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Original Research

Diversity and Distribution of Invasive Plant Species in Suburban Vegetation of Kashmir Himalayas

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Abstract

Biological invasion has been considered one of the most important mechanisms of global change, posing serious threats to the conservation of native ecosystems world-wide. The present study was conducted in the sub-tropical vegetation stands in the suburban areas of Muzaffarabad city to study the diversity and distribution of invasive alien species (IAS) of plants and assess the factors responsible for their spread. A total of 9 sites, including 2 in the city and 7 in suburban areas, were sampled using random quadrate methods. The sampled flora were classified according to the phytogeographic origin and invasion status, whereas the phytosocioogoical attributes of plant communites were also calculated following standard protocols. A total of 121 plant species represented by 108 genera belonging to 58 families was recorded from the study area. Results revealed that 35.6% flora comprised of 43 species were recorded as IAS. The IAS dominating the area included *Parthenium hysterophorus*, *Lantana camara*, *Xanthium strumarium*, *Ailanthus aItissima*, *Cannabis sativa*, *Broussonetia papyrifera*, *Arundo donax* and *Sorghum halepense*. Analysis of the Invasion status revealed that invasive aliens had a weight of 46% followed by naturalized aliens and casual aliens, respectively. The dominance of invasive species resulted in decreased species diversity at the disturbed sites. Landslides and road construction were identified as factors promoting the establishment and spread of invasive species in the area. Principal component analysis revealed significant correlation of edaphic disturbances with the abundance of IAS. An integrated management system is recommended for early detection and control of IAS.

Keywords: biological invasion, diversity, suburban vegetation, land slides, road construction

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Introduction

Biological invasion has been considered an important mechanism of global change posing serious threats to the conservation of native ecosystems worldwide [1]. The invasion of alien plant species in the new regimes has become the second highest threat to plant diversity after habitat loss [2, 3]. Under the Convention on Biological Diversity, invasive alien species (IAS) means species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, eggs, gametes, propagules or seeds of such species that might stay alive and subsequently reproduce; and whose introduction and spread threaten biological diversity. High competitive ability, reproductive effectiveness, efficient dispersal, vegetative reproduction, rapid organization and other traits help IAS adapt to new habitats [4, 5].

The impacts of IAS are globaly significant, long-term and commonly classified as economic, environmental or social in nature. IAS can impede species diversity, richness, composition, abundance and interactions, including mutualisms. The direct effects of IAS at the species level occur through processes such as predation, competition with and parasite transmission to individual organisms [6, 7]. IAS can lead to the fragmentation, destruction, alteration and even the whole replacement of habitats, often resulting in consequences for even more species and ecosystem processes, primary to the functional collapse of the native ecosystem [8]. The potential risk of invasion is directly correlated with human activities synchronized with environmental disturbances and stresses. The disturbed and secondary vegetation is vulnerable to the violently invading invasive alien species [9, 10].

The western Himalayan biotic province is reported to have about 700 alien plant species [11]. The state of Azad Jammu and Kashmir (AJK) is istuated in the Pir Panjal Mountain Range in the western Himalayas, having diverse phytoclimatic zones and harboring high levels of biological diversity [12]. Due to rapid socio-economic transitions synchronized with population rise, defiorestation and urbanization, the local vegetation is highly exposed to the risks of invasions by alien floral elements, potentially leading to environmental degradation and loss of biodiversity [13, 14]. Despite the intensity of the threat, there is no available data about the invasive alien flora in the area. The curent study was designed to investigate the diversity and distribution of invasive species in the suburban areas of Muzaffarabad, the capital of AJK. Specific objectives included analyzing the status of the invasive species along with inestigating the factors responsible for the spread of invasive species in suburban vegetation.

Experimental Procedure

Study Area

Muzaffarabad is the capital of the state of Azad Jammu and Kashmir situated between 34.24° latitude and 73.22° longitude in northeastern Pakistan spreading over an area of 1642 km^2. The topography of Muzaffarabad is mountainous and hilly, characterized by subtropical scrub and pine forests [15]. The climate

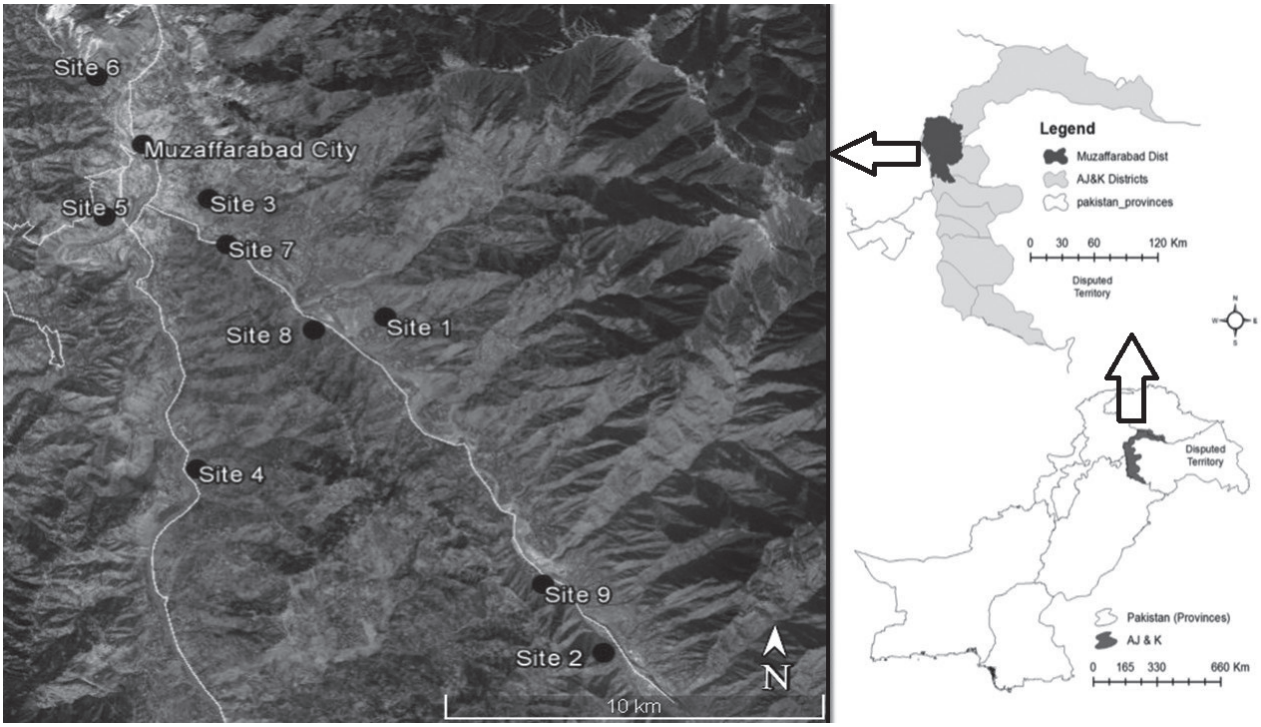

Fig 1. Map of the study area and satellite imagery of the sampling sites.

of the area falls under subtropical and humid type with considerable variations. June and July are the hottest months, with maximum temperature a 40.0 to 47.5ºC and minimum as 28.0 to 37.5ºC, respectively, while January and February are the coldest months with maximum temperatures of 15.0-21.5ºC and minimum -3.0–-1.0ºC. The average annual precipitation of the district is 1511 mm, with maximum rainfall during monsoon and early spring season [16].

Methodology

A total of 9 sites were selected for recording the vegataion composition and community structure having 2 sites in the city area, and 7 in the suburban areas (Fig. 1). The data was recorded systematically using the quadrats method with 10 10 x10 m quadrats for trees at each site. Each quadrat was subdivided into 5 x 5 m sample plots for recording shrubs and samplings, and 1 x 1 m for herbs and seedlings. The herbaceous cover was determined by Daubenmire's cover scale. Trees with diameter at breast height (1.5 m) were measured to obtain basal area [17]. The density, frequency and coverage/basal areas was converted to relative values and added to obtain importance values index (IVI). The phytosociological attributes of the studied vegetation were determined, including species diversity, evenness, leaf spectrum, life form, richness and maturity indexes [18]. The plants were submitted to the herbarium of the Department of Botany, University of AJK Muzaffarabad, and were identified with the help of flora and available literature. The flora was evaluated and categorized on the basis of invasiveness, endemism, history and mode of introduction with the help of published literature and e-floras. The phytogeography analysis of the flora was performed to classify the floral aemements on the basis of continental origion [19]. The invasive alien species were further classified into Invasive, casual, naturalized, casual naturalized and cultivated classes [20]. Results were statistically analyzed by PCA to extract the significant correlations from species data set. The statistical analysis was performed by using software package PAST version 3.20.

Results

Floristic Composition and Biological Spectra

A total of 121 plant species belonging to 58 families and 101 genera were recorded from the study area. The major contribution of local flora included Asteraceae 11 species with a weight age of 10% followed by Poaceae 10 species with a weight age of 8%. Rosaceae and Lamiaceae had 6 species with a weight age of 5%, and Euphorbiaceae were represented by 5 species with a weight age of 4%. Amaranthaceae, Cyperaceae, Papilionaceae, Pteridaceae and Verbenaceae had 4 species with a weight age of 3%. Brassicaceae, Polygonacaea and Moraceae were represented by 3 species with a weight age of 2%, whereas Meliaceae, Apocynaceae, Oleaceae, Malvaceae, Convolvulaceae, Solanaceae, Plantaginaceae, Salicaceae and Anacardiaceae were represented by 2 species with a weight age of 2% each. The remaining 36 families had single representative with a weight age of 30%. Herbs dominated the alien flora and were represented by 65 species, followed by shrubs (28 species), trees (21 species) and climbers (3 species), whereas 4 ferns were also recorded from the area. Therophytes were the dominant life form represented by 31 species with a weight age of 25.61%. Nanophanerophytes were represented by 28 species with a weight age of 23.14%. Megaphanerophytes life form was represented by 22 species (18.18%), followed by Hemicryptophytes with 19 species (15.71%). Geophytes were represented by 18 species (14.87%); Lianas were represented by 3 species (2.47%), whereas Chemophytes were represented by a single species. The dominant leaf size spectrum was microphyll, represented by 60 species with a weight age of 49.5%. Leptophylls were represented by 22 species (18.18%), followed by Nanophylls (21 species) and Mesophylls (18 species), respectively (Table 1).

Phytosociological Attributes

Phytosociological investigations revealed that the average species count at the sites was 43.7 with a maximum of 52 at site 5, whereas a minimum of 16 were found at sites 7 and 9 each. The study sites showed uniform values of Simpson's and Shannon-Wienner's diversity, averaging as 0.96 and 2.6, respectively attributed to the abundance of the common subtropical indicator species. The values of species richness showed significant variation ranging from 1.2 to 2.51 and correspeonding to the differential species count at different sites. The suburban vegetation communities revealed a very low value of maturity index with an average of mere 32.7%, and none of them qualifying as mature (Table 2).

Invasive Alien Flora

A total of 43 invasive alien plant species belonging to 25 families and 41 genera were recorded from the area. The dominnat IAS included *Parthenium hysterophorus* with an IVI of 11.77, followed by *Lantana camara* (10.59), *Xanthium strumarium* (9.92), *Ailanthus altissima* (8.59), *Cannabis sativa* (7.78), *Broussonetia papyrifera* (7.28), *Arundo donax* (6.05) and *Sorghum halepense* (3.11). The major families that contributed to the alien flora included Asteraceae, Poaceae, Amaranthaceae, Brassicaceae, Euphorbiaceae, Fabaceae, Moraceae, Polygonaceae, Plantaginaceae and Salicaceae. The results of IAS classification on the basis of invasion status revealed that invasive aliens were represented by 20 species with a weight of 46%, followed by naturalized aliens represented by 11 species (26%).

Table 1. Species composition, biological spectra and importance values of the suburban flora.

S/no	Botanical name	Family	Habit	Life form	Leaf spectra	IVI
1	*Acacia modesta* Wall.	Mimosaceae	Tree	Mp	Me	3.178
2	*Achyranthes aspera* L.	Amaranthaceae	Herb	H	Mi	0.74
4	*Adiantum caudatum* L.	Pteridaceae	Fern	G	N	0.36
3	*Adiantum venustum* D. Don.	Pteridaceae	Fern	G	N	0.72
6	*Ailanthus altissima* (Mill) Swingle	Simaroubaceae	Tree	Mp	Me	8.59
5	*Ajuga bracteosa* Var. alba (Gurke) Engl.	Lamiaceae	Herb	Th	Mi	2.03
7	*Alternanthera pungens* Kunth.	Amaranthaceae	Herb	H	N	1.33
8	*Amaranthus spinosus* L.	Amaranthaceae	Herb	Th	N	3.61
9	*Amaranthus viridis* L.	Amaranthaceae	Herb	Th	N	1.02
10	*Aristida cyanantha* Steud	Poaceae	Herb	G	L	2.4
11	*Artemisia scoparia* Waldst. & Kit	Asteraceae	Herb	H	N	1.29
12	*Arundo donax* L.	Poaceae	Herb	G	Mi	6.05
13	*Asparagus adscendens* Roxb.	Asparagaceae	Herb	H	L	0.68
14	*Avena sativa* L.	Poaceae	Herb	G	L	0.84
15	*Azadirachta indica* A.Juss	Meliaceae	Tree	Mp	Mi	0.39
16	*Bauhinia variegata* L.	Fabaceae	Tree	Mp	Me	0.53
17	*Berberis lycium* Royle	Berberidaceae	Shrub	Np	Mi	0.51
18	*Bidens pilosa* L.	Asteraceae	Herb	Th	Mi	6.68
19	*Bidens tripartita* L.	Asteraceae	Herb	Th	Mi	0.21
20	*Broussonetia papyrifera* (L.) L Her.ex Vent	Moraceae	Tree	Mp	Me	7.28
21	*Bupleurum falcatum* L.	Apiaceae	Herb	H	N	1.03
22	*Callicarpa macrophylla* Vahl	Verbenaceae	Shrub	Np	Me	1.61
23	*Calotropis gigantea* L.	Apocynaceae	Shrub	Np	Mi	0.43
24	*Cannabis sativa* L.	Cannabaceae	Herb	Th	Mi	7.78
25	*Capsella-bursa –pastoris* (L.) Medik.	Brassicaceae	Herb	Th	L	1.36
26	*Carissa opaca* Stapf ex Haines	Apocynaceae	Shrub	Np	Mi	3.33
27	*Celtis eriocarpa* Decne.	Ulmaceae	Tree	Mp	Mi	0.97
28	*Chenopodium album* L.	Chenopodiaceae	Herb	Th	Mi	3.75
29	*Cichorium intybus* L.	Asteraceae	Herb	H	Mi	0.76
30	*Cirsium ravens* (L.) Scop.	Asteraceae	Herb	H	Mi	0.89
31	*Commelina benghalensis* L.	Commelinaceae	Herb	Th	Mi	0.32
32	*Conyza bonariensis* (L.) Cronquist	Asteraceae	Herb	H	Mi	6.09
33	*Cotinus* coggyria L.	Anacardiaceae	Shrub	Np	Mi	4.06
34	*Cuscuta reflexa* Roxb.	Cuscutaceae	Climber	L	L	0.93
35	*Cynodon dactylon* L. Pers	Poaceae	Herb	G	L	9.56
36	*Cynoglossum lanceolatum* Forssk.	Boraginaceae	Herb	H	N	4.24
37	*Cyperus exaltatus* Retz.	Cyperaceae	Herb	G	L	1.59
38	*Cyperus rotundus* L.	Cyperaceae	Herb	G	L	3.4
39	*Dalbergia sissoo* DC.	Papilionaceae	Tree	Mp	Me	4.56
40	*Debregeasia salicifolia* (D Don) Rendle	Urticaceae	Shrub	Np	Mi	2.45
41	*Desmodium elegans* DC.	Leguminosae	Shrub	Np	Mi	0.63

Table 1. Contimued.

42	*Dichanthium annulatum* (Forssk.) Stapf.	Poaceae	Herb	G	L	2
43	*Diospyros lotus* L.	Ebenaceae	Tree	Mp	Me	0.42
44	*Dodonaea viscosa* (L.) Jacq.	Sapindaceae	Shrub	Np	Mi	10.47
45	*Duchesnea indica* (Jacks.) Focke.	Rosaceae	Herb	Th	Mi	1.32
46	*Echinochloa colona* (L.) Link	Poaceae	Herb	G	L	1.03
47	*Elaeagnus umbellata* Thunb.	Elaeagnaceae	Shrub	Np	Mi	1.32
48	*Eleocharis indica* (Lour) Druces	Cyperaceae	Herb	G	L	2.69
49	*Equisetum debile* Roxb.ex Vaucher	Equisetaceae	Herb	G	L	0.31
50	*Erioscirpus comosus* (Wall).	Cyperaceae	Herb	Th	L	0.55
51	*Nasturtium officinale* R. Br.	Brassicaceae	Herb	H	N	0.49
52	*Eucalyptus alba* Reinw. ex Blume	Myrtaceae	Tree	Mp	Mi	0.53
53	*Euphorbia helioscopia* L.	Euphorbiaceae	Herb	Th	Mi	0.51
54	*Euphorbia hirta* L.	Euphorbiaceae	Herb	Th	N	2.15
55	*Euphorbia prostrata* Aiton.	Euphorbiaceae	Herb	Th	N	3.96
56	*Ficus palmata* Forssk.	Moraceae	Tree	Mp	Me	2.56
57	*Grevillea robusta* A.Cunn.ex R.Br.	Proteaceae	Shrub	Mp	Mi	0.58
58	*Hibiscus rosa sinensis* L.	Malvaceae	Shrub	Np	Mi	0.85
59	*Indigofera heterantha* Brandis	Papilionaceae	Shrub	Np	L	1.41
60	*Ipomoaea lobata* L.	Convolvulaceae	Climber	L	Mi	0.44
61	*Ipomoea eriocarpa* R. Br.	Convolvulaceae	Climber	L	Mi	0.07
62	*Isodon rugosus* (Wall .ex Benth) Codd	Lamiaceae	Shrub	Np	Mi	0.35
63	*Jasminum officinale* L.	Oleaceae	Shrub	Np	Mi	0.43
64	*Juglans regia* L.	Juglandaceae	Tree	Mp	Me	0.63
65	*Justicia adhatoda* L	Acanthaceae	Shrub	Np	Mi	14.42
66	*Lantana camara* L.	Verbenaceae	Shrub	Np	Mi.	10.59
67	*Lepidium bidentatum* Montin.	Brassicaceae	Herb	H	**Mi**	0.72
68	*Mallotus philippensis* (Lam.) Mull.Arg.	Euphorbiaceae	Tree	Mp	Me	3.98
69	*Malvastrum corommandelianum* (L.) Gracke	Malvaceae	Herb	H	Mi	3.1
70	*Maytenus royleana* (Wall ex Lawson) Cufod.	Celasteraceae	Shrub	Np	N	1.88
71	*Medicago sativa* L.	Papilionaceae	Herb	H	N	0.55
72	*Melia azedarach* L.	Meliaceae	Tree	Mp	Me	3.94
73	*Mentha royleana* Benth.	Lamiaceae	Herb	Th	Mi	2.5
74	*Micromeria biflora* (Buch Ham ex DDon) Benth.	Lamiaceae	Herb	Th	L	1.1
75	*Mirabilis jalapa* L.	Nyctaginaceae	Herb	Th	Mi	0.68
76	*Morus alba* L.	Moraceae	Tree	Mp	Mi	1.74
77	*Myrsine africana* L	Myrsinaceae	Shrub	Np	N	1.05
78	*Nepeta erecta* (Royle ex Benth) Benth	Lamiaceae	Herb	H	Mi	3.02
79	*Oenothera rosea* L Her.exAiton	Onagraceae	Herb	Th	Mi	3.37
80	*Olea cuspidata* Wall. Don	Oleaceae	Tree	Mp	Mi	2.93
81	*Otostegia limbata* (Benth.)Boiss.	Lamiaceae	Shrub	Np	Mi	1.95
82	*Oxalis corniculata* L.	Oxalidaceae	Herb	Th	N	5.98
83	*Parthenium hysterophorus* L.	Asteraceae	Herb	Th	Mi	11.77

Table 1. Contimued.

84	*Pennisetum unisetum* (Nees) Benth.	Poaceae	Herb	G	L	1.09
85	*Persicaria barbata* (L.) H.Hara	Polygonaceae	Herb	Th	Mi	3.03
86	*Phlomis tuberosa* L.	Lamiaceae	Herb	Th	N	0.94
87	*Phyllanthus fraternus* G.L Webster.	Phyllanthaceae	Herb	Th	N	1.71
88	*Pinus roxburghii* Sarg.	Pinaceae	Tree	Mp	L	0.86
89	*Pistacia integerimma* J.L Stewart ex Brandis.	Anacardiaceae	Tree	Mp	Me	0.4
90	*Plantago lanceolata* L.	Plantaginaceae	Herb	H	Mi	0.3
91	*Plantago major* L.	Plantaginaceae	Herb	H	Mi	0.36
92	*Populus alba* L.	Salicaceae	Tree	Mp	Mi	2.57
93	*Prunus persica* (L.) Batsch	Rosaceae	Tree	Mp	Mi	0.2
94	*Pteris cretica* L.	Pteridaceae	Fern	G	Me	2.03
95	*Pteris vittata* L.	Pteridaceae	Fern	G	Me	0.21
96	*Punica granatum* L.	Punicaceae	Shrub	Np	Mi	5.96
97	*Pyrus pashia* Buch.Hem.ex D.Don.	Rosaceae	Tree	Mp	Mi	1.08
98	*Ricinus communis* L.	Euphorbiaceae	Shrub	Np	Me	3.27
99	*Rosa macrophylla* Lindl.	Rosaceae	Shrub	Np	Mi	1.75
100	*Rubus ellipticus* Sm.	Rosaceae	Shrub	Np	Mi	1.38
101	*Rubus fruticosus* G.N Jones.	Rosaceae	Shrub	Np	Mi	4.51
102	*Rumex hastatus* D.Don.	Polygonaceae	Shrub	Np	L	0.76
103	*Rumex nepalensis* Spreng.	Polygonaceae	Herb	Th	Me	1.54
104	*Saccharum spontaneum* L.	Poaceae	Herb	G	N	3.94
105	*Salix alba* L.	Salicaceae	Tree	Mp	Mi	0.92
106	*Setaria pumila* (Poir.) Roem & Schult.	Poaceae	Herb	G	L	2.11
107	*Solanum nigrum* L.	Solanaceae	Herb	Th	Mi	1.07
108	*Solanum surattense* Burm	Solanaceae	Herb	Th	Mi	0.19
109	*Sonchus asper* (L.) Hill.	Asteraceae	Herb	Th	Mi	2.01
110	*Sorghum halepense* (L.) Pers.	Poaceae	Herb	G	L	3.11
111	*Stellaria media* (L.) Vill.	Caryophyllaceae	Herb	Th	N	1.12
112	*Tagetes minuta* L.	Asteraceae	Herb	Th	Lp	2.74
113	*Taraxacum officinale* (L.) Weber ex FH Wigg.	Asteraceae	Herb	Th	Mi	2.69
114	*Trifolium repens* L.	Papilionaceae	Herb	H	N	0.55
115	*Verbascum thapsus* L.	Scrophulariaceae	Herb	Th	Me	2.36
116	*Verbena tenuisecta* Briq.	Verbenaceae	Herb	Ch	Lp	3.62
117	*Vitex negundo* L.	Verbenaceae	Herb	Np	N	1.32
118	*Woodfordia fruticosa* (L.) Kurz	Lythraceae	Shrub	Np	Mi	2.59
119	*Xanthium strumarium* L.	Asteraceae	Herb	H	Me	9.92
120	*Zanthoxylum armatum* DC	Rutaceae	Shrub	Np	Mi	2.95
121	*Ziziphus jujuba* Mill.	Rhamnaceae	Shrub	Np	Mi	2.05

Key:
Life Form:
Mp = Megaphanerophytes; Np = Nanophanerophytes; H = Hemiryptophytes; C= Cryptophytes; Th = Therophytes; Ch = Chameophytes; G = Geophytes
Leaf Spectra:
Mi = Mirophyll; Me = Meophyll; N = Nanophyll; L = Leptophyll

Table 2. Invasion status and Phytogeographic origin of alien flora from Muzaffarabad

Sr. no	Species name	Family	Invasion status	Origin	Reference
1	Achyranthes aspera	Amaranthaceae	Cn	NAM	Kaul, (1986); Khuroo et al., 2007
2	*Ailanthus altissima*	Simaroubaceae	In	AS	Ara et al., (1995)
3	*Amaranthus spinosus*	Amaranthaceae	In	SAM	Stewart, (1972); Khuroo et al., 2010
4	Artemisia scoparia	Asteraceae	Nt	AS,EU	Kaul, (1986); Khuroo et al., 2007
5	*Arundo donax*	Poaceae	Cs	AF;EU	Stewart, (1972)
6	Bidens tripartita	Asteraceae	Cn	AF;EU	Kaul, (1986); Khuroo et al., 2010
7	*Broussonetia papyrifera*	Moraceae	In	AS	Stewart, (1972)
8	*Cannabis sativa*	Cannabaceae	In	AS	Kaul, (1986)
9	*Capsella bursa-pastoris*	Brassicaceae	In	EU	Kaul, (1986); Khuroo et al., 2007
10	Chenopodium album	Chenopodiaceae	In	EU	Kaul, (1986)
11	*Cichorium intybus*	Asteraceae	In	EU	Kaul, (1986) ; Khuroo et al., 2010
12	*Cirsium arvense*	Asteraceae	In	AS	Stewart, (1972
13	*Conyza bonariensis*	Asteraceae	Cs	SAM	Kaul, (1986) ; Khuroo et al., 2010
14	*Cyperus rotundus*.	Cyperaceae	In	EU	Kaul, (1986); Khuroo et al., 2007
15	*Elaeagnus umbellata*.	Elaeagnaceae	Nt	AS	Singh and Kachroo, (1976)
16	Euphorbia helioscopia	Euphorbiaceae	In	AS; EU	Kaul, (1986)
17	*Hibiscus rosa-sinensis*	Malvaceae	Nt	AS	Naqshi et al., (1988)
18	*Ipomoea eriocarpa*	Convolvulaceae	Cn	AS;AU	Kaul, (1986); Khuroo et al., 2010
19	*Lantana camara*.	Verbenaceaec	Cs	SAM	Stewart, (1972)
20	*Medicago sativa*	Fabaceae	Nt	AF;EU	Dar et al., (2002)
21	*Melia azedarach*	Meliaceae	Cl	AS	Ara et al., (1995)
22	*Mirabilis jalapa*.	Nyctaginaceae	Cs	SAM	Stewart, (1972)
23	*Morus alba*	Moraceae	Nt	AS	Dar et al., (2002)
24	*Nasturtium officinale*.	Brassicaceae	Nt	EU	Kaul, (1986)
25	*Oenothera rosea*	Onagraceae	In	SAM	Kaul, (1986); Khuroo et al., 2007
26	*Oxalis corniculata*	Oxalidaceae	Nt	AS;EU	Kaul, (1986); Khuroo et al., 2010
27	*Parthenium hysterophorus*	Asteraceae	Cs	SAM	Yaqoob et al., (1988)
28	*Plantago lanceolata*.	Plantaginaceae	In	AF;EU	Kaul, (1986); Khuroo et al., 2010
29	*Plantago major*	Plantaginaceae	In	EU	Kaul, (1986); Khuroo et al., 2007
30	Populus alba	Salicaceae	Nt	EU	Javeid, (1972); Khuroo et al., 2010
31	*Prunus persica*	Rosaceae	Cl	AS	Dar et al., (2002)
32	*Ricinus communis*.	Euphorbiaceae	Cs	AF	Stewart, (1972); Khuroo et al., 2007
33	*Rumex hastatus*	Polygonaceae	In	AS	Reshi, (1984); Khuroo et al., 2010
34	Rumex nepalensis	Polygonaceae	Nt	AF; EU	Munshi and Javied,(1986)
35	*Salix alba*	Salicaceae	Nt	AS; AF; EU	Javeid, (1972); Khuroo et al., 2007
36	Setaria pumila	Poaceae	Cn	AS;AF	Stewart, (1972)
37	*Sorghum halepense*.	Poaceae	In	EU	Kaul, (1986) ; Khuroo et al., 2010
38	*Stellaria media*.	Caryophyllacaeae	In	EU	Kaul, (1986) ; Khuroo et al., 2010
39	*Tagetes minuta*	Asteraceae	Nt	SAM	Singh and Kachroo, (1994)

Table 2. Continued.

40	*Taraxacum officinale*	Asteraceae	In	EU	Kaul, (1986)
41	*Trifolium repens*	Fabaceae	In	EU	Kaul, (1986); Khuroo et al., 2007
42	Verbascum thapsus	Scrophulariaceae	In	EU	Kaul, (1986) ; Khuroo et al., 2010
43	*Xanthium strumarium*.	Asteraceae	In	AF	Kaul, (1986); Khuroo et al., 2007

Key
Origin: NAM: North America; SAM: South America; AF: Africa; EU: Europe; AU: Australia;
AS: Asia (Excluding the sub-continent).
Invasion status: Invasive aliens; Cl: Cultivated un-escaped aliens; Cs: Casual aliens; Cn: Casual or naturalized aliens;
Nt: Naturalized aliens; In:
(Categories used following Richardson et al., 2000; and Pysek et al., 2004).

Casual aliens were represented by 6 (14%), whereas casual naturalized were represented by 4 species (9%). Cultivated un-escaped aliens were represented by 2 species (5%) (Table 3).

Discussion

Plant invasions are visibly a strong force of change, operating on a global scale and affecting many dimensions of society correlated with the increased trade and provision of ecosystem service. The present study was conducted to investigate the diversity and distribution of the invasive alien species and their potential impacts on vegetation of Muzaffarabad.

Mode of Introduction of IAS in the Area

The analysis of the invasion history and mode of investigation revealed that *Lantana camara, Mirabilis jalapa* and *Ipomea eriocarpa* have been introduced from different regions for use as ornamental plants [13, 21]. *Rumex hastatus* and *Artemisia scoparia* are reported to have been introduced for medicinal purposes [22]. *Ailanthus altissima, Elaeagnus umbellata, Melia azedarach*, *Broussonetia papyrifera, Populus alba* and *Salix alba* are among the plants that have been introduced for plantation and revegetation of the barren land due to their high growth rates. *Prunus persica* and *Morus alba* have been introduced for horticulture due to their edible fruits. *Chenopodium album, Ricinus communis* and *Rumex nepalensis* plants have been introduced for food purposes and are used as vegetables [13, 23, 24]. *Medicago sativa, Trifolium repens*, *Setaria pumila* and *Sorghum halepense* have been introduced for utilization as fodder [25]. *Hibiscus rosa-sinensis* has been introduced for landscaping due to its aesthetic beauty. The highest number of the invasive alien plants was recorded to be introduced unintentionally. *Amaranthus spinosus, Achyranthes aspera, Cichorium*

Table 3. Quantitative phytosociological attributes of the investigated vegetation communities

Site	Name	Latitude Longitude	Altitude (m)	No of species	No of IAS	Simpsons diversity	Shannon diversity	Richness	Evenness	Maturity index
1	Langarpora	34.19.035 N 73.31.784 E	731	43	17	0.96	2.57	1.62	0.68	30.69
2	Garidupata	34.15.867 N 73.34.650 E	1199	50	21	0.98	2.81	2.11	0.71	27.4
3	Ambor	34.19.214 N 73.28.483 E	646	48	23	0.97	2.40	2.37	0.62	26.1
4	Dulai	34.18.279 N 73.28.890 E	659	43	18	0.97	2.76	2.36	0.73	27.23
5	Naluchee	34.21.005 N 73.27.669 E	728	52	20	0.96	2.78	2.10	0.68	38.46
6	Shawai	34.23.090 N 73.27.539 E	731	52	19	0.97	2.78	2.04	0.70	36.53
7	Subri	34.19.554 N 73.30.635 E	732	37	16	0.96	2.19	1.61	0.71	33.78
8	Subri	34.22.561 N 73.29.769 E	740	22	7	0.91	2.63	1.20	0.70	41.81
9	Majoi	34.15.579 N 73.39.079 E	751	47	16	0.97	2.61	2.51	0.92	31.91

intybus, *Cirsium arvense*, *Conyza bonariensis, Parthenium hysterophorus, Tagetes minuta, Taraxacum officinale, Xanthium strumarium, Capsella bursa-pastoris, Cannabis sativa, Cyperus rotundus, Euphorbia helioscopia, Oenothera rosea, Oxalis corniculata, Plantago lanceolata, Plantago major, Arundo donax, Verbascum Thapsus, Stellaria media, Bidens tripartite* and *Nasturtium officinale* are species reported to have been introduced unintentionally [13, 26-29]. The introduction of invasive aliens without any well-known purpose unintentionally in a non-native range has also been emphasized [30, 31].

Phytogeographic Origion of Local Floral Elements

On the basis of the origin of the IAS species, a total of 5 different geographical regions were identified in the present study. 39% of the IAS species were revealed to have their origion from Europe, followed by Asia contributing 29% of species. The IAS of African orgion were 16%, followed by South American elements (14%), whereas 2 % of species had North American origins [32, 33].

Principal component analysis revealed the speceies distribution pattern in correlation with the specific sites in the study area. The primary vegetation data was verified by the species spread along the PCA biplot axis, showing the segregation of the dominant IAS including *Parthenium hysterophorus, Lantana camara, Xanthium strumarium, Ailanthus aItissima, Cannabis sativa* and *Broussonetia papyrifera* indicating their over all dominance at all the study sites. *Arundo donax* showed close affinity with Site 7, showing its habitat specificity due to landslide disturbance with low organic matter, and increased solar insolation at the western aspect (Fig. 2).

Disturbance is among the key factors responsible for the spread and dominance of IAS [34, 35]. The disturbance patch invasion model supports our hypothesis that dsiturbances favour invasion by modifying the microclimate and disrupting inter-specific competitive interactions [36, 37]. Landslides and road construction were identified as factors promoting the establishment and spread of invasive species in any area. Results show the dominance of IAS like *Arundo donax, Xanthium strumarium* and *Sorghum halepense* at landslide and road-cutting disturbed sites [38]. The results of the present study are also in conformity with the experimental model of decreasing diversity levels with increasing invasive cover, which is evident from the *Lantana camara*-doiminated comuntities having relatively lower species diversity [39, 40]. However, the values of species evenness were high at the disturbed sites as landslides break canopy dominance, allowing the invasive aliens species to grow rapidly.

The climatic and edaphic similarities between the original and new habitats are very important factors for establishing alien species [41]. A humid subtropical type of climate in lower elevations of the study area with highly leached soils are alike to Latin American home of species such as *Lantana camara* and *Parthenium hysterophorus*, enabling them to invade and abundantly colonize suburban vegetation of Muzaffarabad [42].

Potential Impacts of the Dominant IAS in the Area

Parthenium hysterophorus was present thoughout the investigated communities with an outstanding ability to change the vegetative structure in a wide range of habitats because of its efficient biological activity, allelloppathic effects and adaptability to varying microenvironments [14, 43]. Regular contact with the plant over a prolonged

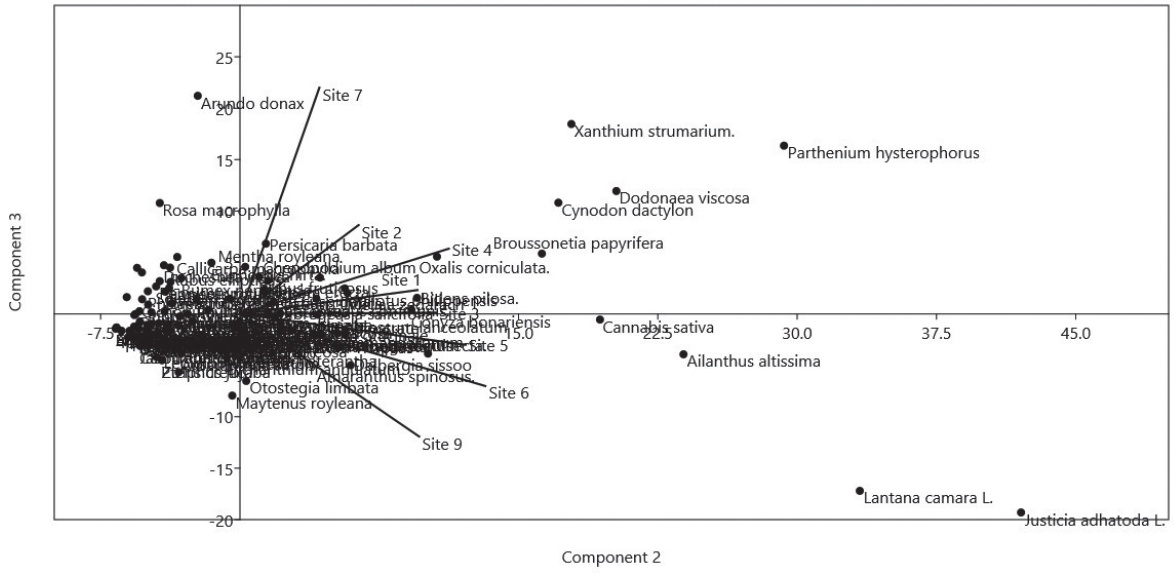

Fig 2. Principal Component Analysis Biplot oft he species data matrix.

period is reported to produce allergenic asthma and dermatitis in humans. *Lantana camara,* a perennial shrub, was the second most abundant invasive attributed to the production of large number of seeds synchronized with an efficient dispersal mechanism facilitated by a variety of pollinators [33, 34]. *Xanthium strumarium* is a heat-loving and drought-resistant invasive plant reported from the area that prefers disturbed sites with open canopies with exposed soil surface. Exposue to this rough-textured plant with irritating surface hair causes itching and can lead to dermatitis and weeping eczema [45]. *Ailanthus aItissima* and *Melia azedarach* were the abundantly distuributed deciduous invasive trees in the study area posing a serious threat to the native flora. These plants are highly competitive due to the secretion of allolopathic chemicals and altering the nutrient availability, thus inhibiting the growth of native plants [11, 44]. *Melia azedarach* saplings also serve as a host for the ambrosia beetle (*Xylosandrus mutilates*), an insect that negatively impacts forest ecosystems. *Arundo donax* is a tall perennial shrub recorded from the disturbed sites that significantly modifies hydrological regimes and decreasing groundwater availability by transpiring large amounts of water, consuming three times the water of native plants. *Arundo donax* is also an extremely flammable plant, which increases the risk of accidental fires in suburban areas and poses a serious threat to people and property [14, 22]. *Cichorium intybus* is a perennial palatable herb recorded from the disturbed stands that prefereably inhabit wasteland, roadsides and sometimes cultivated land, and can survive dry, infertile conditions. Dairy products from *Cichorium* consuming livestock taste pungent, whereas its milky latex may cause dermatitis in humans. *Cirsium arvense* is another herbaceous perennial plant that produces allelopathic chemicals and displaces competing plant species [21, 32]. The spiny leaves are scratch and irritate, and are also highly flammable. Along with being a host for several parasites such as stalk borer, bean aphid and sod-web worm, *Cirsium arvense* is reported to collect nitrates, causing poisoning in livestock [43].

The spread of invasive alien species in the area is expected to further change the native community composition, reduce species diversity, retard ecosystem process, and cause ecological imbalance in the fragile Himalayan vegetation types [47, 48]. The spread of IAS in the urban area needs to be controlled by the application of integrated approaches involving urban landscape planning with the help of land cover maps, remote sensing tools and ecological modelling [49]. Immediate attention also needs to be given to the potential impacts of climate change on local climates and hydrology, paving the way for the introduction and spread of IAS in the area [50, 51].

Results emphasize the need for better management for early detection and reporting of invasive aliens. It is recommended to develop an integrated IAS detection network by establishing communication links between taxonomists, ecologists and land managers.

Conflict of Interest

The authors have not declared any conflict of interest.

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