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Exploration of Plant Species in Relation to Invasive Alien Species in Natural and Man-made Ecosystem Services

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Abstract: ***A total of 119 species of plants were recorded in three sites of Kanchanpur of which 58 species were present at site 1, 83 species at site 2 and 68 species at site 3. The common species recorded in all sites were 23. These species belonged to 46 families of which family Poaceae (20) with highest number of species and family Rhamnaceae (1) with lowest number of species. On the basis of Importance Value Index (IVI) 16 plant species were recorded as dominant (IVI > 15.0) in all of the study sites. Of these, the maximum importance value index of dominant plant species was recorded by Cynodon dactylon (25.30) and minimum by Ludwigia octavalvis (0.06). Of the studied IAPS the frequent occurrence as per IUCN was recorded in the present study 11 species like Ageratum conyzoides, Amaranthus spinosus, Bidens pilosa, Hyptis suaveolens, Ipomea carnea, Lantana camara, Mimosa pudica, Parthenium hysterophprus, Senna occidentalis, Senna tora and Xanthium strumarium species. The analysis of IAPS proved that site 1 has 1 species, site 2 has 9 species and site 3 has 8 species. On the basis of IVI of the recorded invasive species, Ageratum conyzoides (30.29) was most dominant. In the reported species Lantana camara ranked in World's 100 worst invasive species. Of the total 119 species of plants, the floristic analysis was highest 83 species at site 2, 68 species at site 3 and 58 species at site 1. The highest numbers of species were dispersed by means of human (24%), and lowest by means of animal dung (2%). The Shannon-Wiener index values were different in all sites i.e. 6.9 at site 1, 3.73 at site 2 and 7.13 at site 3. The percentage similarity between three sites was 22.12%, indicating a low degree of similarity of species between three sites. Impacts of invasive plant species on environment and human are positive as well as negative. In the present findings the impact of invasive species focused on natural and man-made ecosystem services.***

Keywords: Floristic composition, IAPS, Dominant, IVI,

1. Introduction

Nepal is a landlocked country located in South Asia with an area of about 1, 47,181 sq. km situated between India in west, east, south and China to the north side. The complex topography with altitudinal variation from less than 100 m to 8848 m to the north has created varied climatic condition within the narrow vertical width of 145-241 km in the country. Geometrically, the country has roughly a rectangular outline located between 80^0 04' and 88^0 12' longitude, with an average east-west axis 885 km and north-south 193 km and latitude of 26^0 22' and 30^0 27' (Aryal and Dhungel, 2009). According to land resources mapping project, the physiographic classification was further detailed as Terai, Siwalik, mid lakes, high mountains and high himalayan (LRMP, 1986). Among the total land area 14% is Terai, elevating from 50 – 330 m, 12.7% is Siwalik which ranges from 330 m-1000 m, 29.5% mid hills elevates from 1000 m-2000 m, 19% is covered by high mountains, elevates from 2000 m-3000 m, 23.7% of land area is covered by high himalayan which is over 3000 m (Bhatt *et al.* 2007).

The word 'invasive' comes from the word 'invasion' which means to invade and the word 'alien' means foreigner or migratory. Invasive alien species (IAS) are animals, plants, algae or other organisms that are introduced into places outside their natural range, negatively impacting native biodiversity, ecosystem services or human well-being. Hence, invasive alien plant species (IAPS) can be defined as; non-native, non-indigenous, exotic, and foreign and/or introduced to an ecosystem other than its natural home by direct or indirect involvement of humans knowingly or unknowingly. IAPS develop themselves in short period of time because they have strong vegetative growth, high seed production rate, germination rate, rapid maturation of a sexually reproductive stage, ability to survive on various food types, phenotypic plasticity, high number of agent of dispersal and they can tolerate extreme climatic condition (Tiwari *et al.*, 2005).

IUCN (2000) defines IAS as an alien species, which becomes established in natural or semi-natural ecosystems or habitat, an agent of change, and threatens native biological diversity. Similarly, the Global Invasive Species Programme has defined IAS as "IAS is organisms that have been moved from their native habitat to a new location where they cause significant harm to the environment, economic systems and/or human health". Climate change and invasive species present two of the greatest threats to biodiversity and the provision of valuable ecosystem services (Burgiel and Muir, 2010). Climate may also facilitate the movement of invasive species along previously inaccessible pathways of spread in both natural and man-made environments (Engel *et al.*, 2011). It also reduces biodiversity, replaces important native species and increases investment in agriculture and silviculture, disrupting nutrient cycling (Ricchardi *et al.*, 2000). The estimated damage from invasive species worldwide totals more than 5 percent of the global economy (Stern, 2006). A total of 166 invasive alien plants species of Nepal were noted by IUCN (Tiwari *et al.*, 2005). The world's 100 worst invasive aliens (Lowe *et al.*, 2000) include 11 plant species are found in Nepal and 7 alien invasive species listed for Asia Pacific region

(Sankaran *et al.*, 2005). However, a detailed study on invasive species is lacking in Kanchanpur and present attempts focused on floristic composition and detailed analysis of IAPS

2. Materials and Methods

Kanchanpur is the Far Western Terai district of Nepal, bordered with Kailali district in east, Dadeldhura district in north, and with modern day India in south and west. Kanchanpur covers an area of about 1610 km^2 and had a population of 71,304 (CBS, 2011). It is also a gate way to Shuklaphanta National Park. The survey was carried out during July, 2017 to July, 2019 by systematic visits of the different study sites *i.e.* Site 1 (Agro-fields), Site 2 (Protected fields) and Site 3 (Unprotected areas). During the field visits, the natural habit, growth form, phenology and present status of the plant species was determined by visual observation and quadrats of 1x1 m size were kept randomly in the study sites with three replicate. Density, relative density, frequency, relative frequency, coverage and IVI were calculated as per Misra, (1968) and Curtis and McIntosh (1951) for each species. Diversity Index was calculated by using Shannon-Weiner information index (Shannon-Weiner 1963) and the Index of similarity (IS) between communities was calculated as per Sorenson (1948). All the samples were analyzed critically with the help of authentic literature and organizations.

3. Results

1. Floristic composition and diversity pattern of plant species

A total of 119 species of plants recorded in three sites of Kanchanpur of which 58 species were present at site 1, 83 species at site 2 and 68 species at site 3. Out of total plant species, the highest numbers of plant species were recorded at site 2. The common species recorded at all sites were *Ageratum conyzoides, Brachiaria ramosa, Chloris radiata, Clerodendrum viscosum, Commelina benghalensis, Cynodon dactylon, Cyperus rotundus, Dactyloctenium aegypticum, Desmodium triforum, Echinochloa colona, Eragrostis tenella, Euphorbia hirta, Evolvus nummularis, Imperata cylindrica, Kyllinga brevifolia, Lindernia procumbens, Mecardonia procumbens, Murdania nudiflora, Oxalis corniculata, Phyllanthus niruri, Phyllanthus urinaria, Sida acuta* and *Spilanthes calva*. These species belonged to 46 families (Table 1 & Figure 1).

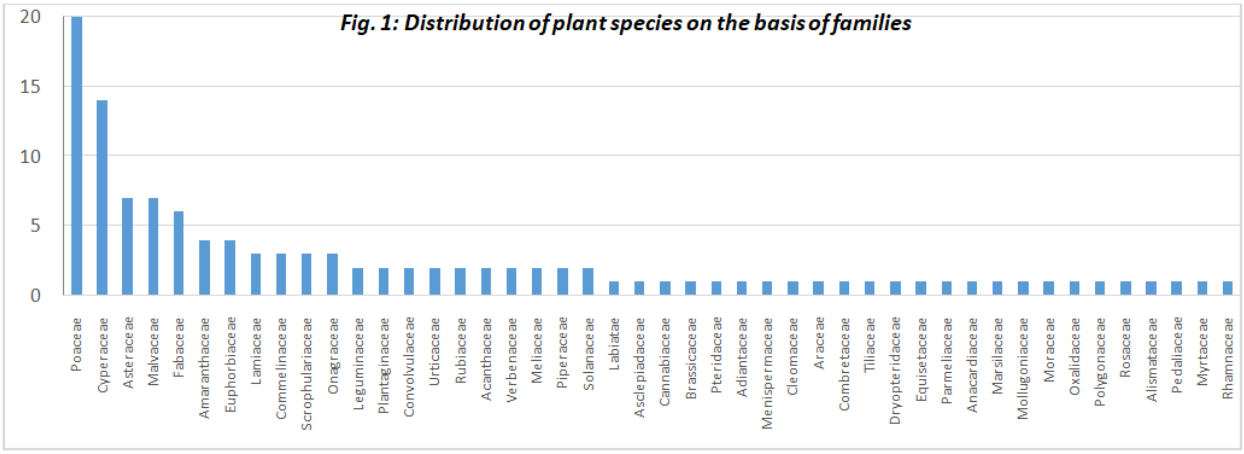
Table 1: Floristic composition, Density and IVI of plant species at different study sites

S. No.	Name of Species	Family	Site 1 (D_1)	Site 2 (D_2)	Site 3 (D_3)	Site 1 (IVI_1)	Site 2 (IVI_2)	Site 3 (IVI_3)
1.	*Abutilon indicum* (L.) Sweet [*#]	Malvaceae	_	_	0.88	_	_	3.10
2.	*Achyranthes aspera* L. [*]	Amaranthaceae	_	0.04	0.38	_	0.43	2.34
3.	*Ageratum conyzoides* L.[@]	Asteraceae	30.29	24.08	14.25	23.02	17.59	23.56
4.	*Ajuga bracteosa* Wall. Ex Benth. [#]	Labiatae	9.54	_	0.63	6.62	_	0.88
5.	*Albizia odoratissima* (L.f.) Benth. [*#]	Fabaceae	_	_	0.5	_	_	2.18
6.	*Alternanthera sessilis* (L.) DC[*!]	Amaranthaceae	_	2.04	_	_	2.60	_
7.	*Alysicarpus vaginalis* (L.) DC. [*]	Leguminaceae	_	0.38	5.19	_	1.12	9.64
8.	*Amaranthus spinosus* L. [*#]	Amaranthaceae	_	_	0.69	_	_	2.33
9.	*Amaranthus viridis* L. [*#]	Amaranthaceae	_	_	0.31	_	_	2.09
10.	*Axonopus compressus* (Sw.) P. Beauv. [*!]	Poaceae	_	6.79	_	_	8.47	_
11.	*Bacopa monnieri* (L.) Pennell[#]	Plantaginaceae	0.95	_	0.19	1.75	_	1.28
12.	*Bidens pilosa* L. [*!]	Asteraceae	_	0.96	_	_	1.59	_
13.	*Brachiaria mutica* (Forssk.) Stapf. [*]	Poaceae	_	4.17	5.69	_	5.64	9.67
14.	*Brachiaria ramosa* (L.) Stapf.[@]	Poaceae	2.13	1.08	9.75	2.85	1.62	17.15
15.	*Calotropis procera* (Aiton) W.T.Aiton [*#]	Asclepiadaceae	_	_	0.13	_	_	0.88
16.	*Cannabis sativa* L. [*#]	Cannabaceae	_	_	2.88	_	_	6.28
17.	*Capsella bursa-pastoris* (L.) Medik.[#!]	Brassicaceae	0.29	_	_	0.91	_	_
18.	*Ceratopteris thalictroides* (L.) Brongniart[!]	Pteridaceae	0.13	1.38	_	0.82	3.56	_
19.	*Cheilanthes tenuifolia* (Burm.f.) Sw. [*!]	Adiantaceae	_	1.63	_	_	3.24	_
20.	*Chloris radiata* (L.) Sw. [@]	Poaceae	0.04	9.0	1.0	0.31	13.42	4.76
21.	*Chrysopogon aciculatus* (Retz.) Trin. [*]	Poaceae	_	3.88	3.13	_	10.70	7.10
22.	*Cirsium arvense* (L.) Scop.[*!]	Asteraceae	_	0.13	_	_	0.45	_
23.	*Cissempelos pareira* L. [*]	Menispermaceae	_	0.18	0.13	_	0.27	1.01
24.	*Clemoe viscosa* L. [*#]	Cleomaceae	_	_	0.48	_	_	1.85
25.	*Clerodendrum viscosum* Vent. [@]	Lamiaceae	1.25	0.83	2.88	1.59	2.53	10.39
26.	*Colocasia esculenta* (L.) Schott. [*]	Araceae	_	0.08	0.81	_	1.13	3.56
27.	*Combretum indicum* (L.) Defilipps[!]	Combretaceae	0.17	0.21	_	0.60	0.96	_
28.	*Commelina benghalensis* L. [@]	Commelianeaceae	1.70	0.96	1.56	3.56	2.65	5.62
29.	*Commelina forsleadii* Vahl.[!]	Commelianeaceae	0.04	1.17	_	0.41	1.48	_
30.	*Corchorus tridens* L. [#]	Tiliaceae	0.13	_	0.19	0.80	_	1.98
31.	*Cynodon dactylon* (L.) Pers. [@]	Poaceae	16.67	8.42	15.56	15.64	9.43	25.30
32.	*Cyperus compressus* L.[!]	Cyperaceae	1.79	1.25	_	3.42	2.94	_
33.	*Cyperus corymbosus* L. [*#]	Cyperaceae	_	_	1.31	_	_	4.80
34.	*Cyperus difformis* L.[!]	Cyperaceae	0.04	0.04	_	0.44	0.51	_
35.	*Cyperus eragrostis* L.[!]	Cyperaceae	0.16	0.21	_	0.77	0.32	_
36.	*Cyperus flavescens* L.[!*]	Cyperaceae	_	0.29	_	_	0.66	_

37.	*Cyperus haspan* L.[!]	Cyperaceae	0.29	2.92	_	0.52	4.15	_
38.	*Cyperus iria* L. [*!]	Cyperaceae	_	0.04	_	_	0.34	_
39.	*Cyperus millispora* L.[!]	Cyperaceae	14.20	0.29	_	13.40	0.56	_
40.	*Cyperus rotundus* L. [@]	Cyperaceae	8.25	0.08	1.31	6.10	0.60	3.55
41.	*Cyperus trachysanthos* Hook. &Arn. [*!]	Cyperaceae	_	0.04	_	_	0.34	_
42.	*Dactyloctenium aegypticum* (L.) P. Beauv[@]	Poaceae	1.16	1.58	0.83	2.35	2.15	3.72
43.	*Dalbergia sissoo* Roxb. [*#]	Fabaceae	_	_	0.50	_	_	1.97
44.	*Desmodium triflorum* (L.) DC. [@]	Fabaceae	0.63	26.13	12.38	1.70	24.12	22.63
45.	*Digitaria ciliaris* (Retz.) Koeler[*]	Poaceae	_	3.42	2.75	_	8.74	5.81
46.	*Digitaria sanguinalis* (L.) Scop. [*]	Poaceae	_	5.25	1.0	_	7.14	3.43
47.	*Dryopteris erythrosore* (D.C. Eaton.) Kuntze. [#!]	Dryopteridiaceae	0.13	_	_	0.80	_	_
48.	*Echinochloa colona* (L.) Beauv. [@]	Poaceae	9.08	0.38	0.13	10.87	1.25	1.01
49.	*Echinochloa glabrescens* P. Beauv. [#!]	Poaceae	2	_	_	3.73	_	_
50.	*Eclipta prostrata* L.[!]	Asteraceae	1.63	1.29	_	3.45	2.83	_
51.	*Eleocharis atropurpurea* (Retz.) J. Presl&C. Presl[#!]	Cyperaceae	0.41	_	_	1.64	_	_
52.	*Elusine corocana* Gaertn. [#!]	Poaceae	1.19	_	_	5.34	_	_
53.	*Elusine indica* (L.) Gaertn. [#]	Poaceae	2.29	_	0.88	3.77	_	4.05
54.	*Equisetum hyemale* L. [*]	Equisetaceae	_	0.04	0.88	_	0.34	4.12
55.	*Eragrostis tenella* (Retz.) Stapf. [@]	Poaceae	4.38	2.42	0.63	4.57	2.89	3.15
56.	*Euphorbia hirta* L. [@]	Euphorbiaceae	0.13	0.04	0.25	0.60	0.10	2.25
57.	*Evolvus nummularis* (L.) L. [@]	Convolvulaceae	2.66	6.75	1.38	4.51	9.09	4.72
58.	*Fimbristylis dichotoma* (L.) Vahl. [!]	Cyperaceae	2.04	4.96	_	4.47	7.18	_
59.	*Fimbristylis miliaceae* (L.) Vahl. [#!]	Cyperaceae	0.54	_	_	1.24	_	_
60.	*Gonostegia pentandra* (Roxb.) Benn. [#!]	Urticaceae	0.45	_	_	1.65	_	_
61.	*Hedyotis corymbosa* (L.) Lam. [!]	Rubiaceae	3.41	4.54	_	1.24	5.37	_
62.	*Hemigraphis hirta* L. [*!]	Acanthaceae	_	0.08	_	_	1.13	_
63.	*Hypotrachyna afrorevoluta* (Krog&Swinscow) [#!]	Parmeliaceae	10.79	_	_	10.01	_	_
64.	*Hyptis suaveolens* (L.) Poit. [*#]	Lamiaceae	_	_	2.25	_	_	10.61
65.	*Imperata cylindrica* (L.) P. Beauv. [@]	Poaceae	6.29	27.13	3.63	10.57	24.62	8.94
66.	*Ipomea carnea* Jace. [*]	Convolvulaceae	_	0.08	0.06	_	1.13	0.74
67.	*Justicia procumbens* L. [#!]	Acanthaceae	0.50	_	_	1.12	_	_
68.	*Kyllinga brevifolia* Rottb. [@]	Cyperaceae	2.83	2.79	2.44	5.35	4.91	6.50
69.	*Lantana camara* (L.) Moldenke[*!]	Verbenaceae	_	0.21	_	_	1.02	_
70.	*Lindernia oppositifolia* (L.) Mukerjee. [!]	Scrophulariaceae	0.29	0.21	_	0.64	0.89	_
71.	*Lindernia procumbens* (Krock.) Borbas[@]	Scrophulariaceae	8.71	3.13	3.25	9.69	6.37	8.50
72.	*Lippia nodiflora* (L.) Rich. [*]	Verbenaceae	_	2.21	1.56	_	2.25	7.18
73.	*Ludwigia octavalvis* (Jacq.) P.H. Raven[*!]	Onagraceae	_	0.08	_	_	0.06	_
74.	*Ludwigia perennis* L. [#!]	Onagraceae	0.41	_	_	1.87	_	_
75.	*Ludwigia repens* J.R.Forst[*#]	Onagraceae	_	_	0.31	_	_	1.46
76.	*Malvastrum coromandelianum* (L.) Garcke. [*]	Malvaceae	_	0.29	0.75	_	1.01	2.79
77.	*Mangifera indica* L. [*!]	Anacardiaceae	_	0.04	_	_	0.51	_
78.	*Marsilea quadrifolia* L. [!]	Marsilaceae	3.88	1.25	_	4.59	0.80	_
79.	*Mecardonia procumbens* (Miller) Small[@]	Scrophulariaceae	20.0	12.38	0.81	16.65	14.30	2.95
80.	*Melia azadiracta* L. [*!]	Meliaceae	_	0.63	_	_	1.76	_
81.	*Mimosa pudica* L. [*!]	Leguminaceae	_	0.96	_	_	3.63	_
82.	*Mollugo oppositifolia* (L.) [!]	Mollugoniaceae	1.50	0.13	_	2.11	0.70	_
83.	*Morus alba* L. [*#]	Moraceae	_	_	0.06	_	_	0.69
84.	*Murdania nudiflora* (L.) Brenan. [@]	Commelianiaceae	8.38	0.54	0.93	9.22	1.23	3.15
85.	*Murraya koenigii* (L.) Sprengel[*#]	Rubaceae	_	_	0.06	_	_	0.74
86.	*Oplismenus burmannii* (Retz.) Beauv. [*]	Urticaceae	_	12.83	7.31	_	13.33	14.07
87.	*Oxalis corniculata* L. [@]	Oxalidiaceae	0.08	0.63	1.0	0.35	1.84	3.60
88.	*Parthenium hysterophorus* L. [*]	Asteraceae	_	2.79	1.81	_	3.08	4.77
89.	*Paspalidium flavidum* (Retz.) A. Camus[*]	Poaceae	_	0.25	0.13	_	1.10	1.01
90.	*Paspalum conjugatum* Berg. [*!]	Poaceae	_	0.42	_	_	1.59	_
91.	*Peperomia pellucida* Kunth. [!]	Piperaceae	1.5	2.29	_	2.30	5.66	_
92.	*Phyllanthus niruri* (L.) [@]	Euphorbiaceae	9.88	0.58	0.56	9.12	0.26	3.12
93.	*Phyllanthus urinaria* (L.) [@]	Euphorbiaceae	7.0	9.68	0.13	9.59	13.96	1.24
94.	*Piper longum* L. [*!]	Piperaceae	_	0.21	_	_	0.67	_
95.	*Pogostemon benghalensis* (Burm. F.) O.Kuntze[*#]	Lamiaceae	_	_	0.31	_	_	1.81
96.	*Polygonum barbatum* L. [*!]	Polygoniaceae	_	0.04	_	_	0.34	_
97.	*Ricinus communis* L. [*#]	Euphorbiaceae	_	_	0.44	_	_	1.50
98.	*Rosa indica* L. [*!]	Rosaceae	_	0.08	_	_	0.15	_
99.	*Rottboelia exaltata* L.f. [#!]	Poaceae	0.38	_	_	2.11	_	_

100.	*Sacchrum spontaneum* L. *	Poaceae	_	0.08	0.63	_	0.49	2.48
101.	*Sagittaria guyonesis* Kunth#!	Alismataceae	0.08	_	_	0.54	_	_
102.	*Sarraca indica* L. *!	Fabaceae	_	0.08	_	_	0.95	_
103.	*Scorpia dulcis* L. *#	Plantaginaceae	_	_	0.25	_	_	1.54
104.	-*Senna occidentals* (L.) Link *	Fabaceae	_	0.04	0.13	_	0.34	1.01
105.	*Senna tora* (L.) Roxb*	Fabaceae	_	4.71	2.06	_	4.45	7.15
106.	*Sesamum indicum* L. #!	Pedaliaceae	9.38	_	_	3.73	_	_
107.	*Setaria pumila* (Poir.) Roem. & Schult. *!	Poaceae	_	0.42	_	_	0.63	
108.	*Sida acuminata* DC#!	Malvaceae	0.08	_	_	0.41	_	_
109.	*Sida acuta* Brum. F. @	Malvaceae	0.13	3.29	14.31	0.94	3.61	22.44
110.	*Sida cordata* (Burm.f.) Borss. Waalk*	Malvaceae	_	0.75	0.13	_	1.43	0.88
111.	*Sida cordifolia* L. *!	Malvaceae	_	0.17	_	_	1.45	_
112.	*Sida rhombifolia* L. *	Malvaceae	_	0.33	0.06	_	0.86	0.74
113.	*Solanum nigrum* L. *#	Solanaceae	_	_	0.06	_	_	0.69
114.	*Solanum virgininium* L. *	Solanaceae	_	0.04	0.13	_	0.34	1.24
115.	*Spilanthes calva* DC@	Asteraceae	2.25	0.08	2.38	5.02	1.13	7.76
116.	*Syzygium cumini* (L.) Skeels!	Myrtaceae	0.38	0.13	_	1.16	0.70	_
117.	*Toona ciliata* M. Roem. *#	Meliaceae	_	_	0.06	_	_	0.74
118.	*Xanthium strumarium* L. *	Asteraceae	_	0.21	1.0	_	0.56	4.02
119.	*Ziziphus mouritiana* Lam.*	Rhamnaceae	_	0.18	1.06	_	0.51	3.80
Total 214.91				221.82	141.5	242.55	296.25	348.02

Key: D1 = Agro-field, D2 = Protected field, D3 = Road side, IVI 1 = Agro field, IVI 2 = Protected field and IVI 3=Road side. * *= absent at site 1,* # *= absent at site 2,* ! *= absent at site 3and* @ *= common species in all study sites.*



2. Dominant plant species

On the basis of Importance Value Index (IVI) 16 plant species were recorded as dominant (IVI > 15.0) in all of the study sites. Of these, the maximum importance value index of dominant plant species at site 1 and minimum by *Ludwigia octavalvis* (0.06) at site 2. Among them *Ageratum conyzoides, Cynodon dactylon, Echinochloa colona, Imperata cylindrica* and *Sida acuta* were reported as being the World worst weed by Holm *et al*. (1977). Of the 16 most important species *Ageratum conyzoides, Brachiaria ramosa, Chloris radiata, Clerodendrum viscosum, Cynodon dactylon, Desmodium triflorum, Echinochloa colona, Imperata cylindrica, Mecardonia procumbens, Phyllanthus urinaria* and *Sida acuta* were common in all study sites (Figure 2).

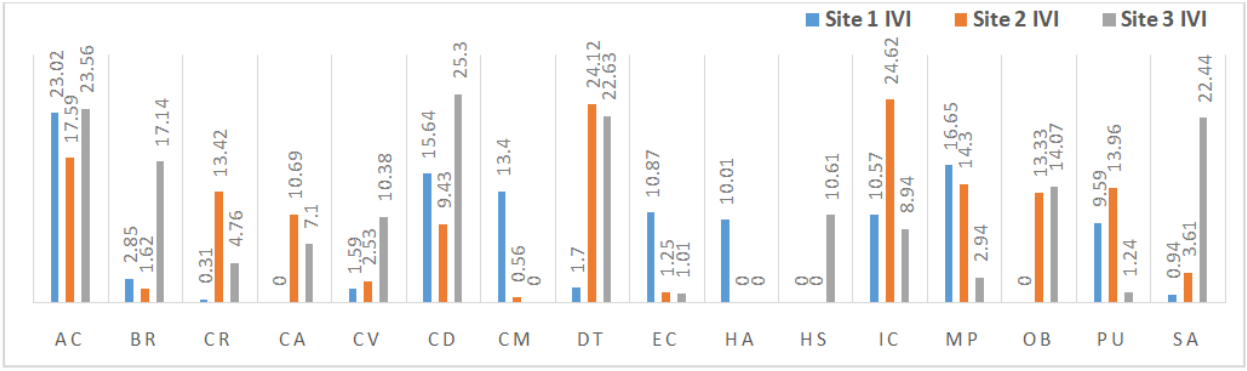
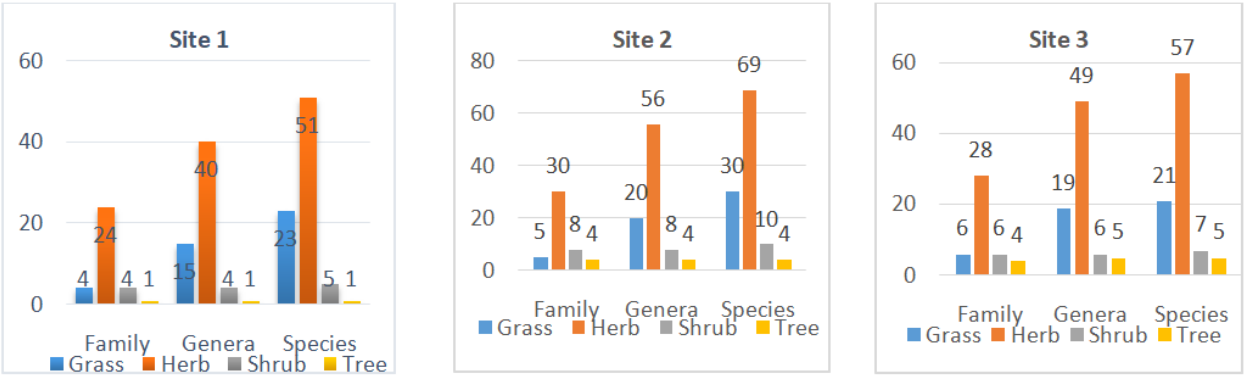


Figure2: Site wise representation of dominant plant species i.e. *AC=Ageratum conyzoides, BR=Brachiaria ramosa, CR=Chloris radiata, CA=Chrysopogon aciculatus, CV=Clerodendrum viscosum, CD=Cynodon dactylon,CM=Cyperus*

millispora, DT=Desmodium triflorum, EC=Echinochloa colona, HA=Hypotrachyna afrorevoluta, HS=Hyptis suareolens, IC=Imperata cylindrica, MP=Mecardonia procumbens,OB=Oplismenus burminnii, PU= Phyllanthus urinaria, SA= Sida acuta.

3. Floristic analysis of plant species

Out of the 119 plant species, the floristic composition was recorded highest number of plant species (83) at site 2 followed by plant species (68) at site 3 and plant species (58) at site 1. The number of genera, species and families as per site is represented by bar diagram (Figure 3, 4 & 5).



4. Inventory of invasive alien plant species

Of the studied IAPS the frequent occurrence as per IUCN was recorded in the present study by 11 species like *Ageratum conyzoides, Amaranthus spinosus, Bidens pilosa, Hyptis suaveolens, Ipomea carnea, Lantana camara, Mimosa pudica, Parthenium hysterophprus, Senna occidentalis, Senna tora* and *Xanthium strumarium* species. On the basis of density and IVI of the recorded invasive species site wise *Ageratum conyzoides* is found to be most dominant and *Sida acuta* is found to be least dominant with density (30.29) and (0.12) respectively in site 1. Similarly, in site 2 the most dominant plant species is found to be *Imperata cylindrica* (27.12) and the least dominant species are *Achyranthus aspera, Equisetum hyemale* and *Senna occidentalis* (0.04) and in site 3 most dominant species is found to be *Sida acuta* (14.31) and least dominant species is found to be *Ipomea carnea* (0.06). The analysis of IAPS proved that site 1 has 1 species of IAPS, site 2 has 9 species IAPS and site 3 has 8 species of IAPS. These IAPS were dominant on the basis of IUCN criteria (Figure 6).

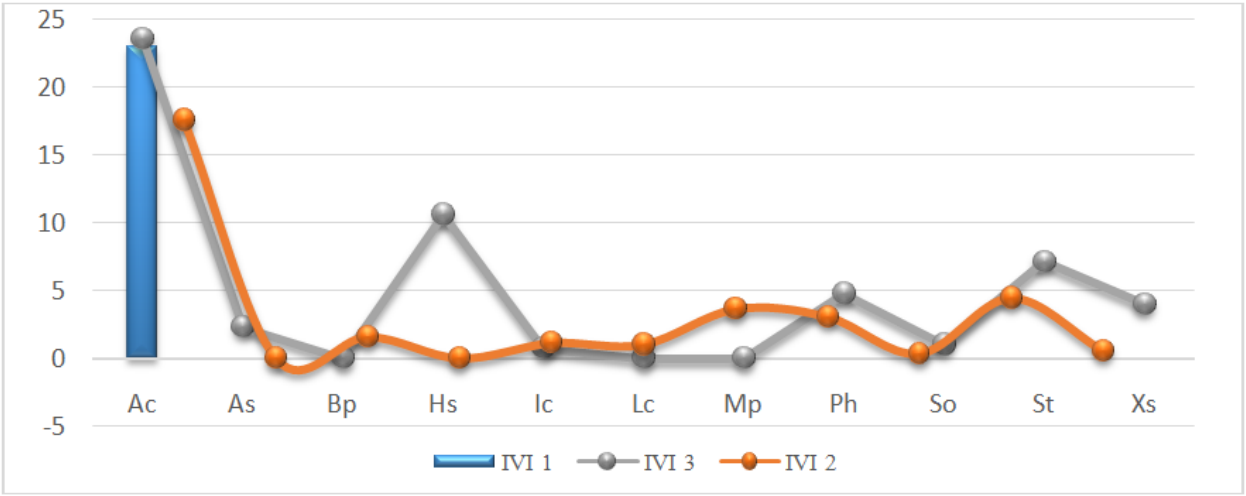


Figure 6: Composition of major IAPs at different study sites *i.e. Ac=Ageratum conyzoides, As=Amaranthus spinosus, Bp=Bidens pilosa,Hs=Hyptis suaveolens, Ic=Ipomea carnea, Lc=Lantana camara, Mp=Mimosa pudica, Ph=Parthenium hysterophprus,So=Senna occidentalis,St=Senna tora* and Xs=*Xanthium strumarium.*

5. Diversity index of invasive alien species

In the present study the species richness was higher (83) in site 2 than in site 3 (68) and site 1 (58). The Shannon-Wiener index values were different in all sites *i.e.* 6.9 at site 1, 3.73 at site 2 and 7.13 at site 3. The percentage of similarity between three sites was 22.12%, indicating a low degree of similarity of species between three sites (Figure7).

6. Agent of dispersal of alien invasive species

Plants have very limited mobility and consequently rely upon a variety of dispersal vectors to transport their

propagules, including both abiotic vectors such as the wind and biotic vectors like birds. Seeds can be dispersed away from the parent plant individually or collectively, as well as dispersed in both space and time. In the present study, agents of dispersal undertaken were agricultural tool, animal, animal dung, bird, human, seed, water and wind in which highest number of species were dispersed by means of human (24%) and lowest by means of animal dung (2%) (Figure 8).

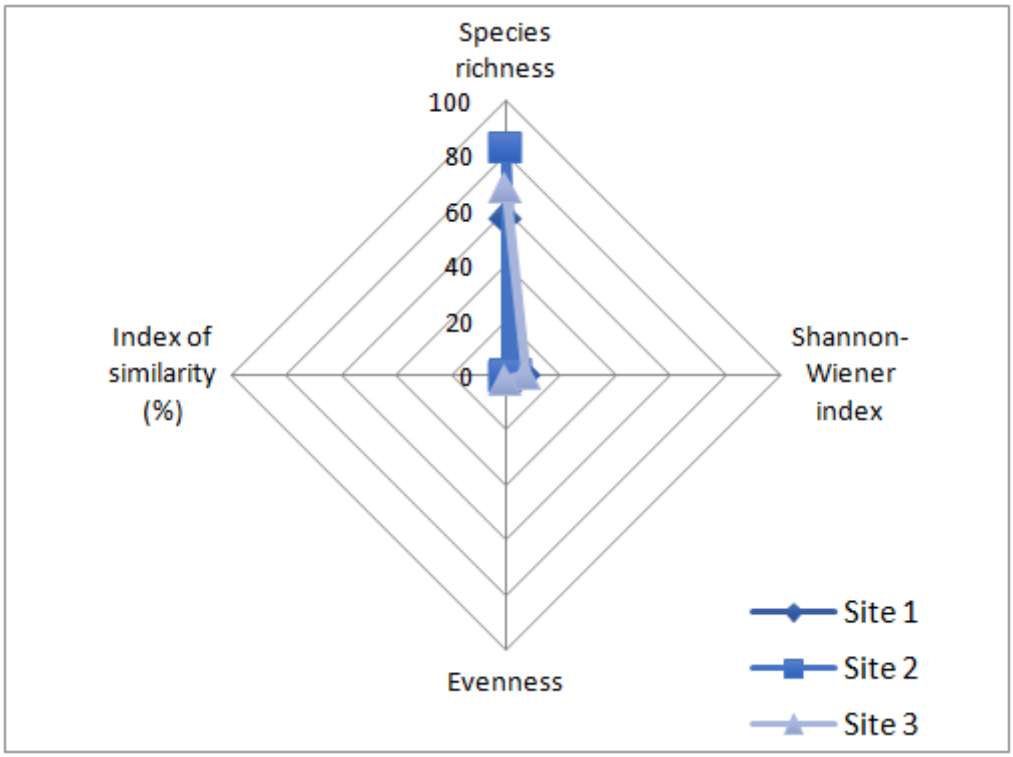


Figure 7: Analysis of species richness, diversity index, evenness, and index of similarity of plant species

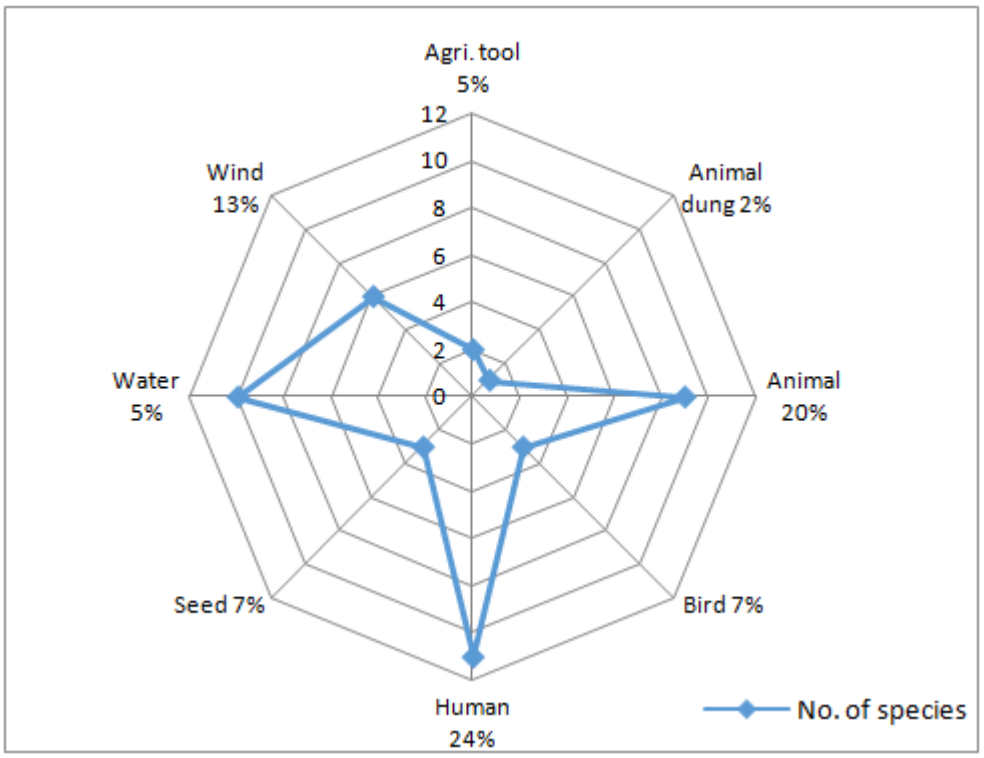


Figure 8: Percentage wise agent of dispersal of IAPS

7. Impact of invasive alien plant species

Alien plant species at any place can be defined as the plant species which originally belonged to that place but have migrated from its native land accidentally or by human for their benefits. The word 'invasive' comes from the word invasion which literally means to entry. Thus, invasive alien plant species are species that are not native to a

specific location, and that has a tendency to spread to a degree believed to cause damage to the environment, human economy or human health. Invasive alien plant species are successful because of; high seed production, survival on extreme condition, high rate of seed germination, maximum number of agent of dispersal, production of chemicals that inhibit growth of plant around, etc. Impacts of invasive plant species on environment and human are positive as well as negative. However, negative impacts are tremendous in comparison to positive impacts. These plants also results in poor quality of agriculture lands, degradation in water quality, increment in soil erosion, decrement in recreational opportunities, etc.

Ageratum conyzoides is noxious weed in agricultural lands and as a colonizer of open fields and degraded areas, causing crop yield reductions and affecting biodiversity. *Amaranthus spinosus* is reported to be the number three weed in maize in the Philippines as well as a principal weed in that crop in Ghana, Hawaii, Mexico and Thailand, and a common weed in Malaysia and Taiwan. Invasive alien species (IAPS) are one of the biggest causes of biodiversity loss and species extinctions, and are also a global threat to food security and livelihoods. Extreme climatic events resulting from climate change, such as hurricanes, floods and droughts can transport IAPS to new areas and decrease the resistance of habitats to invasions. Invasive species alter the production, maintenance, and quality of services by a variety of mechanisms and actions. Poisonous or toxic plants, *i.e.* plants containing toxic compounds, may impact human health generally after the ingestion of part of the plant or of some product derived from toxic plants. Allergenic plants are among the most studied cases of impacts of alien plants, particularly concerning the role of allergenic (*Parthenium hysterophprus*) pollen. The economic and social impacts of invasive species include both direct effects of a species on property values, agricultural productivity, public utility operations, native fisheries, tourism, and outdoor recreation, as well as costs associated with invasive species control efforts.

8. Discussion

Topographically, Nepal is divided into Terai, Hills and Mountains. According to land resources mapping project, the physiographic classification was further detailed as Terai, Siwalik, mid lakes, high mountains and high Himalayan (LRMP, 1986). IUCN (2000) defines IAS as an alien species, which becomes established in natural or semi-natural ecosystems or habitat, an agent of change, and threatens native biological diversity. Invasive plants are usually non-native species that have been introduced intentionally or by accident and spread from human settings into natural areas with negative effects on our economy, environment, and health. Invasive plants usually possess traits that make them effective invaders, such as a short life cycle, high growth rate, large number of seeds with good dispersal ability, and good colonizing capacity.

A total of 166 invasive alien plants species of Nepal were noted by IUCN (Tiwari *et al.*, 2005). However, in a milieu of changing climate, introduction and aggressiveness of invasive alien species is being increased, urging more researches and updates on IAPS. The world's 100 worst invasive aliens (Lowe *et al.*, 2000) include 11 plant species like *Arundo donax, Chromolaena odorata, Eichhornia crissepes, Hedychium gardnerianum, Hiptage benghalensis, Imperata cylindrica, Lantana camara, Leucaena leucocephala, Mikania micrantha, Opuntia stricta* and *Rubus ellipticus* that are found in Nepal. However, they are not equally invasive. Seven toppers alien invasive in the list for Asia Pacific region include: *Ageratina adenophora, Ageratum conyzoides, Chromolaena odorata, Eichhornia crissepes, Lantana camara, Mikania micrantha* and *Parthenium hysterophorus* (Sankaran *et al.*, 2005). All these seven species are problematic in Nepal (Sankaran *et al.*, 2005).

A total of 119 species of plants recorded in three sites of Kanchanpur of which 58 species were present at site 1, 83 species at site 2 and 68 species at site 3. The common species (23) recorded at all study sites. Such type of study was also conducted by Siwakoti and Shrestha (2014) in which 72 plant species were recorded from the five study sites of Ethiopia. These species belonged to 46 families of which highest number included in Poaceae (20) and lowest number in Rhamnaceae (1). Similar family wise composition of species was recorded by Siwakoti and Shrestha (2014) on their study, in which 23 species were Poaceae, 12 were Asteraceae, and the remaining 32 species were from 22 other families.

On the basis of Importance Value Index (IVI) 16 plant species were recorded as dominant (IVI > 15.0) in all of the study sites. Of these, the maximum importance value index of dominant plant species at site 1 was recorded by *Ageratum conyzoides* (23.02) and minimum by *Ludwigia octavalvis* (0.06) at site 2. Among them *Ageratum conyzoides, Cynodon dactylon, Echinochloa colona, Imperata cylindrica* and *Sida acuta* were reported as being the World worst weed by Holm *et al.* (1977). In the present finding the dominance of grasses and sedges corresponded with the findings of Thapa and Jha (2002), Shrestha (2016), Dangol (2002) and Bhatt (2019) in different study sites of Nepal. Of the studied IAPS the frequent occurrence as per IUCN was recorded in the present were 11 invasive species correlate more or less similar with the finding of Tiwari *et al.* (2005). On the basis of density and IVI of the recorded invasive species site wise *Ageratum conyzoides* is found to be most dominant and *Sida acuta* is found to be least dominant with density (30.29) and (0.12) respectively in site 1. Present study agreed with the findings of Bhatt (2007 & 2019), Tiwari *et al.* (2005) and Chaudhary (2011). In the present study the species richness and degree of similarity between three sites was more or less with the findings Bhatt *et al.* (2007). Frequent availability of unused resources increases vulnerability of a habitat to invasion (Davis *et al.*, 2000) while human activities increase propagule pressure of invasive species (Simberloff, 2009). Biological invasion has been considered as an important component of global environmental changes (Vitousek *et al.*, 1997) and a leading cause of decline and/or loss of native biodiversity (Ricciardi *et al.*, 1998, Kohli *et al.*,

2004) and ecosystem services (Pejchar and Mooney, 2009).

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