Diversity of Naturalized Plant Species across the Land Use Types of Kathmandu District, Central Nepal

Rashmi Paudel*, Kushal Gautam, Yogesh Gurung, Sadikshya Pokhrel, Bibhishika Shrestha, Sabi BK, Sajina Hitang, Niharika Shrestha, Maiyan Bajracharya & Ganesh Datt Joshi

Southwestern State College, Basundhara, Kathmandu, Nepal

***Email: rashmipaudel09@gmail.com**

Abstract

Biological invasions is one of the leading threats to biodiversity after habitat destruction. Rapid expansion of invasive plants in Nepal have threatened biodiversity, crop productivity, ecosystems as well as human health, and it has emerged as a new environmental problem in Nepal. The present study was conducted to explore the diversity of naturalized plant species across major land use types in Kathmandu valley. Altogether 18 plots of 10m × 10m were sampled with three replicate plots in six different land use types. A checklist of 90 vascular plant species was prepared; among them nearly half (41 spp.) were naturalized and ca.32% (13spp.) of these naturalized species were invasive alien plant species (IAPS). Among 13 IAPS, *Ageratum houstonianum* Mill.and *Lantana camara* L. had the highest frequency and coverage, respectively. Proportion of the naturalized species as well as the IAPS were higher in highly modified land use types with high disturbance (i.e., road side and grazing land) than in less disturbed natural land use types (i.e., *Pinus* forest and Mixed forest). Mean coverage of IAPS was the highest in road side. Overall, this study concludes that modified and highly disturbed land use types of the Kathmandu district were dominated by naturalized plant species (including both invasive alien plants and non-invasive naturalized) than natural land use types.

Keywords: Grazing land, Invasive alien plant species, Non-invasive naturalized plant species, Road side, Urban ecosystems

Introduction

Invasibility is the susceptibility of an environment to the colonization and establishment of individuals from species not currently part of the resident community (Davis et al., 2005). Species that have been transported from one region to another are defined as alien or exotic to that newly occupied region (Richardson et al., 2000). Most of these species fail to establish self-perpetuating populations, but those that do have become naturalized (Sax & Brown, 2000). Naturalized species serve as a pool of species from which some species turn out to be invasive (Senan et al., 2012). The alien plant species with self-regenerating population become problematic if they spread widely and cause significant negative impacts on native diversity and ecosystems (Sharma et al., 2005).

Biological invasions are impacting all components of ecosystem including biodiversity (Vila et al., 2011), at both local and global scales (Mack et al., 2000). The Invasive alien plant species (IAPS) are able to compete with native plants for resources, space and potential change in below and above ground environment of native plant community (Mack & D'Antonio, 2003). They bring changes in species richness, composition, growth and developments of native plants through altering soil biota. It also transforms diverse native community in to monoculture type vegetation dominated by single IAPS (Reinhart & Callaway, 2004).

As biological invasions is a worldwide problem, it becomes an increasing problem in case of Nepal too. The biological invasion has emerged as a new environmental problem in Nepal, with direct impact to biodiversity conservation, ecosystem services and economic development (Shrestha, 2019). The wide range of habitats and environmental conditions make Nepal especially vulnerable to the establishment of invasive species of foreign origin (Kunwar, 2003). In Nepal, 179 species of alien plants have

been naturalized and 26 species turn out to become invasive (Shrestha et al., 2019). Four IAPS of Nepal; *Chromolaena odorata* (L.) R.M. King & H. Rob., *Eichhornia crassipes* (Mart.) Solms, *Lantana camara* L. and *Mikania micrantha* Kunth. are included in the list of hundred of the world's worst invasive species (Lowe et al., 2000).

Climate change, land use and human disturbance are major driving factors for invasiveness of alien plants (Hobbs, 2000). Land use change and disturbance are major factors which govern the biological invasions, whichpromote major changes in species composition and abundance (Jesse et al., 2018). Human activities like migrations, transportation, roadway construction, tourism and farming practices further favor the process of invasion (Vitousek et al., 1997). Together with these factors diversity of native species also play a major role in plant invasion, nearly 70% of the variation in exotic plant richness among sites around the world is explained by native richness (Lonsdale, 1999). Generally, a community with high diversity of native plant species is supposed to harbor less diversity of naturalized species and *vice versa* (Biotic Resistance hypothesis; Tilman, 1997).

There is a large data gap and paucity of information about the diversity of naturalized plant species across the land use types in our study area. The main aim of this research work is to address the data gap to some extent by identifying the land use types which are more prone to plant invasion by analyzing cover, frequency and percentage share of IAPS, native as well as non-invasive naturalized plants across the different land use types. Results of this study can play an important role for prioritizing management options to control biological invasions.

Materials and Methods

Study area

This study was carried out in the urban areas of Kathmandu district; a part of Bagmati province, Central Nepal. Study was conducted within the geographical range of 27° 39' 38.952"N - 27° 39' 57.1428"N latitude and 85° 17' 36.9636"E - 85° 17' 43.0728" E longitude (Figure 1).With the survey of valley, we identified six different land use types (road side, grazing land, agricultural land, *Pinus* forest, mixed forest and wetland), located in the same climatic and ecological region for vegetation sampling in Chovar, Balkhu, Kalanki and Tokha areas. The climate of the study area is sub-tropical type.

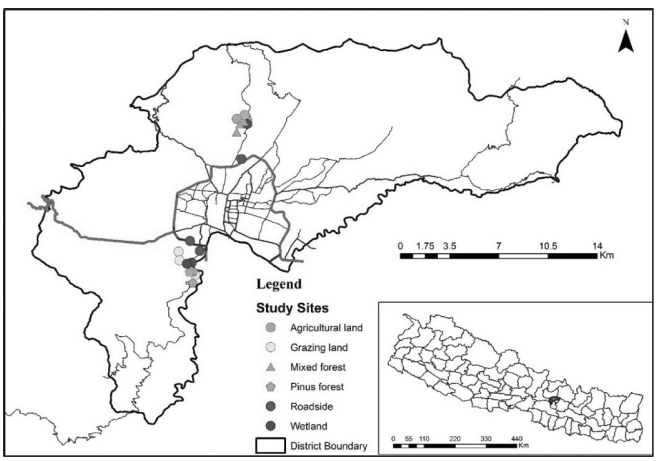

Figure 1: Map of the study area.

Due to comparatively low disturbance; *Pinus* forest, mixed forest and wetland were considered as comparatively less modified land use types, whereas, road side was considered as highly modified. Similarly, grazing land and agricultural land were also slightly modified land use types and agricultural land was seasonal fallow land, where farmer used the land for cultivation in one season and left the land fallow until the next season. We sampled the agricultural land during a fallow period after the harvest of a crop and before the cultivation of the next crop. Detail of individual land use types selected for the present study has been presented in Table 1.

Vegetation sampling

The present study was based on the field survey conducted during September and October of 2019. (10m×10m) sampling plot design was followed for Vegetation analysis across six different land use types. In each land use type, three replicate plots (10m×10m) were sampled; altogether 18 plots were sampled in six land use types. In each land use type, plot locations were chosen subjectively in

Table 1: Feature of the individual land use types selected for the present study.

Land use types	Location	Disturbance type	Dominant IAPS
Road side	Ringroad (Balkhu, Kalanki and Basundhara)	High vehicle movement and anthropogenic activities.	*Parthenium hysterophorus* L., *Lantana camara* L., *Xanthium strumarium* L.
Grazing land	Kritipur	Grazing of livestock as well as other anthropogenic disturbances.	*Parthenium hysterophorus* L., *Bidenspilosa* L., *Lantana camara* L.
Agricultural land	Tokha	Seasonal fallow land (anthropogenic disturbances).	*Ageratum houstonianum* Mill., *Bidenspilosa* L., *Ageratum conyzoides* L.
Pinus forest	Chovar	Undisturbed land use type; protected from livestock grazing, logging and other anthropogenic disturbances.	*Lantana camara* L., *Ageratina adenophora* (Spreng.) R.M. King & H. Rob., *Ageratum houstonianum* Mill.
Mixed forest	Tokha	Undisturbed land use type; protected from livestock grazing and logging.	*Lantana camara* L., *Ageratina adenophora* (Spreng.) R.M. King & H. Rob., *Ageratum houstonianum* Mill.
Wet land (Swamp area)	Balkhu and Tokha	Undisturbed land use type protected from anthropogenic disturbances	*Myriophyllum aquaticum* (Vell.) Verdc., *Alternanthera philoxeroides* (Mart.) Griseb., *Ageratum houstonianum* Mill.

topographically uniform areas, with adjacent plots at a distance of ca.50m. The geographic location (latitude, longitude and elevation) was measured by Global Positioning System (GPS) (model Garmin eTrex 10).

Collection, identification and categorization of vascular plants

Each vascular plants present within the 10m×10m plots were collected and cover of IAPS was also recorded on the basis of Daubenmire cover classification (Daubenmire, 1959). This technique classifies cover in to six categories as: 1) 0-5%, 2) 5-25%, 3) 25-50%, 4) 50-75%, 5) 75-95%, and 6) 95-100%, based on visual estimation method considering each plot as 100 percent. Collected plants were tagged and pressed properly and also field note of each collected plant was prepared. Furthermore, the plant species which were identified during field work were reconfirmed through different literature as well as expert consultation. Most of the species were identified by using appropriate manuals, flora and monographs, relevant taxonomic literature and online database. Flowering Plants of Makawanpur (Chapagain et al., 2016), Flora of China (http://www.efloras.org), tropicos (http://www.tropicos.org) were used for identification and catalogue of Life (http://www.catalogueoflife.org; last accessed on 4th June 2020) was followed for the accepted names. Some of the plants were also identified by comparing herbarium specimen at National Herbarium and Plant Laboratories, Lalitpur, Nepal. The dried specimens (naturalized only) were mounted on the herbarium sheet (43cm×29cm) together with herbarium level (15cm×10cm) and were deposited at National Herbarium and Plant Laboratories, Lalitpur, Nepal.

Identified species were further categorized as native, non-invasive naturalized and invasive ones. The species which were categorized as invasive according to Shrestha (2019) were considered as IAPS. Likewise, non-invasive naturalized were confirmed based on the list of 179 naturalized species of Nepal (Global Register of Introduced and Invasive Species (GRIIS) by Shrestha et al. (2019) and the species which are not included in GRIIS were categorized as native species for Nepal.

Numerical Analysis

Frequency of IAPS: Frequency of each IAPS in the study area (using data of all eighteen plots) was calculated according to Zobel et al. (1987), e.g. by dividing the number of plots in which species occurred by total number of plots and multiplying by 100.

Cover of IAPS: First of all, Daubenmire cover classification was converted in to cover percentage by using mid value of each cover class following Zobel et al. (1987). Cover calculation was done by using following formula:

Cover of individual species,

$$\text{Cover \%} = \frac{\text{Sum of mid value of cover class of particular species}}{\text{Total number of sampling plot}}$$

Mean cover of each land use type =

$$\frac{\text{Sum of cover of all IAPS in all replicate plot of a landuse}}{\text{Number of replicate plots}}$$

Results and Discussion

A total of 90 vascular plants were recorded in six different land use types of Kathmandu district. Among them, 13 were invasive alien plant species (IAPS) which accounted 50% of total IAPS of Nepal. The remaining 28 species were non-invasive naturalized species and 49 were native species (Table 2).

Percentage share of different categories and mean cover of IAPS across land use types

The highest percentage share of IAPS was found in road side (27%) followed by grazing land (24%) and the least percentage was found in *Pinus* forest (12%). Likewise, non-invasive naturalized contributed the highest percentage in grazing land (36%) followed by road side (32%) and the least contribution was found in *Pinus*forest (19%). Whereas, *Pinus* forest (69%) showed the highest percentage share of native species followed by mixed forest (65%) and the least percentage share of native plants was found in grazing land (40%) and road side (41%) **(**Figure 1).When cover of all IAPS was combined, road side had the highest cover (82%) followed by grazing land (77%) and agricultural land (74%) and it was the lowest in wetland (22%) (Figure 2).

Land use change causes fluctuation in the level of resources i.e. soil nutrients, light, water etc. which may facilitate plant invasion (Davis et al., 2000), therefore it is considered as the determining factor

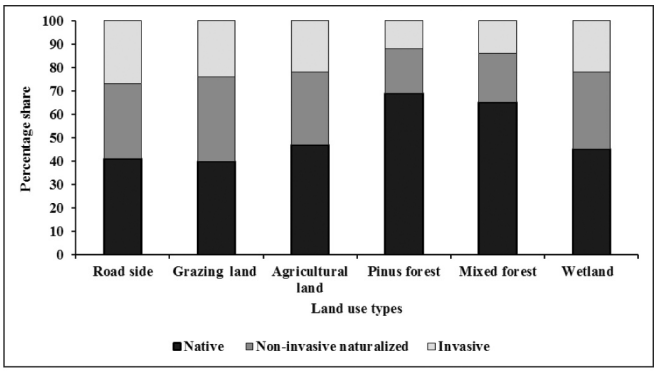

Figure 1: Percentage share of different categories of plants across different land use types.

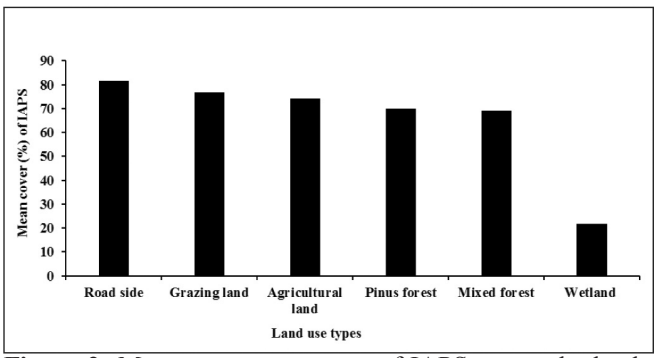

Figure 2: Mean cover percentage of IAPS across the land use types.

for the distribution of alien plant (non-invasive naturalized and invasive) species (Lonsdale, 1999). Among the six land use types studied, the highest percentage share of IAPS was found in road side followed by grazing land. A similar finding was also reported by Pauchard & Alaback (2004). Similarly, grazing land showed the highest percentage share of non-invasive naturalized species followed by road side. Both categories showed that road side and grazing land were colonized by a high number of naturalized species. Mean cover of IAPS also supported this finding as road side and grazing land had the highest cover of IAPS.

The more disturbed the vegetation is, higher the chances of occurrence of the IAPS in that area (Rastogi et al., 2015). In our study roadside and grazing land considered as moderately modified land use types; affected by various disturbance factors in terms of high vehicle movement, grazing intensity as well as other different anthropogenic factors. Such disturbances increase propagule pressure and ultimately increase the invasiveness (Rouget & Richardson, 2003). This was further supported

by Parendes & Jones (2000), who concluded that nearer the distance from road, water resources and settlement area higher will be the chance of invasion.

Pinus forest contributed the least percentage of naturalized (IAPS and non-invasive naturalized) and the highest percentage of native species, this was also supported by biotic resistance hypothesis. According to this hypothesis a community with high diversity of native plant species is supposed to harbor less diversity of naturalized species and *vice versa* (Tilman, 1997).

Frequency and cover of IAPS

Among 13 recorded IAPS, *Ageratum houstonianum, Bidenspilosa* and *Lantana camara* were three most frequent species with ca.67, 62 and 56 frequency percentages, respectively. Whereas, *Myriophyllum aquaticum* and *Ipomoea carnea* subsp. *Fistulosa* (ca. 6% each) were the least frequent IAPS (Figure 3).

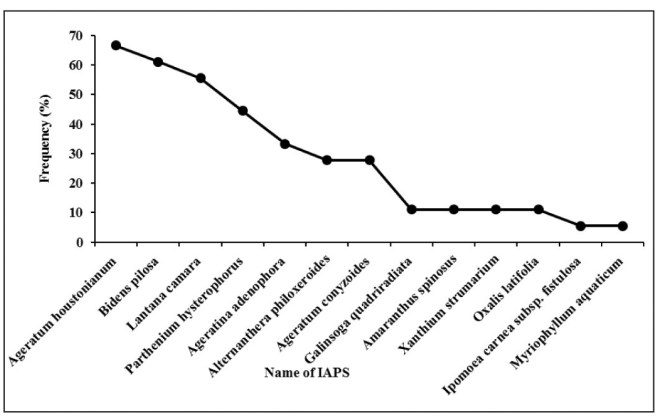

Figure 3: Frequency percentage of IAPS.

Lantana camara was the species with the highest coverage followed by *Parthenium hysterophorus* and *Ageratum houstonianum*, whereas, *Ipomoea carnea* subsp. *fistulosa* was the species with the least coverage (Figure 4).

Ageratum houstonianum was the most frequent species and was present in almost all plots. Prolific seed production and good dispersal ability (Lamsal et al., 2019) can be attributed to high frequency of *Ageratum houstonianum.* It has been reported that *Ageratum houstonianum* is one such problematic IAPS in Nepal with widespread distribution in the mid-hills and the plain areas along roadsides,

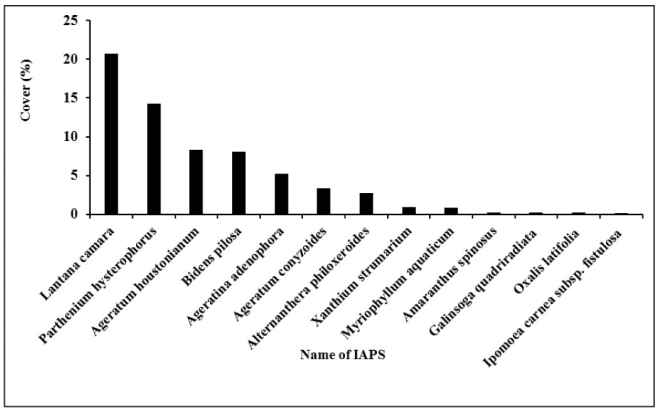

Figure 4: Cover percentage of IAPS.

protected national parks, agricultural fields, fallow lands as well as agro-ecosystem of Chitwan - Annapurna landscape (Shrestha et al., 2018). Production of high number of seeds is the important survival strategy of *Bidens pilosa*. A single plant species of *Bidens pilosa* can produce 3000-6000 seeds (Bartolome et al., 2013). Dhakal et al. (2018) also concluded *Bidens pilosa* as the second most frequent species in Siwalik regions of Nepal.

Myriophyllum aquaticum is a plant of stagnant or slow moving waters, rooting in shallow areas with emergent stems or floating stems extending over deeper water (Orchard, 1981). In our research, wetland is only one land use type suitable for the growth of this species, therefore *Myriophyllum aquaticum* is the least frequent IAPS (found near Balkhu area).

Lantana camara accounted for the high coverage among 13 recorded IAPS, followed by *Parthenium hysterophorus*. Various dispersal agents, easy dispersal pathway and strong root system (Priyanka & Joshi, 2013) might be the reason behind high coverage of *Lantana camara.* The roots of *Lantana camara* gives new flush even after repeated cuttings (Priyanka & Joshi, 2013). Relatively high coverage of *Parthenium hysterophorus* might be due to the ability of species to germinate and establish over a wide range of temperature and photoperiod of introduced habitat (Williams & Groves, 2006). In addition, high number of seed production per plant (20,000) and easy spread (Belgeri et al., 2012) further accelerates its abundance.

Conclusion

Altogether 90 vascular plant species were recorded from Kathmandu district, Central Nepal. Among them, nearly 54% were native and 46% were naturalized (13 spp. invasive and 28 spp. non-invasive naturalized). Highly modified and disturbed land use types such as road side and grazing land had high number and cover of IAPS as well as non-invasive naturalized as compare to natural and less disturbed habitat such as *Pinus* forest and mixed forest. *Ageratum houstonianum* was the most frequent species followed by *Bidens pilosa, Lantana camara* and *Parthenium hysterophorus*. Whereas, *Lantana camara* had the highest cover, followed by *Parthenium hysterophorus, Ageratum houstonianum* and *Bidens pilosa*. Those land use types which had high number of naturalized species including IAPS may serves as sources of propagules for further invasion. Therefore, such land use types should be monitored earlier as compared to those which have less number of naturalized species.

Author Contributions

All the authors were involved in data collection, concept development, research designing, defining of intellectual content and literature research. K. Gautam, Y. Gurung, S. Pokhrel, B. Shrestha, S. BK,S. Hitang, N. Shrestha and M. Bajracharya collected the data, whereasR. Paudel and G.D. Joshi collected and analyzed the data, and prepared manuscript.

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Table 2: Checklist of recorded vascular plants with their category from Kathmandu district

S.N.	Botanical Name	Category
1	*Parthenium hysterophorus* L.	I
2	*Bidens pilosa* L.	I
3	*Galinsoga quadriradiata* Ruiz. & Pav.	I
4	*Amaranthus spinosus* L.	I
5	*Alternanthera philoxeroides* (Mart.) Griseb.	I
6	*Ageratum houstonianum* Mill.	I
7	*Lantana camara* L.	I
8	*Ageratum conyzoides* L.	I
9	*Ipomoea carnea* sub sp. *fistulosa* (Mart.) ex Choisy D.F. Austin	I
10	*Xanthium strumarium* L.	I
11	*Ageratina adenophora* (Spreng.) R. M. King & H. Rob.	I
12	*Oxalis latifolia* Kunth.	I
13	*Myriophyllum aquaticum* (Vell.) Verdc.	I
14	*Eleusine indica* (L.) Gaertn.	N
15	*Justicia simplex* D. Don.	N
16	*Eragrostis pilosa* (L.) P. Beauv.	N
17	*Sigesbeckia orientalis* L.	N
18	*Achyranthes aspera* L.	N
19	*Cynodon dactylon* (L.) Pers.	N
20	*Solanum nigrum* L.	N
21	*Centella asiatica* (L.) Urb.	N
22	*Cuscuta cassytoides* Nees. ex. Engelm.	N
23	*Rumex nepalensis* Speng.	N
24	*Artemisia indica* Willd.	N
25	*Oplismenus burmanni* (Retz.) P. Beauv.	N
26	*Triumfetta rhomboidea* Jacq.	N
27	*Tectaria coadunata* (J.Sm.) C. Chr.	N
28	*Persicaria limbata* (Meisn.) H. Hara	N
29	*Ziziphus mauritiana* Lam.	N
30	*Digitaria ciliaris* (Retz.) Koeler	N
31	*Acmella paniculata* (DC.) R. K. Jansen.	N
32	*Spermadictyon suaveolen s*Roxb.	N
33	*Agave vivipara* L.	N
34	*Alnus nepalensis* D. Don.	N
35	*Rubia manjith* Roxb.	N
36	*Rubus ellipticus* Sm.	N
37	*Cassia fistula* L.	N
38	*Flemingia strobilifera* (L.) W.T. Aiton	N
39	*Syzygium cumini* (L.) Skeels.	N
40	*Urena lobata* L.	N
41	*Dalbergia sissoo* Roxb. ex. DC.	N
42	*Pinus roxburghii* Sarg.	N
43	*Calotropis gigantean* (L.) W.T. Aiton	N
44	*Diplazium esculentum* (Retz.) Sw.	N
45	*Falconeria insigis* Royle.	N
46	*Phyllanthus urinaria* L.	N
47	*Barleria cristata* L.	N
48	*Saccharum officinarum* L.	N
49	*Imperata cylindrica* (L.) P. Beauv.	N
50	*Athyrium cuspidatum* (Bedd.) M. Kato.	N
51	*Eragrostis tenella* (L.) P. Beauv. ex Roem & Schult.	N
52	*Pyracantha crenulata* (D. Don) M. Roem.	N

S.N.	Botanical Name	Category
53	*Globba racemosa* Sm.	N
54	*Plantago major* L.	N
55	*Lygodium flexuosum* (L.) Sw.	N
56	*Digitaria longiflora* (Retz.) Pers.	N
57	*Sida cordata* (Burm.f.) Borss.Waalk	N
58	*Cyperus brevifolius* (Rottb.) Hassk.	N
59	*Fimbristylis dichotoma* (L.) Vahl.	N
60	*Mangifera indica* L.	N
61	*Lyonia ovalifolia* (Wall.) Drude	N
62	*Crassocephalum crepidioides* (Benth.) S. Moore	NIN
63	*Datura metel* L.	NIN
64	*Trifolium repens* L.	NIN
65	*Sonchus asper* (L.) Hill.	NIN
66	*Amaranthus hybridus* L.	NIN
67	*Euphorbia hirta* L.	NIN
68	*Eclipta prostrate* (L.) L.	NIN
69	*Corchorus aestuan s*L.	NIN
70	*Sida cordifolia* L.	NIN
71	*Evolvulus nummularius* (L.) L.	NIN
72	*Drymaria cordata* (L.) Willd. exSchult.	NIN
73	*Solanum aculeatissimum* Moench.	NIN
74	*Erigeron Canadensis* L.	NIN
75	*Dactyloctenium aegyptium* (L.) Willd.	NIN
76	*Duranta erecta* L.	NIN
77	*Alternanther asessilis* (L.) R.Br. ex DC.	NIN
78	*Oxalis corniculata* L.	NIN
79	*Cestrum nocturnum* L.	NIN
80	*Solanum torvum* SW.	NIN
81	*Sida rhombifolia* L.	NIN
82	*Sida acuta* Burm. f.	NIN
83	*Grevillea robusta* A. Cunn. ex R. Br.	NIN
84	*Ipomoea nil* (L.) Roth.	NIN
85	*Euphorbia heterophylla* L.	NIN
86	*Axonopus compressus* (Sw.) P. Beauv.	NIN
87	*Oxalis corniculata* L.	NIN
88	*Psidium guajava* L.	NIN
89	*Paspalum distichum* L.	NIN
90	*Nasturtium officinale* W.T. Aiton	NIN

Note: I= Invasive, N= Native, NIN= Non-Invasive Naturalized