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COMMON INVASION OF NON-NATIVE PLANT SPECIES AND THEIR CO-OCCURRENCE IN AN URBAN AREA OF ONDO STATE, NIGERIA

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ABSTRACT

Urban development is a significant contributor to the loss of biodiversity. Biological invasion is a consequence of urban development where invasive species appear singly or in multiple following unprecedented disturbance. The current study was carried out to assess the presence and impact of the prevailing invasive non-native plant species co-habiting in the Federal University of Technology, Akure, Nigeria. Thirty-two (32) quadrants were systematically laid out to measure the species diversity and species composition of non-native plants across the University landscape. The species abundance of invasive non-native plants found within the quadrants was measured using the diversity indices. The Shannon–Wiener index (H) value was low in all the sites except Centre for Research and Development (CERAD) which was relatively high with 0.31 values. A one-way ANOVA (Duncan, P>0.05) shows that the Shannon-Wiener value and the relative density of the invasive non-native species had no significant difference among the nine selected sites; Forest Plantation (FP), Wild Park (WP), Teaching and Research Farm (T&RF), West African Science Service Centre on Climate Change and Adapted Land Use (WASKA), Centre for Research and Development (CERAD), University Senate (US), New Undergraduate Hostel (NUH), New Postgraduate Hostel (NPH) and New Road (NR). It was observed from the result that ten different instances of invasive non-native species colonized and dominated a particular study area following disturbance. In summary, it was observed that the infestation of these plant species is currently affecting the indigenous plant growth and survival at every season of the year. However, the study shows that biological control is easier done when a single species forms a colony in a site than when it is systemically spread across all areas.

Keywords invasive species, non-native plant species, conservation ecology, ecosystem disturbance, complex systems.

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INTRODUCTION

A large variety of exotic species in urban areas were absolutely related to urban afforestation (Silva *et al.,* 2021). With increasing urbanization and globalization, prior studies on the species of urban forests were proportionally ascribed to continuously increase in invasive tree species at the global level (Doroski *et al.*, 2020). Consequently, various drivers influence biological loss. One dynamic change in urban forest development is people's choices of trees to plant and promote. Based on geographical gaps in ecological knowledge and benefits, the proportion of tree species composition and distribution in urban cities have contributed to change in urban ecosystems. Urban ecosystem changes can adequately be handled and controlled when different land uses and existing land covers including the national park, natural heritage museum, botanical garden, recreational centre, arboretum, permanent sampling plot and strict nature reserve are professionally addressed globally (Divakara *et al.,* 2020; Esperon-Rodriguez *et al.,* 2022; Omomoh *et al.,* 2019). As illustrated by Doroski *et al.* (2020), monoculture planting is incidental to the ecosystem imbalance and biological invasion in the urban forest. Biological invasion in connection with forest disturbance changes in the forest ecosystem have affected a large proportion of the world's biodiversity (Richardson and Rejmanek, 2011, Charly *et al.,* 2021). Information on the biological loss and damage caused as a result of non-native species invasion were reported as affecting the species composition of specific regions (Lone *et al.,* 2019) and accompanied a rapid expansion. For example, Chytry *et al.* (2008) reported unprecedented habitat invasions in Europe.

A positive relationship of biological invasion in selected regions and habitats was recorded with prediction of higher future invasions due to the large proportion of invasions found at specific habitats. Ecological impacts of biological invasion based on climatic conditions vary among different regions of the forest ecosystem Chytry *et al.* (2008). Woody species performance in different ecosystems of the world require certain conditions for survival, and thus, acclimation to a new climate or new conditions would result in introduced species depending on whether they have been invaded before (Richardson and Rejmanek 2011). Similarly, such was the case of a single species and non-native plant, *Clerondendrum paniculatum.* In many parts of the world, this species composition is well-known as invasive and in some parts of the world (Englberger 2009) such as Asian continent, it is highly known and well distributed as native. Recent research revealed the species to be understated due to its low impact on the rainforest region of Nigeria (Omomoh *et al.,* 2021a). Nevertheless, most non-native plants are capable of outcompeting native species and thriving in their new environment. In addition to negatively affecting native biodiversity, the invasion of non-native plants influences the socioeconomic status level of rural households that rely on non-timber forest products (Nuñez and Pauchard 2010). Therefore, invasion of non-native plant species is established as a great threat to tropical areas (Castro-Diez *et al.,* 2019). Meanwhile, in Nigeria, the impacts of the distribution of non-native plant species in rural communities are relatively unknown, suggesting that more studies are needed to unravel the interplay of these important variables (Omomoh *et al.,* 2021a, 2021b). The aim of this research was to construct an inventory of invasive non-native species within selected locations on the university landscape. This was accomplished by assessing the non-native species present, their co-occurrence, abundance, and distribution as they are spread across the selected areas of the Federal University of Technology, Akure's campus.

MATERIALS AND METHODS

Study Area

The study was carried out at the Federal University of Technology, Akure, Nigeria with a total land mass of 640 ha. The annual climate and ecological zone of this area followed the description given in the previous studies (Omomoh *et al.* 2019, 2020) as a tropical humid lowland ecosystem. The research study consists of nine selected sites: Forest Plantation (FP), Wild Park (WP), Teaching and Research Farm (T&RF), West African Science Service Centre on Climate Change and Adapted Land Use (WASKA), Centre for Research and Development (CERAD), University Senate (US), New Undergraduate Hostel (NUH), New Postgraduate Hostel (NPH) and New Road (NR) (Figure 1). The sites were selected with respect to their degree of an anthropocentric disturbance. These were grouped into two categories. The first category is post-disturbance areas such as the Secondary Forest and Forest Plantation (FP), Wildlife Park (WP), and the *Tectona/Gmelina* Plantation. The second category is degraded areas with incessant disturbance related to activities associated with building construction. The first category consists of the close canopy and vegetation cover, whereas the second section is an open area adjacent to forest vegetation sites (e.g., *Ochroma lagopus*) along the New Road (NR), and the built-up areas of the University campus. These areas include the West African Science Service Centre on Climate Change and Adapted Land Use (WASCA), the Centre for Research and Development (CERAD), University Senate (US), the New Undergraduate Hostel (NUH), the New Postgraduate Hostel (NPH) and the Teaching and Research Farm (T&RF).

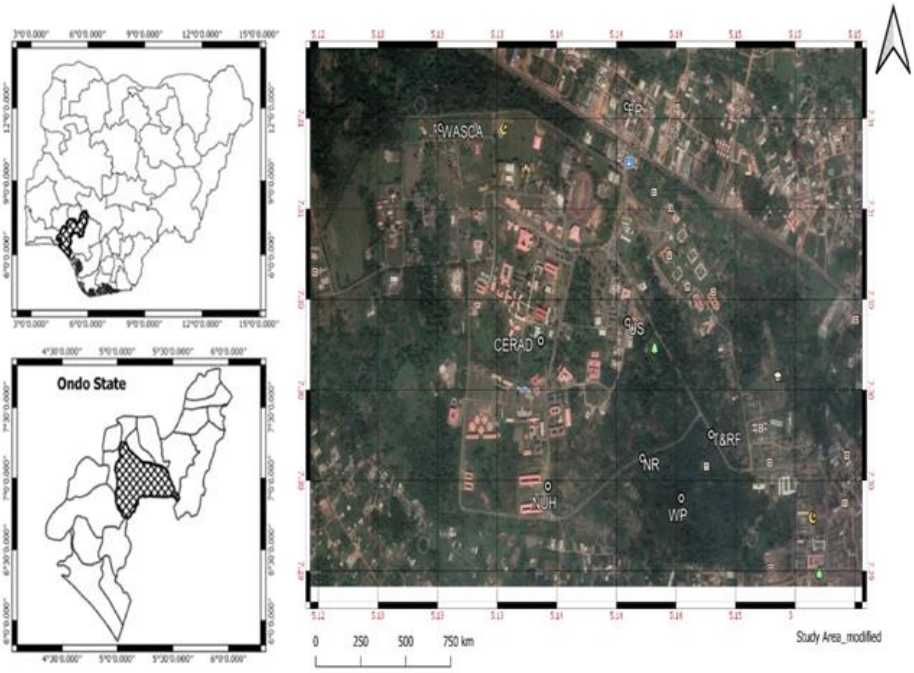


Figure 1: Map of the Study Location

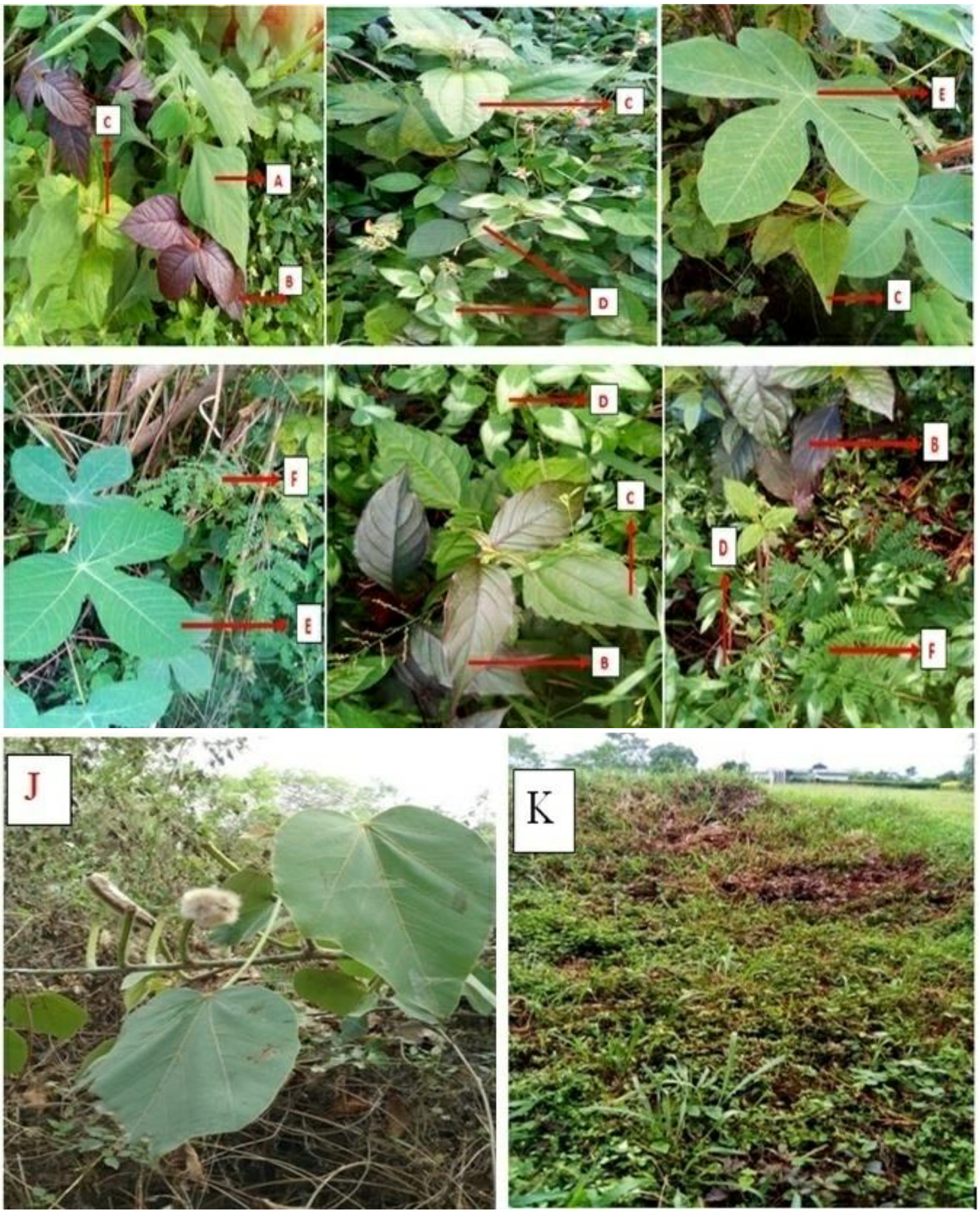
The Wildlife Park is a late-successional secondary forest absolutely devoid of *Tectona grandis* and *Gmelina arborea*, but characterized by diverse indigenous plant species encompassing categories of threatened wildlife for conservation (Omomoh *et al.*, 2021b). The university forest plantation is a large-scale plantation consisting of *Tectona grandis* and *Gmelina arborea* and was established for teaching and research. It was influenced by anthropogenic disturbance, exposing the current stage to plant succession for over three decades. Cohabitation of invasive native species and non-native species were major challenges facing the plantation. This mixed plantation (*Tectona grandis* and *Gmelina arborea* trees) are currently estimated at a range between 20m to 24m tall, while their diameters, at a breadth height of 1.3m, were between 0.18m to 0.55m, with a relatively thick canopy cover and low sunlight. The natural regeneration of this forest plantation encompassed the understory plants which were co-dominated by various resident indigenous species. The sites from the second category were selected based on their characterized open cover ground habitat, consisting of six sites with common features. This open habitat harbours well-known tropical light-tolerant plant species with diverse invasive plants of native and non-native plant species.

Study area sampling

The sampling units such as the locations used were obtained from the experimental unit, the university landscape. The experimental design was a completely randomized design (CRD) comprising nine selected locations as experimental treatments. The raw data from the sampling unit were statistically treated using analytical methods. The density and distribution of invasive non-native plants absolutely vary from one site to another following disturbance. These plant species were however enumerated and estimated in order to record the ecological variation of each site. A temporal sample plot of 2500 m^2 square was laid out. Four quadrants of $2m^2$ were also positioned at the four corners of each plot, and one at the centre in an alternate format along a 24 m line transecting at 5m intervals, resulting in 32 quadrants distributed across the 9 sites of the University. The identification of these invasive non-native plant species was done by the first author from the species to family level. The plant voucher specimen of each plant was prepared and deposited at the University herbarium (FUTA herbarium) with their voucher herbarium number. The abundance and the distribution of each invasive non-native plant across the selected sites were also measured using the DAFOR scale of preference.

Procedural database techniques adopted

Online database search engines such as the Integrated Taxonomic Information System (ITIS) updated database (2020), Kew Science, and Google Scholar were consulted using the keywords 'non-native', and 'introduced' in combination with 'species'. Additional searches on plant species' origin, species taxonomy, scientific citation authority, and plant geographic origins were compiled using JSTOR Global for plants, flora of West Tropical Africa object and grey literature such as Flora of West Tropical Africa text (Hutchinson *et al.*, 1963) to consolidate the jurisdiction findings of invasive non-native species. Part of the query list of Drake et al. (2003) for invasive species was adopted in assessing and characterizing the invasive non-native species found in this study. The basis for this study is to identify: 1) the hotspot of non-native invasive species in the University campus, 2) the number of non-native invasive plants that can tolerate one another by the way of cohabitation, and 3) the invasive non-native species distribution and abundance in the University campus following anthropogenic disturbance. GPS (Garmin GPS 60) coordinates for each location were taken.



Key: (A) =Tithonia diversifolia a Hemsl, (B) = Alternanthera brasiliensis Hort ex. Vilmorin, (C) = Chromolaena odorata (L.) R. M. King & H. Rob, (D) = Euphorbia graminea Jacq, (E) =Manihot glaziovii Müll. Arg, (F) =Leucaena leucocephala (Lam.) de Wit (G) = Gmelina arborea Roxb, (H) = A matured tree of Tectona grandis Linn. F (I) = A mature tree of Gmelina arborea, (J) = Ochroma lagopus Sw, (K) = Open herbaceous grassland

Data analyses

One-way ANOVA (Duncan test) was carried out to obtain the significant differences between the variables. Moreover, the data obtained were computed and processed using Microsoft Excel 2007 to get the mean and the standard error (SE). The 1000 bootstrap replicates in the PAST software 3.0 were also used to observe the diversity indices of the study area to understand the forest structure. To study the variance of analyses, the principal component analysis (PCA) ordination was used to explain the variations in the distribution of invasive non-native plant species of the study area. The plant species were categorized into their life forms using Hutchinson *et al.* (1963). The species relative density (Kent and Coker 1992) was calculated using:

Relative Density:

$$RD = \frac{n_i}{N} \times 100 \; ..... \; (1)$$

Where *RD* = species relative density, n*i* = number of individuals of species *i*, *N* = total number of all plant species in the entire community.

Shannon-Wiener diversity index (Michael 1990):

$$H' = -\sum_{i=1}^{S} p_i \ln(p_i) \; .... \; (2)$$

Where H^I = Shannon diversity index, *S* = the total number of species in the community, p_i = proportion *S* (species in the family) made up of the *i*th species and ln = natural logarithm.

(iii). Species richness index (Margalef 1958):

$$R = \frac{S-1}{LN(N)} \; ..... \; (3)$$

Where *S* = the total number of species in the community, *Ln* = natural logarithm and *N* = total number of all plant species in the entire community.

RESULTS

A total number of 23 invasive non-native species (seven trees, four shrubs, and eleven forbs) were found and recorded in 11 families in 9 different locations of the University campus (Table 1). The species frequency distributions across the study areas are shown in Figure 2a whereby one to two species of plants were predominant. The subfamily *Leguminosa,e* such as *Caesalpinioideae* and *Papilionoideae* (LPWG 2017), consists of the highest contributing invasive non-native members in the area study, followed by *Verbenaceae*. There were no areas without presence of two to three non-native plants activities. However, one species of non-native plant was observed in the following areas of study: Forest Plantation, New Road, Wildlife Park, and CERAD, as shown in Table 2. From our result, three invasive non-native species cohabited in the same community within nearly 0.5-4.0 mm of close range. These were mainly found in the Forest Plantation and WASCA, the herbaceous/grassland open field adjacent to the Forest Plantation, and around the Wildlife Park and built-up area (University Senate). The outcome of the plant identification carried out in this study according to Table 2 shows that two non-native plants species, *Chromolaena odorata* and *Leucaena leucocephala,* were identified in all the nine locations within the University landscape. The canopy covers areas such as the Forest Plantation, Wildlife Park and New Road, increasing and supporting the dense shade of the forest floor which thereby affects the natural regeneration of most native ground flora.

Table 1 showing the nine different locations in the study area of the University

		Study sites								
Families	**Scientific names**	**FP**	**WP**	**T&RF**	**WASCA**	**CERAD**	**US**	**NUH**	**NPH**	**NR**
Amaranthaceae	*Alternanthera brasiliensis* Hort ex. Vilmorin (FUTA Herbarium Voucher: 0267)	X	X	X	X	X	X	X	X	
Asteraceae	*Chromolaena odorata* (L.) R. M. King & H. Rob (FUTA Herbarium Voucher: 0268)	X	X	X	X	X	X	X	X	X
	Ageratum houstanianum Mill. (FUTA Herbarium Voucher: 0269)	X								
	Tithoniadiversifolia Hemsl (FUTA Herbarium Voucher: 0270)		X	X	X	X	X	X	X	X
Bombacaceae	*Ochroma lagopus* Sw. (FUTA Herbarium Voucher: 0272)									X
Caesalpinioideae	*Mimosa diplotricha* C. Wright ex Sauvalle (syn*Mimosa invisa*Mart) (FUTA Herbarium Voucher: 0271)					X			X	X
	Mimosa pudica Linn (FUTA Herbarium Voucher: 0273)	X		X	X	X	X	X	X	
	Leucaena leucocephala(Lam.) de Wit (FUTA Herbarium Voucher: 0274)	X	X	X	X	X	X	X	X	X
	Schrankia leptocarpa DC (FUTA Herbarium Voucher: 0275)			X			X			
	Senna hirsute (L.) H.S. Irwin &Barneby (FUTA Herbarium Voucher: 0276)		X							
	Senna siamea (Lam.) H.S. Irwin &Barneby (FUTA Herbarium Voucher: 0271)	X								X
Cannaraceae	*Canna indica* Linn FUTA Herbarium Voucher: 0278)		X							
Euphorbiaceae	*Manihot glaziovii* Müll. Arg (FUTA Herbarium Voucher: 0279)		X	X		X	X	X		X
Lamiaceae	*Clerodendrum*x *speciosum* (FUTA Herbarium Voucher: 0288)					X				
	Euphorbia graminea Jacq (FUTA Herbarium Voucher: 0280)	X								
Papilionoideae	*Gliricidia sepium* (Jacq.) Walp (FUTA Herbarium Voucher: 0281)					X				
Phytolaccaceae	*Hilleria latifolia* (Lam.) H. Walt (FUTA Herbarium Voucher: 0282)		X							
Portulacaceae	*Talinum triangulare*(Jacq.) Willd (FUTA Herbarium Voucher: 0283)	X	X	X		X			X	
Solanaceae	*Physalisangulata* Linn. (FUTA Herbarium Voucher: 0284)		X		X				X	
	*Physalis peruviana*Linn (FUTA Herbarium Voucher: 0285)		X							
Verbenaceae	*Tectonagrandis* Linn. F (FUTA Herbarium Voucher: 0286)	X								
	*Gmelinaarborea*Roxb (FUTA Herbarium Voucher: 0287)	X	X	X		X				X
	Stachytarphetacayennensis (L. C. Rich.) Schau (FUTA Herbarium Voucher: 0289)		X					X		X

Table 1. FUTA Herbarium Voucher= Federal University of Technology Akure Herbarium Voucher, FP= Forest Plantation, WP=Wild Park, T&RF=Teaching and Research Farm, WASCA= West African Science Service Centre on Climate Change and Adapted Land Use, CERAD=Centre for Research and Development, US=University Senate, NUH=New Undergraduate Hostel, NPH=New Postgraduate Hostel, NR=New Road. X = Present

Table 2 showing the mean and standard error frequency distribution of the invasive non-native species existing in the study areas

		SITES								
Species names	**Habitat**	**FP**	**WP**	**T&RF**	**WASCA**	**CERAD**	**US**	**NUH**	**NPH**	**NR**
Ageratum houstanianum Mill.	Forb	39.5±14								
Alternanthera brasiliensis Hort ex. Vil	Forb	11.5±5.5	16±1.1	24.4±4.2	29.4±4.5	10.8±0.8	19.8±1.74	2.8±0.57	4.2±1.1	
Canna indica Linn	Forb		9.6±3.1							
Chromolaena odorata (L.) R. M. King	Forb	9.8±3.2	13±0.8	37.4±6.3	18.6±3.1	20.2±4.85	8.5±1.75	61.4±13.8	65.8±20.3	37.1±1.11
Clerodendron speciosa	Shrub					3.6±0.38				
Euphorbia graminea Jacq	Forb	339±135								
Gliricidia sepium (Jacq.) Walp	Tree					9.0±1.87				
Gmelina arborea Roxb	Tree	16.8±3.2	7.3±2.3	3		2.23±0.47				4±0.91
Hilleria latifolia (Lam.) H. Walt	Forb		16.6±3							
Leucaena leucocephala (Lam.) de Wit	Tree	72±16.2	8.7±2.5	14.6±1.7	3±0.4	5.4±0.81	2	5	2.75±0.47	43.8±9.87
Manihot glaziovii Müll. Arg	Tree		12±2.3	2		2	6	1		22.5±2.5
Mimosa diplotricha C. Wright ex	Shrub					2			3	2.66±0.33
Mimosa pudica Linn	Forb	8		3.0±2.0	4±0.57	1.5±0.33	2.5±0.64	7	4.8±0.4	
Ochroma lagopus Sw.	Tree									16.8±3.95
Physalis angulata Linn.	Forb		3.5±0.5		3±0.57				2.8±0.66	
Physalis peruviana Linn	Forb		2.7±0.6							
Schrankia leptocarpa DC	Shrub			2.8±0.91			2.0±0.4			
Senna hirsuta (L.) H.S. Irwin & Barn	Shrub		2.4±0.7							
Senna siamea (Lam.) H.S. Irwin & Bar	Tree	4.0±1.0								4.6±0.81
Stachytarpheta cayennensis (L. C. R)	Forb		2.7±0.8					4		7
Talinum triangulare (Jacq.) Willd	Forb	39.3±10.5	24±4.2	3		2.75±1.03			4.25±0.62	
Tectona grandis Linn. F	Tree	45.2±16.5								
Tithonia diversifolia Hemsl	Forb		5.0±0.5	3.75±1.7	2.3±0.3	23±5.1	4.4±1.12	18.4±3.17	15±2.23	11.2±1.75
	Total	290±161	**511**	**375**	**300**	**349**	**181**	**422**	**483**	**692**

Key: FP= Forest Plantation, **WP**=Wild Park, **T&RF**=Teaching and Research Farm, **WASCA**= West African Science Service Centre on Climate Change and Adapted Land Use, **CERAD**=Centre for Research and Development, **US**=University Senate, **NUH**=New Undergraduate Hostel, **NPH**=New Postgraduate Hostel, **NR**=New Road

Table 3: The statistical summary of the study areas

	FP	**WP**	**T&RF**	**WASCA**	**CERAD**	**US**	**NUH**	**NPH**	**NR**
Species Number	290±161	39.3±9.49	41.7±19.17	50.0±25.7	31.7±10.4	25.9±12.9	60.3±42.9	60.4±39.0	76.9±26.3
Shannon Wiener	0.14±0.03	0.17±0.03	0.03±0.05	0.19±0.05	0.31±0.15	0.19±0.04	0.11±0.06	0.14±0.03	0.19±0.04
Relative Density	10.0±5.55	7.69±1.86	11.1±5.11	16.7±8.56	9.09±2.98	14.3±7.11	14.3±10.2	12.5±8.08	11.1±3.79
Elevation	392m	414m	401m	388m	389m	392m	378m	371m	394m
Latitude	N07^{0}308.43	N07^{0}295.46	N07^{0}297.57	N07^{0}30773	N07^{0}300.67	N07^{0}301.29	N07^0.295.86	N07^0 295.98	N07^0.296.79
Longitude	E005^{0}139.55	E005^{0}142.29	E005.143.80	E005^{0}13018	E005^{0}135.22	E005^{0}139.60	E005^0.135.58	E005^0 131.15	E005^0.140.33

Key: FP= Forest Plantation, WP=Wild Park, T&RF=Teaching and Research Farm, WASCA= West African Science Service Centre on Climate Change and Adapted Land Use, CERAD=Centre for Research and Development, US=University Senate, NUH=New Undergraduate Hostel, NPH=New Postgraduate Hostel, NR=New Road

According to Table 3, the DAFOR scale of preference shows that 39.4% of taxa in the University campus were rare, 33.6% were occasional, and 27.3% were frequent. No result was recorded for dominance and abundance. Species under rare status (DAFOR) were found in most of the locations (Table 3). For example, *Alternanthera brasiliensis*, an invasive non-native plant species in tropical Africa, and usually a perennial herbaceous plant in the open areas, is the most abundant non-native species (147 and 99) common within WASCA and the University Senate (US) only. *Alternanthera brasiliensis* and *Tithonia diversifolia* are identified in eight (8) of the nine locations within the University landscape, and only *Mimosa pudica* was identified in seven locations. A diminished presence of the non-native plant species *Manihot glaziovii* was identified in six locations, *Gmelina arborea* and

Talinum triangulare in five locations, *Mimosa diplotricha*, *Physalis angulata* and *Stachytarpheta cayennensis* in three locations, *Schrankia leptocarpa* and *Senna siamea* in two locations. Meanwhile *Ageratum houstanianum*, *Canna indica*, *Euphorbia graminea*, *Gliricidia sepium*, *Hilleria latifolia*, *Ochroma lagopus*, *Physalis peruviana*, *Senna hirsuta*, and *Tectona grandis* had a minor presence in only one location each. Among the sites studied (Table 2), only the Forest Plantation had the highest relative density of 290±161. However, a low proportion of *Alternanthera brasiliensis* was found in all the study locations, except in WASCA and New Undergraduate Hostel, with high numbers of 147 and 99 (Table 2) of the same species. Another invasive non-native, *Chromolaena odorata*, was discovered and was also found to have the highest number of individuals in all the selected sites, most especially in the New Postgraduate Hostel (328), followed by the New Undergraduate Hostel (307). These species had become naturalized in Africa for many decades. In Table 4, the Shannon–Wiener index (H^i) value was low in all the sites except CERAD which was relatively high with 0.31±0.15 values, as seen in Table 3. A one-way ANOVA (Duncan, P>0.05) showed that the Shannon-Wiener value and the relative density of the invasive non-native species have no significant difference among the nine selected sites. The statistical summary of all the study areas were shown accordingly in Tables 1 and 2. Looking at the species variation (Figure 4) among the invasive non-native plant species, the result from the PCA showed there was a small variation of these species between the study areas including New Undergraduate Hostel (NUH), New Postgraduate Hostel (NPH), CERAD, and WASCA.

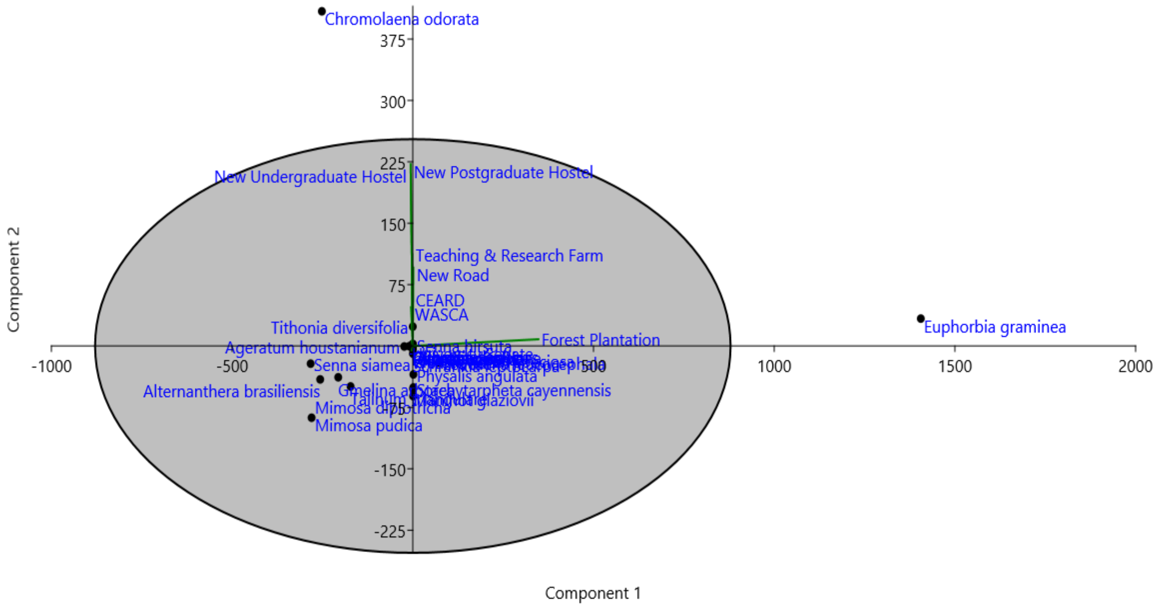
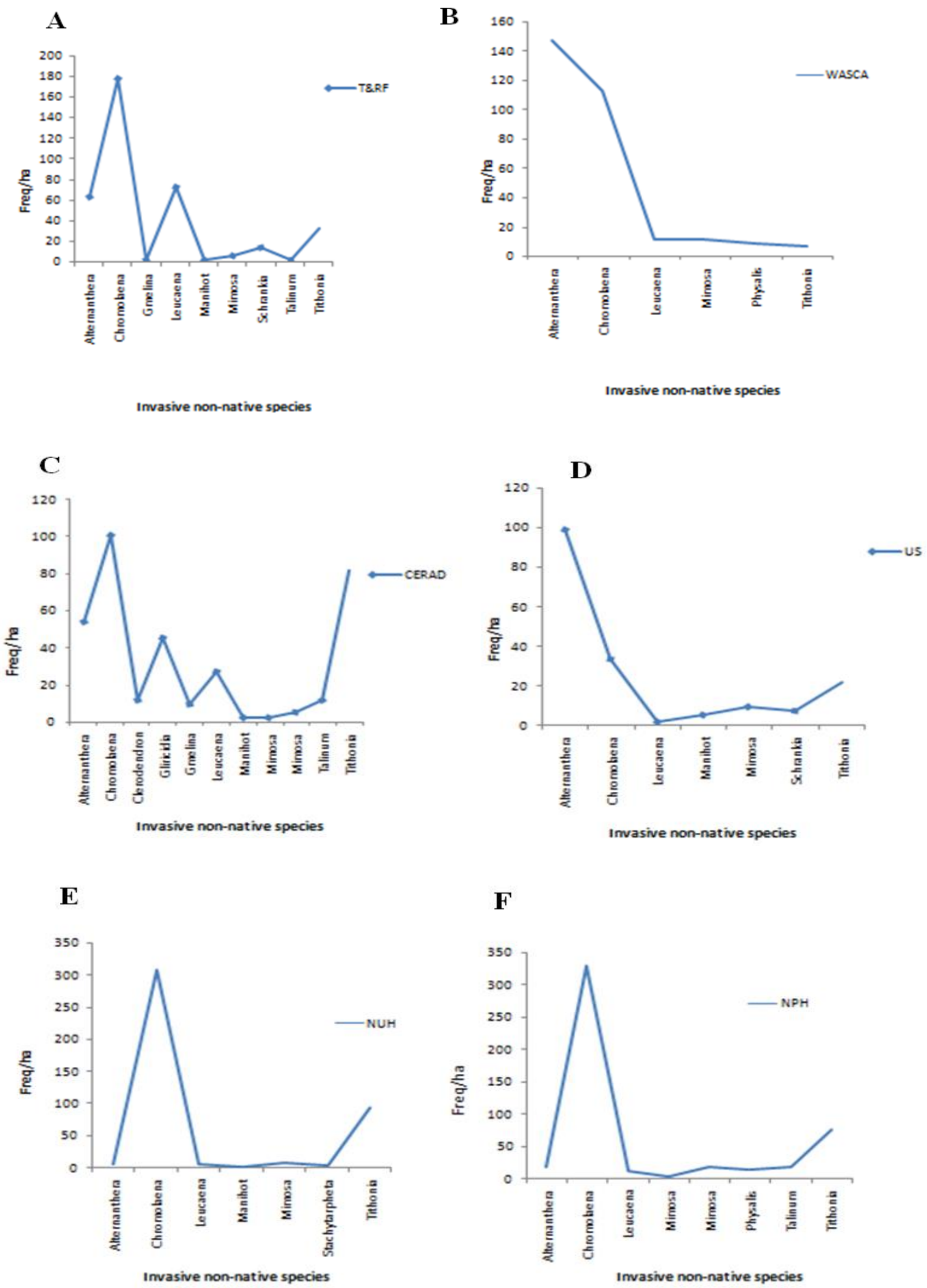


Figure 4: Principal components analysis showing variations in the distribution of invasive non-native plant species

The larger percentage of the variation in the species composition was observed at the Forest Plantation. The outliers of the 95% eclipse were the *Chromolaena odorata* and *Euphorbia graminea.* Invasive non-native species were investigated across the study location; the two locations at CEARD and Wildlife Park had a high frequency distribution across the sites studied and a similarly high species abundance was only observed in the Forest Plantation from the same study (Figure 3a, Table 2). The number of invasive non-native species increased across the study area with an increase in Forest Plantation, followed by New Road, Wildlife Park, and Post Graduate Hostel (Table 2). However, the increase in individual species varies from one location to another. For example, *Euphorbia graminea* (339±135) had a high number frequency in Table 2 as it is denoted in Figure 3.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Leucaena
Manihot
Mimosa
Schrankia
Talinum
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Invasive non-native species
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Alternanthera
Chromolaena
Leucaena
Mimosa
Physalis
Tithonia
Invasive non-native species
C
CERAD
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Chromolaena
Clerodendron
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Mimosa
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Physalis
Talinum
Tithonia
Invasive non-native species

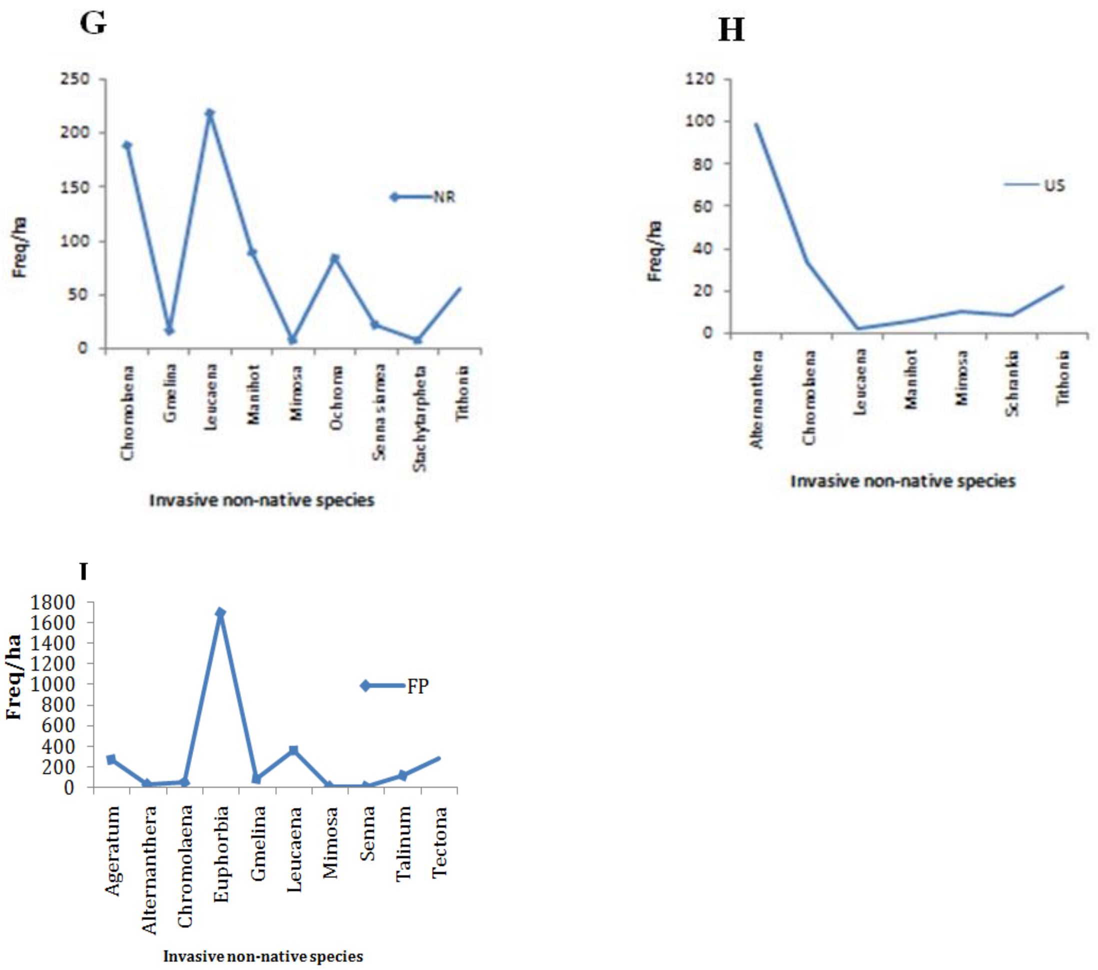

Figure 3a: Graph A to I showing the invasive non-native species distribution in each study area. *NUH=New Undergraduate Hostel, NPH= New Postgraduate Hostel, US= University Senate, FP= Forest Plantation, T&RF= Teaching and Research Farm, WASCA= West African Science Service Centre on Climate Change and Adapted Land Use, NR= New Road, CERAD= Centre for Research and Development and WP= Wildlife Park*

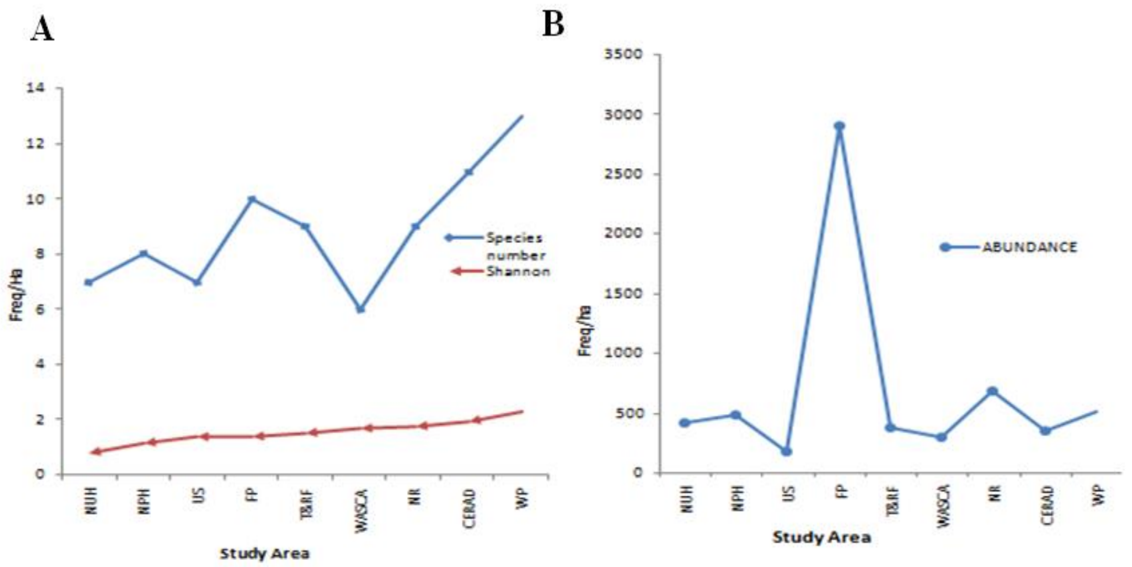

Figure 3b: Showing different frequency distribution and abundance in the study area.

Table 4: Relative occurrence of alien invasive species in the study area based on DAFOR scale of preference

Species name	Habitat	Freq (%)	DAFOR
Ageratum houstanianum Mill.	Forb	4.3	Rare
Alternanthera brasiliensis Hort ex. Vilmorin	Forb	7.9	Rare
Canna indica Linn	Forb	0.5	Rare
Chromolaena odorata (L.) R. M. King & H. Rob	Forb	21.5	Occasional
Clerodendron speciosa	Forb	0.2	Rare
*Euphorbia graminea*Jacq	Forb	27.3	Frequent
Gliricidia sepium (Jacq.) Walp	Wildling	0.7	Rare
Gmelina arborea Roxb	Wildling	2.2	Rare
Hilleria latifolia(Lam.) H. Walt	Forb	1.3	Rare
Leucaena leucocephala (Lam.) de Wit	Wildling	12.1	Occasional
Manihot glaziovii Müll. Arg	Wildling	2.4	Rare
Mimosa diplotricha C. Wright ex Sauvalle	Forb	0.2	Rare
Mimosa pudica Linn	Forb	1.1	Rare
Ochroma lagopus Sw.	Wildling	1.4	Rare
Physalis angulata Linn.	Forb	0.5	Rare
Physalis peruviana Linn	Forb	0.2	Rare
Schrankia leptocarpa DC	Forb	0.4	Rare
Senna hirsute (L.) H.S. Irwin & Barneby	Wildling	0.2	Rare
Senna siamea (Lam.) H.S. Irwin & Barneby	Wildling	0.5	Rare
Stachytarpheta cayennensis L. C. Rich.	Forb	0.4	Rare
Talinum triangulare (Jacq.) Willd	Forb	4.4	Rare
Tectona grandis Linn. F	Wildling	4.5	Rare
Tithonia diversifolia Hemsl	Forb	6.1	Rare

The following categories are based on DAFOR scale: D=Dominant (> 75%), A=Abundant (51 - 75%), F=Frequent (26 - 50%), O=Occasional (11 - 25%), R=Rare (1 - 10%)

Table 5 showing species origin and mode of dispersal

Scientific name	**Common Name**	**Species' Origin**	**Dispersal Mode**	**Reference**
Ageratum houstanianum Mill.	Blue Billy goatweed	Mexico	Seeds	Akobundu (1987)
Alternanthera brasiliensis Hort ex. Vilmorin	Nil	South America	Seeds	Llamas (2003), GBIF (2021).
Canna indica Linn	Indian shot	Tropical America	Rhizomes	GISD (2021)
Chromolaenaodorata (L.) R. M. King & H. Rob	Siamweed	South East Asia, Central & South tropical America	Seeds	GBIF (2021), Isichei and Akin-Fajiye, (2013), Akobundu (1987)
*Clerodendrum*x *speciosum*	Pagoda flower		Stem	DBrito de Almeida et al (2010)
Ochroma lagopus Sw.	Balsa wood tree	central America	Seeds	Aikman (1955)
Euphorbia graminea Jacq	Brazilian joyweed	North America	Seeds	Vincent (2013), Scafidi et al (2016), Aigbokhan & Agyakwa (1998)
Gliricidia sepium (Jacq.) Walp		Tropical America	Stems	GBIF (2021)
Gmelina arborea Roxb	Gmelina	Tropical Asia	Seeds	GBIF (2021)
Hilleria latifolia (Lam.) H.Walt.		South America	Seeds	GBIF (2021)
Leucaena leucocephala (Lam.) de Wit,		America	Seeds	GISD (2015), Hutchinson et al (1963)
Manihot glaziovii Müll. Arg.	Ceara Rubber	Brazil	Seeds	Burkill HM (1985)
Mimosa diplotricha C. Wright ex Sauvalle (syn) *Mimosa invisa (*Mart)	Giant sensitive plant	Tropical America	Seeds	Isichei and Akin-Fajiye, (2013), Akobundu, (1987)
Mimosa pudica Linn	Sensitive plant	Tropical America	Seeds	Akobundu (1987)
Physalis angulata Linn	Wild cape gooseberry	Tropical America	Seeds	Hunziker (2001), Toledo & Barboza (2005)
Physalis peruviana Linn		South America	Seeds	Hunziker 2001, Toledo & Barboza (2005)
Schrankia leptocarpa DC	Sensitive plant	Tropical America	Seeds	GBIF (2020)
Senna hirsute (L.) H.S. Irwin &Barneby		Tropical Asia	Seeds	GBIF (2020)
Senna siamea(Lam.) H.S. Irwin &Barneby	Cassia	Tropical America	Seeds	Tropical Plants Database (2021)
Stachytarpheta cayennensis (L. C. Rich.) Schau	Blue rat's tail	Tropical America	Seeds	Akobundu (1987)
Talinum triangulare(Jacq.) Willd	Waterleaf	Tropical America and West Indies	Seeds	Akobundu (1987)
Tectona grandis Linn. f.	Teak	Tropical Asia	Seeds, Coppice	GBIF (2020)
Tithonia diversifolia Hemsl	Mexican sunflower	North & Central America	Seeds	Ajao and Moteetee (2017), Akobundu (1987), Lordbanjou (1994)

DISCUSSION

The higher numbers of invasive non-native plant species were brought about by the university landscape architecture following infrastructural development, which led to ecosystem disturbance and vegetation removal of many indigenous species in the university (Charly *et al.*, 2021). The bulk of disturbances were centred on the anthropocentric praxis of building on existing ecosystems a long time ago. However, this disturbance has left the cutover area to invasive species, viz. widespread of wildling in the area met for forest reserve, and invariably making it difficult for natural regeneration to occur in this region (Sample *et al.*, 2019). This research studied the invasive non-native species colonizing the University landscape. From our assessment, the vegetable origin or native ranges of these invasive non-native plant species were not known in the course of this research but were related to recent studies on tropical soil seed banks (Omomoh *et al.*, 2019; 2020), forest disturbance (Omomoh *et al.*, 2021; Shackelford *et al.*, 2012), and contemporary inward dispersal (Crawley 2020) in recent times. However, the literature studies of the origins of the non-native trees in the region i.e., *Leucaena leucocephala*, *Gmelina arborea*, *Ochroma lagopus*, *Tectona grandis*, etc. (Richardson and Rejmanek 2011, Aikman, 1955) were nevertheless peculiar to anthropocentric methods introduced in the colonial era to tropical countries in Africa for the purpose of wood productivity. Moreover, many other possible and alternative mediums were further mentioned in Richardson and Rejmanek's (2011) results.

Further, other inhabitants such as annual and perennial forbs (*Chromolaena odorata*, *Tithonia diversifolia*, *Canna indica*, *Clerodendron speciosa*, *Euphorbia graminea*) also have their seeds residingd in the soil seed bank (Omomoh et al 2019, 2020). Different soils piled for horticultural uses are home to seeds of the non-native plant species for very long time periods (Crawley 2020; Omomoh *et al.*, 2020, 2019; Ajao and Moteetee 2017; Aigbokhan and Ekutu 2012; Inderjit and Callaway 2008; Reichard and White 2001). From recent studies, all the plants studied were non-native to the flora of West Tropical Africa. Naturally, many of the species are common colonizers not new to the area where they were found while some are both novel and introduced (Omomoh *et al.*, 2021b). According to Davis and Thompson (2000), a species is novel to a new region when the species range has no expansion at a given time. A different type of colonizer was observed, and many of these invasive non-native colonizers were found to possess the type one character described in Davis and Thompson 2000 viz *Ageratum houstanianum*, *Ochroma lagopus*, *Senna hirsuta*, *Canna indica*, *Euphorbia graminea*, *Gliricidia sepium*, *Hilleria latifolia*, *Physalis peruviana*, *Tectona grandis*, and *Clerodendron speciosa* with no range expansion to other area studied. *Chromolaena odorata* is a fully naturalised invasive non-native plant in a disturbed tropical or degraded forest. It was recorded as one of the common early-succession plants in the tropical areas (Omomoh et al 2021a; Isichei and Akin-Fajiye 2013) of this region. It is an aggressive fast-growing invasive non-native species, currently ravaging the vegetation in Africa (Akin-Fajiye and Akomolafe 2021; Omomoh *et al.*, 2020). However, fractions of it were found scattered all over the study locations.

Moreso, another non-native species found across the university campus was *Tithonia diversifolia*, originally from North and Central America. Today, this non-native forb was reported to be a widespread common weed in the whole of South West Nigeria (Isichei and Akin-Fajiye 2013). Small patches of this species were noticed scattered in every area of all the selected locations with the highest number of individuals and highest relative density only in CERAD (82, 23.5) and New Undergraduate Hostel (92, 21.8). *Leucaena leucocephala* (Lam.) de Wit, or *jumbie bean*, is a native of America (Hutchinson *et al.*, 1963), and widely distributed as a weed and tree over 20 countries across all continents (Global Invasive Species Database 2015). This individual tree species was initially an introduced species in Africa and half naturalized in the tropical forest as it simply supplies nitrogen to the soil for agricultural growth. The seeds are in pods and dehiscent when mature and dried. It is often dispersed by wind and flowing water to form the next generation of community trees in the new area. It is an aggressive, invasive non-native in a tropical or subtropical forest with a natural or semi-natural habitat. Within its habitat, a fast-growing tree causes a substantial change in the new community as it spreads its seedlings and saplings across all the eight selected sites, and typically adapts to all habitats (open field or intact forest) of this region. The ecological characteristics of invasive non-native species, such as dispersal, singularity, and environment impact, appeared singly in one location at the time of this study. Owing to these characteristics, it can be generalised that the invasive non-native plant species were found in a small proportion of space in a single community, which was called short dispersal distance (Davis and Thompson, 2000). For example, *Euphorbia graminea,* an invasive non-native species, and a shade-tolerant herbaceous plant, was discovered to have a unique affinity for either *Tectona* or *Gmelina* plantation and a preference for mixed plantation (*Tectona* and *Gmelina* plantation, Table 2). In spite of this, the interaction between Forest Plantation as non-native trees, i.e., *Tectona* and *Gmelina,* habituating with herbaceous species, *Euphorbia graminea*, as non- native forbs were similarly described by Kuebbing *et al.* (2013) as multiple invasive non-native species co-existing in the same community. The ability of multiple non-native species to successfully tolerate the new areas was noted as the only prevailing association that facilitated the mutual interaction for their co-existence.

Similarly, our studies also show that the Wildlife Park, a secondary forest in this area, has created a favourable environment for a non-native herb, *Hilleria latifolia,* to establish in this new habitat. The impact of this invasive non-native herb in the new environment is minute and with no range expansion to other habitats (Davis and Thompson 2000). Other species with the Dafor's scale of 'rare' which did not have their spread across all the other nine sites were as follows: *Mimosa pudica* (7 sites), *Manihot glaziovii* (6 sites), *Talinum triangulare* and *Gmelina arborea* (5 sites), while other invasive non-native species such as *Ageratum houstanianum, Schrankia leptocarpa,* and *Mimosa invisa* fall within the range of 1 site to 3 sites. Some other single species not co-occurring with other non-native species were found singly colonizing a particular site. This was possible because of the environmental condition of the specific area, e.g., *Ageratum houstanianum*, a blue billygoat weed, is an annual or biennial fugacious herbaceous plant often found in disturbed or waste areas of mostly waterways or marshland. It is native to Mexico, Central America, and the Caribbean. It is extensively distributed in the coastal districts of eastern Australia and widely naturalised in the tropical region of the world. This plant species is currently found only in the Forest Plantation along the waterlogged marshes region where it poses a negligible threat. The spread is broadly controlled by the seasonal watercourse of the area, especially in the dry season where it is reduced to an extremely small range.

Another species singly crown dominating another area is *Manihot glaziovi.,* a ceara rubber tree widely known and cultivated from Brazil, and introduced to Africa as an ornamental (Burkhill, 1985; Hutchinson *et al.,* 1963) for wood production. It is recorded as a mid-successional tree in the tropical regions of a degraded or disturbed forest (Omomoh *et al.*, 2021b). This is followed by *Ochroma lagopus,* or balsa wood tree, an introduced species from Central America to Africa. It is also a transient, fast-growing tree with heart shaped leaves and mostly found as a pioneer species following a disturbance in a cutover area of land in the tropical forest (Burkhill 1985; Aikman 1955; Hutchinson *et al.,* 1963). Of the 23 non-native invasive species studied, only Forest Plantation and Wildlife Park had the numbers of three non-native invasive species matched in a community at the same time. *Euphorbia graminea,* or seasonal Brazilian joy weed, is a stout annual to perennial herb, and a native of North America (Hutchinson et al. 1963; Yang *et al*. 2005), and a naturalised herb in some other parts of the world (Steinmann and Porter, 2002; Rzedowski and Rzedowski, 2004). It is widely distributed in lowland or regrowth forests at the early succession stage under a moderate shaded canopy and extensively colonizes a single or mixed Forest plantation of *Tectona grandis* and *Gmelina arborea* in tropical regions. This perennial species was specifically found cohabiting with two other non-native invasive species (*Alternanthera brasiliana* and *Leucaena leucocephala*) in the same habitat.

In certain situations, some invaders are aggressively intrusive plant species and others are not. In this study, an interaction was successfully established as multiple invasive non-native species coexisted with one another

(Kuebbing *et al.* 2013), at the same time providing an enabling environment for externality to strive well. The beneficence of this is to the entire plant community. A typical example of this is *Leucaena leucocephala.* It is best known for this form of interaction among multiple species because of its nitrogen-fixing ability (Kuebbing and Nuñez 2015; Sample *et al.* 2019). Nitrogen is an important soil nutrient beneficial for plant growth. Apparently, there are no plant species that cannot be tolerated by this plant. This is not in contrary to the Kuebbing *et al.* (2013) report of finding multiple invaders in conservation areas; instead, this result also reported multiple invasive non-native species at all habitat levels, such as the Forest Plantation, open field area, and Wildlife Park, etc. This was in agreement with the report of Chytry *et al.* (2008), whereby different habitats such as areas of human disturbance, the littoral zone, and the coastal water habitat accounted for a higher number of alien species in Peshawar. Even so, some studies from the temperate region are of the opinion that the tropical areas are less susceptible to biological invasion than the temperate areas (Petruzzella *et al.* 2020; Freestone *et al.* 2013). Other areas are specifically invasive species-based e.g., North America and Europe (Shackelford *et al.* 2021). Nevertheless, our study revealed that those invasive non-native hotspots are highly susceptible to biological invasions as in other areas in the world (Mack *et al*. 2000). Consequently, natural resilience is affected as natural regeneration operations are hindered. The Shannon-Wiener value from our study was not in any way disconfirming what Akomolafe *et al.* (2021) revealed about the ecological impact of invasive non-native species from their study; instead, this study revealed the negative impact the current invasive non-native species is having on the stability of the ecosystem, which is serious and calls for urgent attention.

CONCLUSION

The study revealed some habitats have more levels of invasive non-native plant species than other areas and this comes in various degrees, from single instances to multiple invasive non-native species. Nevertheless, the biological invasion scales of disturbance for this study area have not been studied for us to know the degree of disturbance in these selected locations. But rather, a similar study on a single invasive non-native species, *Parthenium hysterophorus* L., in the University Campus, Peshawar, exemplified the occurrences of the plant in the seed bank of a soil sample taken from weed flora. However, this study will serve as a preliminary investigation into the prediction, identification, and management of large-scale biological invasions in the University campus in the future. To avert this large-scale predicament, proper monitoring procedures for biological invasions should be put in place, such as range expansion monitoring of each invasive non-native species. Extensive clearing of invasive non-native species on those areas can be carried out mechanically on foot by chopping on a smaller scale to a larger scale, and likewise chemically, by spraying those areas with registered herbicides although chemical application and control were reported to be expensive throughout the world. Land rehabilitation and knowledge mobilization of the measures needed to conserve native ecosystems should follow immediately to prevent invasive non-native from occupying the area again.

REFERENCES

Adekunle VAJ (2007) Ecological and environmental implication of National development: A case study of Obanla natural forest, Federal University of Technology, Akure, Nigeria. *Research Journal of Environmental Sciences* 1 (4): 127-140

Aikman, J. M. (1955) "The Ecology of Balsa (Ochroma lagopus Swartz) in Ecuador," Proceedings of the Iowa Academy of Science, 62(1), 245-252.

Aigbokhan, E. I. and Ekutu O. (2012). Aspects of the biology and ecology of Euphorbia graminea jacq. (Euphorbiaceae) a potentially invasive herbaceous plant in Nigeria. Nigerian Journal of Botany 25 (1): 35-53

Ajao AA and Moteetee AN (2017) Tithonia diversifolia (Hemsl) A. Gray. (Asteraceae: Heliantheae), an invasive plant of significant ethnopharmacological importance: A review. *South African Journal of Botany* 113: 396–403

Akin-Fajiye M and Akomolafe G.F (2021) Disturbance is an important predictor of the distribution of *Lantana camara* and *Chromolaena odorata* in Africa. *Vegetos* 34:42-49. Doi.org/10.1007/s42535-020-00179-6

Akobundu IO, Ekeleme F, Agyakwa CW and Ogazie CA (1987) A handbook of West African weeds Third edition. *International Institute of Tropical Agriculture*, Nigeria

Akobundu, I.O. and Agyakwa, C.W. (1998) *A handbook of West African Weeds*. Second Edition. International Institute of Tropical Agriculture. African Book Builders, Ibadan, Nigeria. 565pp.

Azani. N., Babineau. M., Bailey. CD, Banks H, Barbosa AR, Pinto RB, Boatwright JS, Borges LM, Brown GK, Bruneau A., Candido E, Cardoso D, Chung K, Clark RP, Conceição A, Crisp M, Cubas P, Delgado-Salinas A, Dexter KG, Doyle JJ, Duminil J, Egan AN, Estrella M, Falcão MJ, Filatov DA, Fortuna-Perez AP, Fortunato RH, Gagnon E, Gasson P, Rando JG, Tozzi AG, Gunn B, Harris D, Haston E, Hawkins JA, Herendeen PS, Hughes CE, Iganci JRV, Firouzeh F, Kanu SA, Kazempour-Osaloo S, Kite GC, Klitgaard BB, Kochanovski FJ, Koenen EJM, Kovar L, Lavin M, Roux M, Lewis GP, de Lima HC, López-Roberts MC, Mackinder B, Maia VH, Malécot V, Mansano VF, Marazzi B, Mattapha. S, Miller JT, Mitsuyuki C, Moura T, Murphy DJ, Nageswara-Rao M, Nevado B, Neves D, Ojeda DI, Pennington RT, Prado. D. E., Prenner. G., Paganucci de Queiroz. L., Ramos. G., RanzatoFilardi. F.L., Ribeiro PG, Rico-Arce M, Sanderson MJ, Santos-Silva J, São-Mateus WMB, Silva. MJS, Simon MF, Sinou C, Snak C, de Souza É, Sprent J, Steele KP, Steier JE, Steeves R, Stirton CH, Tagane S, Torke BM, Toyama H, da Cruz DT, Vatanparast. M., Wieringa. J. J, Wink,.M., Wojciechowski..M. F, Yahara. T., Yi.T., Zimmerman E (2017). A new subfamily classification of the Leguminosae based on a taxonomically comprehensive phylogeny LPWG *TAXON* 66 (1): 44–77. https://doi.org/10.12705/661.3

Brundu G and Richardson DM (2016). Planted forests and invasive alien trees in Europe: a Code for managing existing and future plantings to mitigate the risk of negative impacts from invasions. *Neobiota* 30, 5–47

Burkhill HM (1985) The useful plants of tropical West Africa. Royal Botanical Gardens Kew, Edition 2, Volume 2, 3, 4, 5.

Castro-Diez P, Vaz AS, Silva JS, van Loo M, Alonso A, Aponte C, Bayon A, Bellingham PJ, Chiuffo MC, DiManno N, Julian K, Kandert S, Porta NL, Marchante H, Maule HG, Mayfield MM, Metcalfe D, Monteverdi MC, Nunez MA, Ostertag R, Parker IM, Peltzer DA, Potgieter LJ, Raymundo M, Rayome D, Reisman- Berman O, Richardson DM, Roos RE, Saldana A, Shackleton RT, Torres A, Trudgen M, Urban J, Vicente JR, Vila M, Ylioja T, Zenni RD, Godoy O et al (2019) Global effects of non-native tree species on multiple ecosystem services. Biol Rev 94:1477–1501. https ://doi.org/10.1111/brv.12511

Charly G, Jonas JL, Jan B, Jonathan L, Rafiq H, Gregory M, Ivan N and Arnaud M (2021) Urban alien plant in temperate oceanic regions of Europe originate from warmer native ranges. *Biological Invasions.* https??doi.org?10.1007/s10530-021-02469-9

Chromolaena odorata (L.) R.King & H.Rob. in GBIF Secretariat (2021). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2021-06-30

Chytry M, Maskell LC, Pino J, Pysek P, Vilà M, Font X and Smart SM (2008) Habitat invasions by alien plants: a quantitative comparison among Mediterranean, subcontinental and oceanic regions of Europe. *Journal of Applied Ecology*. 45: 448–458 doi: 10.1111/j.1365-2664.2007.01398.x

Crawley MJ (2020) *Galeopsis speciosa* (Lamiaceae): an open vegetation seed bank community at Worsley in Salford (v.c.59), revealed during construction of the new Royal Horticultural Society

Garden at Bridgewater. *British & Irish Botany* 2(4): 377-406

Davis MA and Thompson K (2000) Eight ways to be a colonizer; two ways to be an invader. Bulletin of the *Ecological Society of America* 81: 226–230

Divakara BN, Nikitha, CU, Nölke N, Tewari VP and Kleinn C (2022) Tree Diversity and Tree Community Composition in Northern Part of Megacity Bengaluru, India. Sustainability. 14, 1295. https://doi.org/10.3390/su14031295

Drake S.J, Weltzin JF and Parr PD (2003) Assessment of Non-Native Invasive Plant Species on the United States Department of Energy Oak Ridge National Environmental Research Park *CASTANEA* 68(1): 15-30.

Doroski DA, Ashton MS and Duguid MC (2020) The future urban forest – A survey of tree planting programs in the Northeastern United States. *Urban Forestry & Urban Greening* 55 (2020) 126816. https://doi.org/10.1016/j.ufug.2020.126816

Englberger K (2009) Invasive weeds of Pohnpei: A guide for identification and public awareness. Kolomia. Federated States of Micronesia: Conservation Society of Pohnpei, pp 2

Esperon-Rodriguez M, Rymer PD, Power SA, Barton DN, Cariñanos P, Dobbs C, Eleuterio AA, Escobedo FJ, Hauer R, Hermy M, Jahani A, Onyekwelu JC, Östberg J, Pataki D, Randrup TB, Rasmussen T, Roman LA, Russo A, Shackleton C, Tjoelker MG (2022) Assessing climate risk to support urban forests in a changing climate. *Plants, People, Planet*, 1–13. https://doi.org/10.1002/ppp3.10240

Freestone AL, Ruiz GM and Torchin ME (2013) Stronger biotic resistance in tropics relative to temperate zone: effects of predation on marine invasion dynamics. *Ecology* 94: 1370–1377

GBIF Secretariat (2021). GBIF Backbone Taxonomy. *Alternanthera brasiliensis* hort. ex Vilm. in checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2021-06-30.

GBIF Secretariat (2021). GBIF Backbone Taxonomy. *Hilleria latifolia* H Walter in Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2021-06-30.

GBIF Secretariat (2021). GBIF Backbone Taxonomy. *Gliricidia sepium* (Jacq.) Steud. in Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2021-06-30.

GBIF Secretariat (2021). GBIF Backbone Taxonomy. *Gmelina arborea* Roxb. ex Sm. in Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2021-06-30.

Global Invasive Species Database, GISD (2015) Species profile *Leucaena leucocephala*. Available from: http://www.iucngisd.org/gisd/species.php?sc=23 [Accessed 01 June 2020]

Global Invasive Species Database, GISD (2021) Species profile *Canna indica*. Available from: http://www.iucngisd.org/gisd/species.php?sc=640 [Accessed 07 May 2021]

global review. *Diversity and Distributions*, (Diversity Distrib.) 17, 788–809

Hunziker AT (2001). Genera Solanacearum. The genera of Solanaceae illustrated, arranged according to a new system. Gantner Verlag. Ruggell pp 45

Hutchinson J, Dalziel JM and Hepper FN (1963). Flora of West Tropical Africa. Volume II. *Flora of West Tropical Africa. Volume II.*, (2nd ed.(rev.)

Hutchinson, J. and Dalziel, J.M. (1954-72).Flora of West Tropical Africa (2nd eds) by RWJ Keay and FN Hepper, Crown Agents, London pp 145

Inderjit SM and Callaway RM (2008) Exotic invasive plant accumulates native soil pathogens which inhibit native plants. *Journal of Ecology*, 96: 58–67 doi:10.1111/j.13652745.2007.01312.x

Isichei AO and Akin-Fajiye MA (2013) Plant Invasions in Nigeria: *Nigerian Forests: Protection and Sustainable Development*. Okon, E, Bown, D. and Isichei, A. (eds). JABU Environmental Symposium Series, Joseph Ayo Babalola University, Ikeji-Arakeji, Osun State, Nigeria 20: 320 pp ISBN: 978-978-8447-009

Kuebbing SE and Nuñez MA (2015) Negative, neutral, and positive interactions among nonnative plants: patterns, processes, and management implications. *Glob. Chang. Biol*. 21, 926–34. https://doi.org/10.1111/gcb.12711

Kuebbing SE, Nuñez MA and Simberloff D (2013) Current mismatch between research and conservation efforts: The need to study co-occurring invasive plant species. *Biological Conservation.* 160: 121–129

Llamas KA (2003) Tropical Flowering Plants. A guide to Identification and Cultivation Handout Publisher Timber Press, Incorporated. Page 424

Lone PA, Dar JA, Subashree K, Raha D, Pandey PK, Ray T, Khare PK and Khan ML (2019) Impact of plant invasion on physical, chemical and biological aspects of ecosystems: A review. Tropical Plant Research 6(3): 528–544]

Lordbanjou DT (1991) Studies on Mexican sunflower *Tithonia diversifolia* (Hemsl.) A. Gray in Southwestern Nigeria. M.Sc. Thesis. University of Ibadan

Mack RN (2003) Global plant dispersal, naturalization and invasion: pathways, modes and circumstances. In: Ruiz G, Carlton J (eds) Global Pathways of Biotic invasions. Island Press, Washington, pp 3–30

Mack RN, Simberloff D, Lonsdale WM, Evans H, Clout M and Bazzaz FA (2000) Biotic invasions: causes, epidemiology, global consequences, and control. *Ecol Appl* 10:689–710

Margalef R (1958) Information theory in ecology. Gen Syst 3:36–71

Michael P (1990) Ecological methods for field and laboratory investigation. Tata Mc Graw Hill Publishing Co, pp 404–424

Nuñez and Pauchard (2010) Biological invasions in developing and developed countries: does one model fit all? *Biological Invasions*. 12:707–714. DOI 10.1007/s10530-009-9517-1

Omomoh B, Adekunle. V, Lawal A and Akinbi O (2019) Tree species diversity and regeneration potential of soil seed bank in Akure forest reserve, Ondo State, Nigeria. *Taiwania,* 64(4): 409-416, 2019. DOI: 10.6165/tai.2019.64.40

Omomoh BE, Adekunle VAJ, Aigbe PD, Ademoh FO and Omomoh BM (2020) Evaluation of soil seed bank-vegetation and regeneration potential of *Tectona grandis* L. f. plantation (Taungya farm) in Akure forest reserve, Ondo State, Nigeria. *Tropical Plant Research.* 7(1): 37–45

Omomoh BE, Brown L, Meijer K, Adekunle VAJ and Oboh G (2021a) Ecological studies on introduction of alien species (*Clerodendrum paniculatum* Linn) in Forest Plantation and Nature Reserve Forest of Tropical Africa, Nigeria. *Vegetos.* https://doi.org/10.1007/s42535-021-00313-y

Omomoh BE, Akomolafe FG and Brown L (2021b) A 17-year successional enrichment plantation of tree recruitment and restoration in a tropical rainforest forest. *Vegetos.* DOI: 10.1007/s42535-021-00255-5

Petruzzella A, Rodrigues TSSR, Leeuwen CHA, Esteves F, Figueiredo-Barros MP and Bakker ES (2020) Species identity and diversity effects on invasion resistance of tropical freshwater plant communities *Scientific Reports 10:5626.* https://doi.org/10.1038/s41598-020-62660-1

Reichard SH and White P (2001) Horticulture as a pathway of invasive plant introductions in the United States. *Bioscience* 51 (2) 104-113

Richardson DM and Rejmanek M (2011) Trees and shrubs as invasive alien species – a global review. *Diversity and Distributions.* 17: 788–809

Rzedowski GC and Rzedowski J. (2004) *Manual weed in the region of Salvatierra*, Guanajuato. Flora del Bajio and Adjacent Regions. Alkaloids XX. Institute of Ecology-Centre Bajio Regional. National Council for Science and Technology and National Commission Awareness and Use of Biodiversity. Patzcuaro, Michoacan. 315pp.

Sample M, Aslan CE, Policelli N, Sanford RL, Nielsene and Nuñez MA (2019) Increase in nonnative understorey vegetation cover after nonnative conifer removal and passive restoration. *Austral Ecology*.44 (8) 1384-1397. doi:10.1111/aec.12812

Scafidi F, Raimondo FM and Domina G (2016) First record of *Euphorbia graminea* (*Euphorbiaceae*) in Italy. *Fl. Medit*. 26: 25-30. doi: 10.7320/FlMedit26.025

Silva ACA, Martins SV and Balestrin D (2021). Soil seed bank as a bioindicator to identify invasive species. FLORESTA, Curitiba, PR, v. 51, n. 3, p. 760-766, jul/set 2021. ISSN eletrônico 1982-4688. DOI: 10.5380/rf.v51 i3. 72709

Shackelford N, Paterno GB, Winkler ED., *et al* (2021) Drivers of seedling establishment success in dryland restoration efforts *Nature ecology and evolution* https://DOI:10.1038/s41559-021-01510-3

Steinmann V.W and Porter J.M (2002) Phylogenetic Relationships in Euphorbiaceae (Euphorbiaceae) Based on *ITS* and *ndhF* Sequence. *Annals of the Missouri Botanical Garden*, 89 (4): 453-490

Toledo JM and Barboza GE (2005) Novedades en *Physalis* (Solanaceae). *Kurtziana* 31: 69–85.

Tropical Plants Database, Ken Fern. Tropical.theferns.info. 2021-07-06. <tropical.theferns.info/viewtropical.php?id=Senna+siamea>

Vincent, M.A. (2013). Euphorbia graminea Jacq. (Euphorbiaceae), new to the Bahamas. *Phytoneuron* 2013-20: 1–3. ISSN 2153 733X

Yang S. Z, Chen C. F, Lo, K. P and Hsieh G. P (2005) *Euphorbia graminea* Jacquin (Euphorbiaceae) a newly naturalized plant in Taiwan, *Taiwania*, 50(2): 131-136.