculated values varied from one quadrat to another. For instance, species richness ranged from 0 to 0.28 (Table 1) without a discernible trend within the control and experimental sites. Therefore, the richness was sometimes either higher in the experimental site or in the control site without a systematic trend (Table 1). On the other hand, the calculated values for species equitability ranged from -2.12 to 0 (Table 1). In terms of the equitability in the sites there was a systematic trend in Gutubane, Hlatane and Lachachacha where it was higher in the experimental sites than in the control sites (Table 1). Worth noting is that the negative values of the species equitability are indicative of an uneven distribution of species in the quadrats.

During the field work, it was also noted that the *Psidium guajava* trees were very tall and they grew closer to each other such that they formed a continuous canopy. Accordingly, native species were overshadowed and deprived of sunlight. Subsequently, understory in the *Psidium guajava* invaded sites comprised very small herbs or a generally bareground, which makes the ground prone to erosion (Fig. 2).

Effects of IAPS on the chemical properties of the soil: In general, there is a variation of the soil pH, electrical conductivity and CEC in invaded and un-invaded sites. The results indicate that the soil pH in the experimental sites range from 4.88 to 5.89 while that of the control sites range from 5.09 to 6.52 (Table 2). These results show that although the soils of the area are generally acidic, those in the invaded sites are more acidic (lower pH values).

Table 1: Number of species, species richness and equitability in the sampling sites

Site	Quadrat	No. of species	No. of plants	Species richness (D)	Species equitability (E)
Gutubane (*Psidium guajava*)	Exp. 1	10	67	0.15	0.00
	Ctrl. 1	9	87	0.10	-2.00
	Exp. 2	5	63	0.08	0.00
	Ctrl. 2	7	92	0.08	-2.18
Hlatane (*Lantana*)	Exp. 1	4	52	0.08	-1.50
	Ctrl. 1	11	73	0.15	-1.92
	Exp. 2	5	67	0.07	-1.26
	Ctrl. 2	15	77	0.19	-1.70
Lachachacha (*Psidium guajava*)	Exp. 1	6	49	0.12	-1.68
	Ctrl. 1	13	57	0.23	-2.12
	Exp. 2	6	38	0.16	-1.79
	Ctrl. 2	11	63	0.17	-1.97
School (*Lantana*)	Exp. 1	6	92	0.07	-1.48
	Ctrl. 1	2	1	0.28	0.00
	Exp. 2	5	93	0.05	-1.55
	Ctrl. 2	1	0	0.00	0.00

Table 2: EC, pH and CEC of the soil

Site	Quadrat	Soil depth (cm)	EC microsiemens (cm)	pH	CEC ($cmol_c$ kg^{-1})
Gutubane	Exp. 1	15	19.08	5.04	26.59
		30	13.07	5.40	28.18
	Ctrl.1	15	20.63	5.31	22.62
		30	33.48	5.59	27.00
	Exp. 2	15	20.58	5.08	27.66
		30	16.27	5.40	23.47
	Ctrl. 2	15	30.23	5.80	14.81
		30	42.18	6.52	18.28
Hlatane	Exp. 1	15	22.15	5.24	11.94
		30	21.48	5.35	3.83
	Ctrl. 1	15	32.28	5.74	14.37
		30	26.88	5.61	9.66
	Exp. 2	15	17.66	5.27	11.95
		30	17.18	5.49	13.87
	Ctrl. 2	15	27.88	5.75	8.93
		30	25.58	5.77	8.64
Lachachacha	Exp. 1	15	14.66	5.63	11.62
		30	18.65	5.89	23.07
	Ctrl. 1	15	8.76	5.21	11.48
		30	19.22	5.81	16.00
	Exp. 2	15	17.66	5.73	14.18
		30	14.29	5.75	18.28
	Ctrl. 2	15	17.53	5.84	13.98
		30	19.55	5.86	13.51
School	Exp. 1	15	17.38	5.24	12.09
		30	22.08	5.34	16.34
	Ctrl. 1	15	15.48	5.30	12.56
		30	12.32	5.48	5.75
	Exp. 2	15	12.53	4.88	12.66
		30	9.92	5.22	7.70
	Ctrl. 2	15	14.80	5.60	4.81
		30	9.06	5.09	4.95

CEC: Cation Exchange Capacity, EC: Electrical Conductivity

Electrical Conductivity (EC): Electrical Conductivity (EC) is a measure of the conduction of electricity through a soil water extract. The value can reflect the amount of soluble salts in a soil extract therefore providing an indication of the soil salinity. It is expected for the EC of the soil to increase with an increase in the soil depth. This is because as the nutrient elements are leached down into the soil, the salt forming elements are also leached downwards.

From the results, only six out of sixteen (37.5%) of the samples showed the expected trend. In Gutubane, only the control quadrats had a higher EC at the 30 cm depth than the 15 cm depth as expected (Table 2). The experimental quadrats showed an opposite pattern. In Hlatane, all the quadrats do not show the expected trend, that is, they all had a higher conductivity at the 15 cm depth than at the 30 cm depth.

Since this site was by the roadside, the only reason to explain this unusual trend would be the disturbance of the soil during the road construction such that the subsoil was brought over the topsoil. This unusual trend was also seen at the School site which was also by the road side and probably disturbed in the same manner as that of Hlatane. The only difference in the School site was experimental quadrat 1 which showed the expected, that is high conductivity at 30 cm (22.08) than at the 15 cm (17.38), (Table 2). In Lachachacha, the results show the expected trend with only one exception experimental quadrat 2 with 14.29 at 30 cm and 17.66 at 15 cm (Table 2).

It was noted that both of the *Lantana camara* invaded sites (Hlatane and School) showed an opposite of the expected trend, this could be ascribed to the turnover of the soil during the road construction since both of the sites were by roadside. From the *Psidium guajava* invaded sites (Gutubane and Lachachacha), it was observed that the presence of the alien species had an effect on the trend of the EC of the soil. This is because all the control quadrats showed the expected trend while the experimental quadrats showed the opposite of what was expected with only one quadrat as an exception, Lachachacha experimental quadrat 1 with 18.65 at the 30 cm and 14.66 at the 15 cm (Table 2).

In general plant roots do not tolerate saline soils (that is, soils with a high EC) and the results of the *Psidium guajava* invaded sites justify why only small herbs were found growing under the *Psidium guajava* trees. This is because the herbs have short roots most of which do not grow beyond 15 cm so the high conductivity at the 30 cm depth forbids shrubs and trees with longer roots from growing under the *Psidium guajava* trees. The results from the *Lantana* invaded sites show that *Lantana* tolerates saline soils since although it has short fibrous roots it is able to thrive in the site with a high conductivity at the 15 cm depth. This also explains the reason behind growing of almost the same species in both of the *Lantana* invaded sites. This suggests that such species are tolerant of saline soils although they have short roots.

When using the EC to compare the experimental and control sites, the results show that there is a difference in two of the sites; hence the calculated values of t are greater than the critical values. For instance, the calculated value of t in Hlatane was 4.41 whereas the critical value was 2.13 (Table 3). Henceforth; the EC within the study area is likely to be largely affected by the presence of the alien species.

Table 3: Student t-test for EC

Site	t-test	Degrees of freedom	Critical value
Gutubane	3.03	2	2.92
Hlatane	4.41	4	2.13
Lachachacha	0.02	4	2.13
School	0.84	3	2.35

EC: Electrical Conductivity

Soil pH: The pH is defined as the negative log of the hydrogen ion activity. Since pH is logarithmic, the H-ion concentration in solution increases ten times when its pH is lowered by one unit. The pH range normally found in soils varies from 3 to 9. Various categories of soil pH may be arbitrarily described as follows: strongly acid (pH <5.0), moderately to slightly acid (5.0-6.5), moderately alkaline (7.5-8.5) and strongly alkaline (>8.5).

Notably, different horizons or even parts of horizons within the same soil may exhibit substantial differences in pH[32]. In many instances, the pH in the upper horizons is lower (more acid) than the deeper horizons but many patterns of variability exist. Acidifying processes usually proceed initially near the soil surface and slowly work their way down the profile. Examples include the acid input from rainfall; the oxidation of N applied fertilizer to the soil surface and the decomposition of plant litter falling on the soil surface. Reinforcing this vertical trend; many natural alkalizing processes such as mineral weathering are typically most active in the lower soil horizons where the more weather-able minerals from the parent material are still present. So a general conclusion that can be drawn is that the deeper the soil, less acid it becomes. The results obtained from this study follow the expected trend, that is, the 15 cm depths had more acid soils when compared to the 30 cm depths. However, Hlatane control site quadrat 1 and School control site quadrat 2 deviated from this trend. In Hlatane, a pH of 5.74 was observed at 15 cm depth while 5.61 were observed at the 30 cm depth (Table 2). In School control site quadrat 2, there was a pH of 5.60 at the 15 cm depth and 5.09 at the 30 cm depth (Table 2). Overall, the pH results from all the four sites show the expected trend with only two exceptions. So, in general this suggests that the presence of *Psidium guajava* and *Lantana camara* on the soil had no marked effect on the pH of the soil.

From the results it is evident that the samples that were taken at the 15 cm depth were more acidic. For example, in Gutubane experimental site quadrat 1, there was a pH of 5.04 than those taken at the 30 cm depth of 5.40 (Table 2). This indicates that soil acidity decreases with an increasing soil depth.

When comparing the experimental and control sites on the basis of pH, the results indicate that there is no difference

Table 4: Student t-test for pH

Site	t-test	Degrees of freedom	Critical value
Gutubane	2.07	4	2.13
Hlatane	6.20	1	6.31
Lachachacha	0.42	4	2.13
School	0.15	2	2.92

between the sites. Hence, the calculated values of t were less than the critical values (Table 4). This indicates that the pH of the soil varied between the quadrats without a discernible difference between the sites.

Cation Exchange Capacity (CEC): The cation exchange capacity of the soil can be defined as the sum total of the exchangeable cations that a soil can absorb. It is sometimes called the total-exchange capacity, base-exchange capacity or cation adsorption capacity. It is expected that effective CEC increases as the pH level rises. Also, sandy soils which are generally low in all colloidal material have a low CEC compared to those exhibited by silt loam and clay loam.

The results reveal that the *Psidium guajava* infested sites (Lachachacha and Gutubane) had a high CEC compared to the *Lantana camara* infested sites (School and Hlatane). From the results it is revealed that the CEC of the *Psidium guajava* infested sites ranges from 11.48 to 28.18 $cmol_c$ kg^{-1} while that of the *Lantana camara* infested sites range from 3.83 to 16.34 $cmol_c$ kg^{-1} (Table 2). As it would be expected, the results reveal that the CEC of the soils increased with an increase in the pH with only six out of the sixteen samples being an exception.

In Gutubane, the experimental sites had a higher CEC than the control sites (Table 2). For example, in the 15 cm depth, experimental site quadrats 1 and 2 had a CEC of 26.59 and 27.66 $cmol_c$ kg^{-1}, respectively. On the other hand, the control quadrats 1 and 2 had a CEC of 22.62 and 14.81 $cmol_c$ kg^{-1}, respectively (Table 2). It was also noted that the CEC from the 30 cm depth was higher than that from the 15 cm depth. For example, experimental site quadrat 1 had a CEC of 26.59 $cmol_c$ kg^{-1} at 15 cm and 28.18 $cmol_c$ kg^{-1} at 30 cm depth (Table 2). However, experimental site quadrat 2 did not follow the observed trend since it had a high CEC at 15 cm depth (27.66 $cmol_c$ kg^{-1}) than at 30 cm depth (23.47 $cmol_c$ kg^{-1}) (Table 2).

At Lachachacha, the results depict a similar trend to that observed at Gutubane. In this site too, the experimental site quadrats had a high CEC than the control quadrats (Table 2). For example, at 30 cm depth, the experimental site quadrat 1 and 2 had a CEC of 23.07 and 18.28 $cmol_c$ kg^{-1}, respectively. On the other hand, the control site quadrats had a CEC of 16 and 13.51 $cmol_c$ kg^{-1}, respectively (Table 2). From this site, it was also observed that the 15 cm depth had a high CEC than the 30 cm depth. However, control site quadrat 2 deviated from the observed trend because it had a CEC of 13.98 $cmol_c$ kg^{-1} at 15 cm and 13.51 $cmol_c$ kg^{-1} at 30 cm depth (Table 2).

Table 5: Student t-test for CEC

Site	t-test	Degrees of freedom	Critical value
Gutubane	2.04	4	2.13
Hlatane	0.00096	3	2.35
Lachachacha	1.15	3	2.35
School	2.02	2	2.92

CEC: Cation Exchange Capacity

At the School, the experimental site quadrats had a high CEC with only one exception and that was experimental site quadrat 1 which had a lower CEC (12.09 $cmol_c$ kg^{-1}) compared to control site quadrat 1 (12.56 $cmol_c$ kg^{-1}) (Table 2). In this site, two quadrats (experimental site quadrat 1 and control site quadrat 1) show a high CEC at the 15 cm depth and the remaining two (experimental site quadrat 1 and control site quadrat 2) show a high CEC at the 30 cm depth (Table 2).

In the last site, Hlatane, the results do not show any uniform trend. For example, experimental site quadrat 1, 15 cm had lower CEC (11.95 $cmol_c$ kg^{-1}) than control site quadrat 1 (14.35 $cmol_c$ kg^{-1}) (Table 2). Moreover, experimental site quadrat 2 on the other hand had a higher CEC (11.95 $cmol_c$ kg^{-1}) than control site quadrat 2 (8.93 $cmol_c$ kg^{-1}) (Table 2). It was noted that in this site, the soil from 15 cm depth had a high CEC than that from 30 cm depth, with experimental site quadrat 2 being the only exception where 15 cm depth had a CEC of 11.95 $cmol_c$ kg^{-1} while 30 cm depth had a CEC of 13.87 $cmol_c$ kg^{-1} (Table 2).

When comparing the experimental and control sites on the basis of CEC, the results indicate that there is no difference between the sites. Hence, the calculated values of t were less than the critical values (Table 5). This indicates that the CEC of the soil varied between the quadrats without a discernible difference between the sites.

Elements of the soil:

Potassium content: Potassium is readily lost by leaching. Drainage waters from soil receiving liberal fertilizer applications usually contain considerable quantities of K. From representative humid region soils growing annual crops and receiving only moderate rates of fertilizer, the annual loss of K by leaching is usually about 25 to 50 kg ha^{-1} the greater values being typical of acid sandy soils[32]. Because of K's susceptibility to leaching, one would expect to find a high K content at

Table 6: K, Zn, Mg and Mn in the soil

Site	Quadrat	Soil depth (cm)	K	Zn	Mg	Mn	Na	Ca
			(mg L^{-1})					
Gutubane	Exp. 1	15	28.31	2.26	143.09	18.67	17.72	0.48
		30	30.57	2.65	151.39	28.52	18.65	0.69
	Ctrl. 1	15	45.67	2.28	108.66	19.19	27.16	0.31
		30	54.92	2.46	120.88	19.95	48.18	0.99
	Exp. 2	15	29.11	2.45	151.54	25.29	13.76	0.30
		30	31.82	3.28	124.05	25.43	15.89	0.37
	Ctrl. 2	15	30.02	2.11	66.97	10.95	25.19	0.63
		30	31.51	2.43	91.49	18.33	16.68	1.56
Hlatane	Exp. 1	15	30.21	2.51	54.22	30.57	16.34	0.45
		30	28.61	2.44	66.98	38.95	13.40	0.50
	Ctrl. 1	15	33.67	2.19	36.09	50.00	11.45	0.16
		30	29.95	2.36	38.62	46.76	20.08	0.23
	Exp. 2	15	28.50	2.34	50.95	38.95	23.60	0.48
		30	21.64	2.38	65.11	38.71	22.85	0.61
	Ctrl. 2	15	27.87	2.21	36.02	64.71	17.88	0.18
		30	33.95	2.24	31.74	48.43	19.02	0.27
Lachachacha	Exp. 1	15	33.47	1.99	52.35	25.48	14.14	0.63
		30	29.23	2.48	120.90	30.29	17.75	1.28
	Ctrl. 1	15	31.16	2.28	44.25	19.05	29.35	0.49
		30	31.05	2.40	78.62	57.00	15.98	0.76
	Exp. 2	15	31.46	1.96	68.08	20.24	14.39	1.13
		30	27.94	2.41	91.97	35.90	18.23	0.63
	Ctrl. 2	15	35.71	2.08	59.75	39.90	25.46	1.04
		30	37.29	2.49	84.53	35.76	21.80	1.03
School	Exp. 1	15	35.00	2.24	21.50	4.52	77.72	0.03
		30	34.09	2.40	58.36	3.76	7.64	0.20
	Ctrl. 1	15	40.20	2.23	17.32	4.24	87.92	0.01
		30	42.21	2.14	18.62	2.76	5.86	0.11
	Exp. 2	15	33.56	2.35	21.02	4.86	85.96	0.06
		30	32.52	2.23	29.97	3.86	12.59	0.12
	Ctrl. 2	15	29.68	2.21	13.90	3.81	76.89	0.07
		30	32.23	2.33	14.89	5.9	9.73	0.02

k: Potassium, Zn: Zinc, Mg: Magnesium, Mn: Manganese, Na: Sodium, Ca: Calcium

30 cm depth than 15 cm depth. From the results, only Gutubane showed what was expected (Table 6). Noteworthy, Gutubane was an acid sandy soil that is why it showed an increased susceptibility to the leaching of the K element. In two of the sites (Hlatane and Lachachacha), only control sites quadrats 2 followed the expected trend with the other quadrats deviating from it (Table 6).

At the School site, only the control site quadrats followed the expected trend and the experimental site quadrats did not. The deviation from the expected trend observed at the Hlatane site can be ascribed to the soil turnover during the road construction. At the School site, since the deviation is only observed in the experimental site quadrats, it can be ascribed to the pattern of K uptake by the *Lantana camara*. The results suggest that the *Lantana* species uses more of the K than does the native species on the site.

In most instances, the control site quadrats had a high K content than the experimental site quadrats. This suggests that the alien species must be using up the K in the soil at a much higher rate compared to the native species. For instance, the impact of invasive plants on the chemical properties of the soils are strongly varied depending on the site but in a predictable way (that is, increased nutrient availability in the sites with low initial nutrient availability and the opposite pattern in initially rich soil)[22]. This observation has proven true when considering the potassium analysis results in this study. In Gutubane control site quadrat 1, the potassium content was high but in the experimental site quadrat it was low (Table 6).

Similarly, in School control site quadrat 1 the potassium content was still high but lower in the experimental site quadrat (35 mg L^{-1} at 15 cm and 34.09 mg L^{-1} at 30 cm) (Table 6). When considering school control site quadrat 2, the potassium content was low (29.68 mg L^{-1} at 15 cm and 32.23 mg L^{-1} at 30 cm) but now in the experimental site quadrat, the values are higher (33.56 mg L^{-1} at 15 cm and 32.52 mg L^{-1} at 30 cm) symbolizing an increase in the potassium content of the soil[22].

Table 7: Student t-test for K

Site	T-test	Degrees of freedom	Critical values
Gutubane	1.76	4	2.13
Lachachacha	1.71	1	6.31
School	1.63	3	2.35
Hlatane	0.74	3	2.35

k: Potassium

Table 8: Student t-test for Zn

Site	t-test	Degrees of freedom	Critical values
Gutubane	1.45	5	2.01
Lachachacha	0.62	4	2.13
School	1.53	4	2.13
Hlatane	3.21	5	2.01

Zn: Zinc

When comparing the experimental and control sites on the basis of K content of the soil, the results indicate that there is no difference between the sites. Hence, the calculated values of t were less than the critical values (Table7). This indicates that the K content of the soil varied between the quadrats without a discernible difference between the sites.

Zinc content: In general, it was noted that the Zinc (Zn) concentration was higher at 30 cm depth than at 15 cm depth in all the four sites (Table 6). This trend could be a result of leaching by which the Zinc was carried from the 15 cm to the 30 cm by infiltrating and percolating rain water. However, there was a deviation from the general trend and this was observed in School experimental site quadrat 2, control site quadrat 1 and Hlatane experimental site quadrat 1 (Table 6). It was also observed that there were no significant differences in the Zinc content of the *Lantana camara* and *Psidium guajava* invaded sites.

In Gutubane especially at 30 cm depth, the results reveal that the Zn content of the soil from the experimental site quadrats was higher than in the control site quadrats. For example, experimental site quadrats 1 and 2 had a Zn content of 2.65 and 3.28 mg L^{-1}, while in the control site quadrats 1 and 2 the content was 2.46 and 2.43 mg L^{-1} (Table 6). At 15 cm depth, experimental site quadrat 2 had a higher Zn content than control site quadrat 2, while experimental site quadrat 1 had a lower Zn content than control site quadrat 1.

Contrariwise in Lachachacha, the results show that the experimental site quadrats had a low Zn content compared to the control site quadrats. Experimental site quadrats 1 and 2 had a Zn content of 1.99 and 1.96 mg L^{-1}, respectively while the control site quadrats had a content of 2.28 and 2.08 mg L^{-1} (Table 6). At 30 cm depth, experimental site quadrat 1 had a high Zn content (2.48 mg L^{-1}) than the control site quadrat 1 (2.4 mg L^{-1}), while experimental site quadrat 2 had a low Zn content (2.41 mg L^{-1}) than control site quadrat 2 (2.49 mg L^{-1}). From the results, it can generally be deduced that the control site quadrats had a high Zn content than the experimental site quadrats with only one exception, experimental site quadrat 1at 30 cm (Table 6).

In School, the results from the 15 cm depth reveal that the experimental site quadrats had a high Zn content than the control site quadrats (Table 6). It could be observed that experimental site quadrats 1 and 2 had a Zn content of 2.24 and 2.35 mg L^{-1}, respectively, while the control site quadrats 1 and 2 had a content of 2.23 and 2.21 mg L^{-1} (Table 6). At 30 cm depth, experimental site quadrat showed a Zn content of 2.4 mg L^{-1} and this was higher than the 2.14 mg L^{-1} which was observed from control site quadrat 1. Experimental site quadrat 2 on the other hand, had a content of 2.23 mg L^{-1}, which was lower than the 2.33 mg L^{-1} observed from control site quadrat 2 (Table 6). From the results of this site, a general observation reveals that the experimental site quadrats had a high Zn content than the control site quadrats. Only one quadrat showed deviation from the observed trend and this was control site quadrat 2 which had a content of 2.33 mg L^{-1} while experimental site quadrat 2 had a content of 2.23 mg L^{-1} (Table 6).

Furthermore, in Hlatane a high Zn content was observed in the experimental site than in the control site. For example, in the experimental site quadrats 1 and 2 at 15 cm depth had a content of 2.19 and 2.21 mg L^{-1}, respectively (Table 6).

The results of the Zn analysis show that three of the sites namely Gutubane, School and Hlatane had a high Zn content in the experimental sites than in the control sites. Thus, only Lachachacha showed a high Zn content in the control site than in the experimental site.

When comparing the experimental and control sites on the basis of the Zn content of the soil, the results indicate that there is no difference between the sites. Hence, the calculated values of t were less than the critical values (Table 8). This indicates that the Zn content of the soil varied between the quadrats without a discernible difference between the sites. Only in one site was the difference significant and that was Hlatane (Table 8).

Manganese content: In Gutubane, the results reveal that the site has a high Manganese (Mn) content at 30 cm depth than at 15 cm depth, with experimental site quadrat 2 being the only exception, where the concentration was 25.29 mg L^{-1} at 15 cm depth and 18.33 mg L^{-1} at 30 cm depth (Table 6). At 15 cm depth, control site quadrat 1 had a high Mn content than experimental site quadrat 1. Control site quadrat 2 on the other hand, had a low Mn content of 10.95 mg L^{-1} compared to 25.29 mg L^{-1} in the experimental site quadrat 2. At 30 cm depth, the experimental site quadrats had a high Mn content than the control site quadrats. This is demonstrated by a concentration of 28.52 and 25.43 mg L^{-1} in the experimental site quadrats and 19.95 and 18.33 mg L^{-1} in the control site quadrats (Table 6).

Moreover, in Lachachacha a high Mn content was seen at 30 cm depth than at 15 cm depth with the only exception being control site quadrat 2 where a high content (39.9 mg L^{-1}) was found at 15 cm than at 30 cm depth (35.76 mg L^{-1}) (Table 6). In this site there was no visible uniform trend between the experimental and control site. In some cases, the control site had a high Mn content than the experimental site. For example, at 30 cm depth control site quadrat 1 had a high content (57 mg L^{-1}) than in experimental site quadrat 1 (30.29 mg L^{-1}) (Table 6). Nonetheless, in some other cases the experimental site had a high content of Mnthan the control site. For example, experimental site quadrat 1 had content of 25.48 mg L^{-1} while the control site had a content of 19.05 mg L^{-1} (Table 6).

Furthermore, in the school site, the results portray a strange pattern where unlike in the other sites, the content decreased with an increase in depth. Specifically, the soils from the 15 cm depth had a high Mn content than those from the 30 cm depth (Table 6). This is in spite of the fact that under normal circumstances we expect that the plant nutrients will be leached from the 15 cm depth into the 30 cm depth.

Finally, in Hlatane, it was noted that at 30 cm depth there was a low Mn content in all but one of the quadrats. The only exception to the trend was experimental site quadrat 1, which had a high content ofMn (38.95 mg L^{-1}) at 30 cm depth and (30.57 mg L^{-1}) at 15 cm (Table 6). It was also noted that the control site' quadrats of this site had a high Mn content than those in the experimental sites. For example, at 15 cm depth control sites quadrats 1 and 2 had a content of 50 and 64.71 mg L^{-1}, while the experimental site had a content of 30.57 and 38.95 mg L^{-1}, respectively (Table 6).

When comparing the experimental and control sites on the basis of the Mn content of the soil, the results indicate that there is no difference between the sites. Hence, the calculated values of t were less than the critical values (Table 9). This indicates that the Mn content of the soil varied between the quadrats without a discernible difference between the sites. The difference was only significant in Hlatane where the calculated value of t was 3.39 while the critical value was 2.13 (Table 9).

Magnesium content: The Magnesium (Mg) analysis results reveal that a high content was found at 30 cm depth than at 15 cm depth (Table 6). For instance, in Gutubane, a high content was contained at 30 cm depth than at 15 cm depth. Only one quadrat deviated from the trend, experimental site quadrat 2 where a content of 124.05 mg L^{-1} was observed at 30 cm quadrat, compared to the 151.54 mg L^{-1} observed at 15 cm depth (Table 6). It was also noted that the control site quadrats had a low content compared to the experimental site quadrats. This was demonstrated by concentrations of 143.09 and 151.54 mg L^{-1} at 15 cm depth in the experimental site quadrats 1 and 2 and 108.66 and 66.97 mg L^{-1} in the control site quadrats 1 and 2 at 15 cm depth (Table 6).

Table 9: Student t-test for Mn

Site	t-test	Degrees of freedom	Critical values
Gutubane	0.24	6	1.94
Lachachacha	1.15	4	2.13
School	0.10	1	6.31
Hlatane	3.39	4	2.13

Mn: Manganese

Table 10: Student t-test for Mg

Site	t-test	Degrees of freedom	Critical values
Gutubane	3.41	6	1.94
Lachachacha	0.94	4	2.13
School	1.87	1	6.31
Hlatane	5.63	4	2.13

Mg: Magnesium

Likewise in Hlatane, the 30 cm depth had a high Mg content, with only one exception, namely control site quadrat 2, which had a Mg content of 31.74 mg L^{-1} at 30 cm depth and 36.02 mg L^{-1} at t 15 cm depth (Table 6). It was observed that in this site, the experimental site quadrats had a high Mg content than the control site quadrats. For example, at 15 cm depth in experimental site quadrat1 and 2 the Mg content was 54.22 and 50.95 mg L^{-1}, while in the control site quadrats 1 and 2 it was 36.90 and 36.02 mg L^{-1} (Table 6).

Contrariwise, in Lachachacha and in the school the Mg content was high at 30 cm depth in all the quadrats (Table 6). When comparing the experimental and control sites on the basis of Mg content of the soil, the results indicate that there is a difference between the sites. Hence, the calculated values of t were more than the critical values (Table 10). This indicates that the Mg content of the soil varied between the quadrats with a discernible difference between the sites.

Calcium content of the soil: The results reveal that Calcium (Ca) was the least available element in the soils of the area (Table 6). Its concentration increased with an increase in the soil depth and this suggests that Ca is also prone to leaching. Gutubane and Hlatane sites had a high the concentration of the Ca at 30 cm depth than at 15 cm depth (Table 6). However,

Table 11: Student-test for Ca

Site	t-test	Degrees of freedom	Critical values
Gutubane	1.47	2	2.92
Lachachacha	6.98	5	2.01
School	0.41	3	2.35
Hlatane	1.13	2	2.92

Ca: Calcium

Table 12: Student t-test for Na

Site	t-test	Degrees of freedom	Critical values
Gutubane	1.89	3	2.35
Lachachacha	0.62	7	1.89
School	1.40	1	6.31
Hlatane	0.07	4	2.13

Na: Sodium

Lachachacha and School had some deviations from the expected trend although some of their quadrats displayed the expected trend (Table 6).

When comparing the experimental and control sites on the basis of the Ca content of the soil, the results indicate that there is no difference between the sites. Hence, the calculated values of t were less than the critical values (Table 11). This indicates that the Ca content of the soil varied between the quadrats without a discernible difference between the sites. The difference was only significant in Lachachacha where the calculated value of t was 6.89 while the critical value was 2.01 (Table 11).

Sodium content of the soil: The Na content results show that the element is also susceptible to leaching. Its concentration increased with an increase in the soil depth and this suggests that Na is also prone to leaching. Gutubane site followed the expected pattern, that is, the deeper the soil, the higher the concentration of the Na. However, Lachachacha, Hlatane and School had some deviations from the expected trend, although some of their quadrats displayed the expected trend (Table 6).

When comparing the experimental and control sites on the basis of the Na content of the soil, the results indicate that there is no difference between the sites. Hence, the calculated values of t were less than the critical values (Table 12). This indicates that the Na content of the soil varied between the quadrats without a discernible difference between the sites.

DISCUSSION

From the results, the number of species decreased with an increasing abundance of the alien species. This pattern may be in part due to the allelopathetic properties of the alien species which inhibits the growth of the native species close by the invasive species. Evidence also suggests that a majority of alien invasive species depict traits capable of modifying natural systems at both ecosystem and community/population scales (ecosystem alteration)[33]. Furthermore, the occurrence of almost the same species in association with the invasive plants suggests that such plants have either evolved to tolerate the changes in the soil properties inflicted by the alien species or the species are exotic weeds that were introduced to the area together with the alien species understudy. Evidence indicates thatplant introductions around the world have clearly stimulated hybridization in many plant taxa, whereby such hybridisations have been identified as a threat to many native species[34]. Considering the rate of the invasion event, the native species will soon be endangered and if nothing is done on time they will be threatened with extinction from the area. In view that the native species are homes or habitats to numerous insects and other animal types, their being threatened also threatens these organisms and this has a serious deleterious effect on the ecology of the area.

With reference to the chemical properties of the soil, the results indicate a clear variation with the soil depth other than with the invasion. With respect to the increase in soil pH with increasing depth in particular, Brady and Weil, asserts that the lowest pH values usually occur in the surface horizons in association with acid decomposition products of organic matter[32]. Furthermore, within the normal range of soil pH the principal controlling factors are organic matter and the type and amount of cations[32]. This qualifies that the soil acidity and the CEC of the soil are related since an increase in the soil acidity induces and increase in the CEC of the soil.

Generally, *Psidium guajava* has a wide tolerance range of soil properties, which is depicted through its tolerance of a soil pH ranging from 4.5 to 9.4[12]. The findings of this study are in agreement with the preceding observation, since *Psidium guajava* was seen to be doing very well in the soils of Ngudzeni with a pH of between 5.04 and 6.52, an EC of between 13.07 and 22.08 and they were seen to be growing well in both the clayey soil of Lachachacha and the sandy soil of Gutubane. Evidence depicts that *Psidium guajava* L. is a plant often employed in popular medicine, which however has toxic substances that can pose risks to the human health[35]. At the same time, the toxic substances inevitably have an effect on native plants since *Psidium guajava* is an allelophathic plant species. Contrariwise, *Lantana camara* grows best in open un-shaded areas and disturbed sites[13]. This study has proved this to be true since the *Lantana camara* invaded sites were by the roadside and this means they were on disturbed soil. Moreover, *Lantana camara* invades sites with high moisture content and this too has been proved to be true since the *Lantana camara* invaded study sites were located a stone throw away from streams[13]. In a study conducted in South Africa by Ruwanza and Shackleton[36], it transpired that *Lantana camara* is an invasive alien shrub of worldwide significance due to its impacts on biodiversity, which can alter the soil properties of invaded ecosystems and, as a result, affect management outcomes[36].

On the other hand, salt forming elements such EC are prone to leaching therefore, are least concentrated on the surface horizons but their levels increase with an increase in soil depth as they are leached into the deeper horizons[32]. As a result, the uppermost horizons generally have a high EC than the lower mineral horizons. The results of this study did not portray the expected pattern especially in the *Lantana camara* invaded sites and this is mostly likely to be a result of the soil turnover during the road construction since the sites were by the road side.

Finally, since when looking at the abundance and diversity of native species in relation to the presence of the alien species there is a clear evidence of a competitive exclusion of the native species since most of the native species that were observed in the control sites were not seen in the experimental sites. This implies that the native species are not tolerant to the soil conditions inflicted by the alien species. For instance, in a study conducted in Indonesia, it transpired that *Lantana camara* possess suppressive effects against the growth of red chill which denotes that it is an allelopathic plant species, hence it also has an effect on native plant species[37]. Therefore, a continued invasion by the alien species may eventually lead to the extinction of some endemic native plant species.

In terms of the comparison between the experimental and control sites, clear differences were observed on the basis of the number of species and species richness. This in turn indicates that the presence of the alien species has affected the distribution and diversity of plants at the Ngudzeni area. Based on the alternative hypothesis which states that the alien species have an effect on the abundance of the native species, the results of the t-test indicate that the hypothesis is acceptable. This is to say, difference between the invaded and un-invaded site in terms of the number of species and species richness indicates a decline in species diversity. Furthermore, the occurrence of some species only in the control site validates the assertion made by the hypothesis. In spite of the observed decline in the species diversity within the study area, a further decline is possible through the loss of productive land as a result of the invasion event.

CONCLUSION

The results of the study indicate that the alien plant species have deleterious effects on the abundance and diversity of the native species as well as on chemical nutrient elements. Therefore, native species cannot flourish in the soil conditions induced by the alien species and as a result they tend to occur in lower densities. The loss of species in turn reduces the species diversity and the land cover which prevents the soil surface against the agents of erosion. It also reduces the habitats for some native fauna and this has serious negative implications on the ecology of the area. Therefore, considering the rate at which the alien species are spreading in the area, there is clear evidence that in the near future species diversity will decline drastically with a likelihood of extinction of some endemic species. Furthermore, the presence of the alien species on the soil has shown to have some detrimental effects on the chemical properties of the soil. For instance, some of the nutrient elements occurred in lower concentrations in the invaded sites when compared to the un-invaded sites, which suggested a higher rate of absorption of the elements by the alien species when compared to the rate of absorption by the native species.

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