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Plant communities and alien invasion in Kalika community forest, Kailai district, Sudurpashchim Province, Nepal

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Abstract

One of the major threats to native biological diversity is caused by invasive alien plant species (IAPS). As the documentation of plant communities and alien plant invasion in Far-west Nepal is very scarce, this study was carried out in the Kalika community forest of Kailali district, Sudurpaschim Province, Nepal. The aim of the study was to identify plant communities and the status of IAPS in the forest. A total of 43 plots (size 10 m × 10 m) were sampled. Plant communities were distinguished based on the Sorenson similarity index and cluster dendrogram. Cover of the tree canopy and IAPS was measured. A total of 101 species of vascular plants were recorded from five types of plant communities in the forest. The communities were named as (i) Buchanania latifolia-Terminalia alata community (ii) Casearia glomerata-Mallotus philippensis community (iii) Shorea robusta-Terminalia alata community (iv) Adina cordifolia-Mallotus philippensis community (v) Terminalia-Shorea-Trewia mixed community. These communities were invaded by invasive Ageratum houstonianum, A. conyzoides, Bidens pilosa, Cassia tora, and Argemone mexicana. A high cover of IAPS was found in Terminalia-Shorea-Trewia mixed community. The cover of IAPS was low under the high tree canopy. Control and management of IAPS should be done to protect the native plant communities in the forest for reducing disturbance to maintain tree canopies. It is hoped to be an effective method to reduce alien plant invasions.

Keywords: Plant invasion, native plants, IAPS, tree canopy, community forestry

Introduction

Plant communities differing in the identity of dominant or associated species in forest ecosystems may occur in the same landscape and share common environmental requirements (Whittaker 1965). Each community has its unique structure, function, diversity, and species composition. Identification and characterization of such communities highlighting potential threats are important tasks for ecologists, environmentalists and managers (Khan *et al.* 2016). Such studies provide useful habitat information of many plant and animal species and contribute to conserve and manage unique habitats and biodiversity in forest ecosystems.

Community forestry has become one of the successful participatory approaches for protection and management of forests in Nepal (Gurung *et al.* 2013, Ghimire & Lamichhane 2020). Also, community forestry has played a significant role in the promotion and conservation of biological diversity (Gautam 2009). Despite the success of community-based management, studies on identification of plant communities within forest and potential threats of alien plant invasions are meagre.

Thousands of alien species are known to establish around the world and the increased incidences of invasion poses a major threat to native biological diversity (Dogra *et al.* 2009). The invasive alien plant species (IAPS) are capable to change native species diversity, composition, growth and development, and alter soil qualities (Richardson & Van Wilgen 2004, Vilà *et al.* 2011, Tererai *et al.* 2013, Darji *et al.* 2021). In Nepal, more than two dozen of species are recognized as the problematic IAPS (Shrestha & Shrestha 2021) and some of them (*Lantana camara, Mikania micrantha, Chromolaena odorata* and *Eichhornia crassipes*) are among the 100 world's worst invasive alien species (Lowe et al., 2000).

In comparison to other parts of Nepal (for example, Pandey *et al.* 2016, Joshi *et al.* 2019, Thapa *et al.* 2016a, 2016b), the Far-west region is relatively less explored for vegetation, plant communities, and biological invasion. This study aims to identify plant communities in the Kalika community forest located near the east-west highway of Kailali District, Sudurpaschim Province, Nepal. The study also highlights the status of alien plant invasion in these communities, and the relationship between tree canopy and IAPS cover. This study has sought answers of the following research questions (i) what are the plant communities in the forest? (ii) what is the status of alien plant invasion in the forest? (iii) does tree canopy limit the invasion of alien species?

Methods and materials

Study site

The present study was conducted in the Kalika community forest of Gauriganga Municipality, Kailali District, Sudurpashchim Province, Nepal (Figure 1). The forest is located in 28°45.079' N and 80°46.918' E. The elevation of the study site ranges from 170 to 196 masl. The area of the forest is 150 ha and managed by community forest user groups of the Rajipur and Khurkhuriya villages of the municipality. The forest lies near the human settlement towards northern side of East-west highway which is a source of fire wood, timber, fodder, wild vegetables and fruits for the community people.

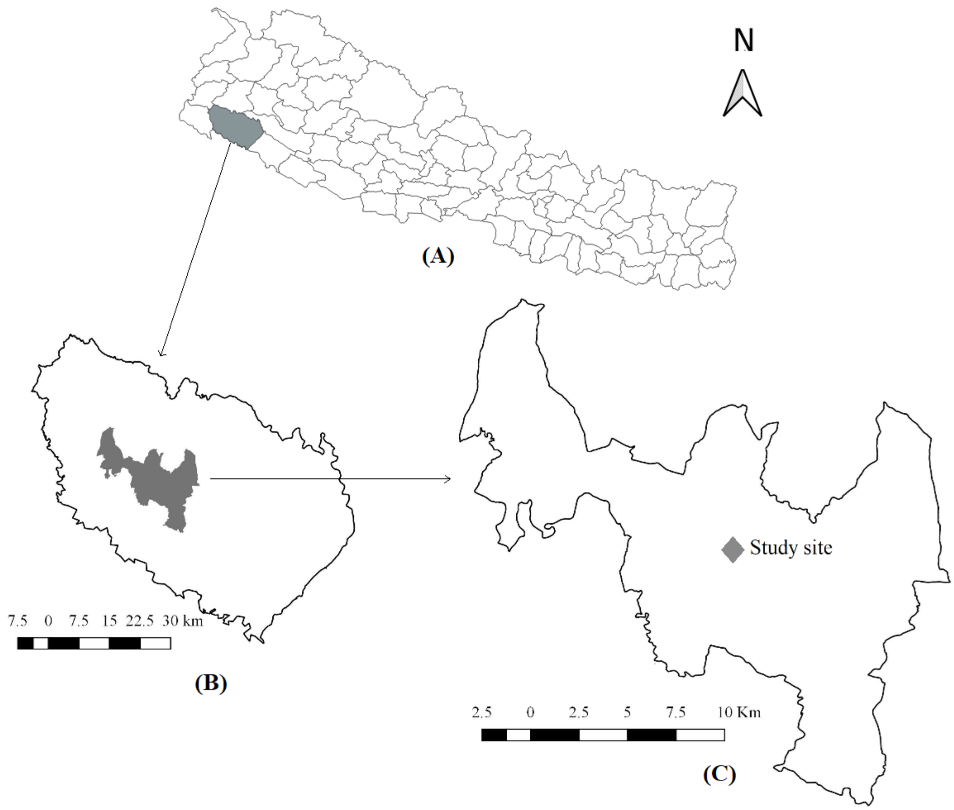

Figure 1: Map of study site (A) Nepal (B) Kailali District (C) Gauriganga Municipality

Field survey and plot sampling

Field survey was carried out in August 2017. A total of five horizontal transects were made in the community forest at an interval of 100 m. Plots of size 10 m × 10 m were sampled along each transect. The number of plots in each transect varied from 8 to10. A total, 43 plots were sampled. Cover of tree canopy and IAPS in each plot was estimated as percentage cover by visual estimation (1%, 2%, 5% and increments up to 100%). The plants encountered in each plot were reported and identified in the field and with the help of standard literature and expert knowledge. The specimens are deposited at the Tribhuvan University Central Herbarium (TUCH), Central Department of Botany, Tribhuvan University, Kathmandu, Nepal.

Statistical analysis

Plant communities were identified based on the similarity among the communities. Sorensen similarity coefficient was calculated between the study plots following Kent and Cocker (1992). Sorenson similarity index and cluster dendrogram were generated for distinguishing plant communities. The relationship between tree canopy cover and IAPS cover was analyzed by simple linear regression. The analyses were performed using the SPSS (version 20).

Results and discussion

Plant species richness

A total of 101 species of the vascular plants were recorded in the study site belonging to 76 Genera and 48 Families (Table 1). Among them 54 species were herbs, 33 species trees, 13 species shrubs, and 1 species was climber. Among the families, Fabaceae was the richest family having 10 species followed by Asteraceae and Poaceae (6 species each); Moraceae and Euphorbiaceae (5 species each); Anacardiaceae, Combretaceae, Malvaceae and Rubiaceae (4 species each). The families Lamiaceae, Moraceae, Myrtaceae and Rutaceae had three species each and Apocynaceae, Araceae, Asparagaceae, Cyperaceae, Lythraceae and Ophioglossaceae (fern) were represented by two species each. Rest, 28 families were represented by only one species each (Table 1). Five of the species (*Ageratum conyzoides, A. houstonianum*, *Argemone mexicana, Bidens pilosa* and *Senna tora*) were the IAPS in the forest.

Among the vascular plants, >50% of species were herbaceous plants and 13 species were shrubs. The herbaceous and shrub plants forming understory layers are crucial component of the functional diversity in the forest (Perea *et al.* 2022). The families Fabaceae, Poaceae, Asteraceae, and Euphorbiaceae have a greater number of species. These are the families having mostly herbaceous species. Similarly, most of the other families were also represented by herbaceous species (Table 1). In terms of biomass, the herbaceous species contribute negligible but their foliar litter contribution to the forest floor is significant (Gilliam 2007).

Table 1: List of the plant families with the number of species

S.N.	Families	No. of species	S.N.	Families	No. of species
1	Fabaceae	10	25	Cannnabaceae	1
2	Asteraceae	6	26	Dioscoreaceae	1
3	Poaceae	6	27	Dipterocarpaceae	1
4	Euphorbiaceae	5	28	Dryopterideaceae	1
5	Moraceae	5	29	Hypoxidaceae	1
6	Anacardiaceae	4	30	Leaceae	1
7	Combretaceae	4	31	Lecythidaceae	1
8	Malvaceae	4	32	Lygodeaceae	1
9	Rubiaceae	4	33	Meliaceae	1
10	Lamiaceae	3	34	Orchidaceae	1
11	Moreceae	3	35	Oxalidaceae	1
12	Myritaceae	3	36	Papaveraceae	1
13	Rutaceae	3	37	Phylianthaceae	1
14	Apocynaceae	2	38	Piperaceae	1
15	Araceae	2	39	Polygonaceae	1
16	Asparagaceae	2	40	Primuleraceae	1
17	Cyperaceae	2	41	Pteridaceae	1
18	Lythraceae	2	42	Ranunculaceae	1
19	Ophioglossaceae	2	43	Rhamaceae	1
20	Amaranthaceae	1	44	Salicaceae	1
21	Arecaceae	1	45	Sapotaceae	1
22	Asclepiadaceae	1	46	Urticeaceae	1
23	Bombaceae	1	47	Verbenaceae	1
24	Burseraceae	1	48	Vitaceae	1

Plant communities

Distribution of plant communities is determined together by soil moisture, soil nutrients, rainfall, past disturbances, mass effects, etc. (Bengtsson *et al.* 1994, Roem & Berendse 2000, Carney & Matson 2005). Despite the small area of the Kalika community forest (150 ha), cluster analysis and Sorensen similarity matrix distinguished five types of plant communities in the forest (Figure 2).

Buchanania latifolia-Terminalia alata community (C-1)

A total of five plots (plot no. 1-5) were included in the community characterized by the presence of *B. latifolia* and *T. alata* species (Figure 2). This community is situated at a slightly higher altitude (179-196 m asl). A total of 48 plant species were reported from this community. Common tree species in the community were *Madhuca longifolia,* *Shorea robusta, T. alata*, *Casearia glomerata. Woodfordia fruticosa, Xeromphis spinosa,* and *Phoenix humilis* were the major shrubs and herbaceous plants like *Dioscorea* sp*.,* *Imperata cylindrica, Desmodium multiflorum* were dominant in that community.

Casearia glomerata-Mallotus philippensis community (C-2)

A total of six plots (plot no. 18-23) were included in this community where two species, *C. glomerata* and *M. philippensis,* were dominant tree species (Figure 2). This community is situated at 175-194 masl. A total of 57 plant species were reported from this community. Other tree species associated in this community were *M. longifolia, S. robusta* and *T. alata*. *Murraya koenigii* was the major shrubs. The common herbaceous species were *Dioscorea bulbifera* and *Cyperus rotundus* in this community.

Shorea robusta-Terminalia alata community (C-3)

This community includes a total of twelve plots (plot no. 33-44) (Figure 2). The tree species *S. robusta* and *T. alata*, were the most frequent species in this community along the elevation 176-186 m asl. Number of plant species in the community is high (63 species) comparing to other communities. Plot number 33 to 38 (Figure 2) were characterized by frequent presence of *Mallotus philippensis* and *Lea crispa* with associated shrubs and herbs like *Clerodendrum viscocum, Dioscorea* spp*., Urena lobata, Cyperus* sp. The understory vegetation in plots 39-44 (Fig. 2) was represented by *C. glomerata, Lagerstroemia parviflora* and *Semecarpus anacardium. Chrysopogon aciculatus I. cylindrica, Ardisia solanacea, Senna tora* etc.

Adina cordifolia-Mallotus philippensis community (C-4)

In this community (plot no. 24-32), *A. cordifolia* and *M. philippensis* were the most frequent tree species (Fig. 2). This community lies at 175-196 m asl. A total of 58 plant species were reported in that community. The tree species *S. anacardium, T. alata, L. parviflora* and the shrub *L. crispa* were associated with *A. cordifolia* and *M. philippensis*. The ground cover was represented by *U. lobata, C. aciculatus* and *D. bulbifera*.

Terminalia-Shorea-Trewia community (C-5)

The cluster analysis grouped the plots 6-17 in one cluster (Figure 2). The plots were characterized by presence of tree species *T. alata, S. robusta* and *Trewia nudiflora* frequently. These plots were distributed at the elevation 175-190 m asl. A total of 57 plant species were found in this community. Among them, *Ageratum haustonianum, S. tora*. *Elephantopus scaber, D. bulbifera, C. rotundus, I. cylindrica* were the major herbaceous plants.

Cluster analysis showed that the plant species composition among the communities was different. Five distinct clusters indicate diverse plant communities even within small forest area. The plots showing similarity among themselves suggest similar floristic patterns. It indicates that the forest has habitats for varied plant species and each community has been characterized by the unique composition of plant species. Types of the frequent trees and associated shrubs and herbs have important role to shape the distinct plant communities.

Shorea robusta-Terminalia alata community was the richest community in terms of number of species. This community has supported many shrubs and herbaceous species. It shows the coexistence of diverse plant species within the canopy of *S. robusta* and *T. alata.* It may be due to the contribution of litter from both the trees as the litter contributes to soil formation and nutrient dynamics (Koorem *et al.* 2011). Some of the herbaceous species such as *Dioscorea* spp. and *I. cylindrica* showed their presence in all the communities indicating that they share a wide range of habitats and association with other species.

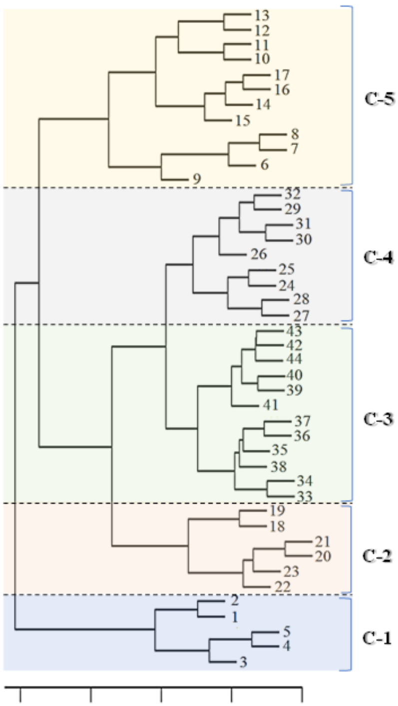

Figure 2: Dendrogram showing plant communities (C-1 to C-5 represent the plant communities in the Kalika community forest, Kailali)

Invasive alien plant species (IAPS)

Five species of IAPS (*A. houstonianum*, *A. conyzoides*, *Argemone mexicana, B. pilosa* and *S. tora*) were found in the community forest. Among them, *A. houstonianum*, *A. conyzoides* and *B. pilosa* belong to the family Asteraceae. *S. tora* belongs to the family Fabaceae and *Argemone mexicana* to Papaveraceae. *Terminalia-Shorea-Trewia* mixed community (C-5) were invaded by the IAPS showing the cover 5 to 55% (Figure 3). Few plots of *Casearia glomerata*-*Mallotus philippensis* (C-2) and *Shorea robusta-Terminalia alata* community (C-3) also had high IAPS cover i.e., >30%. Comparatively, the community *Buchanania latifolia*-*Terminalia alata* community (C-1) and *Adina cordifolia-Mallotus philippensis* community (C-4) showed low cover percent of IAPS (<28%) (Figure 3).

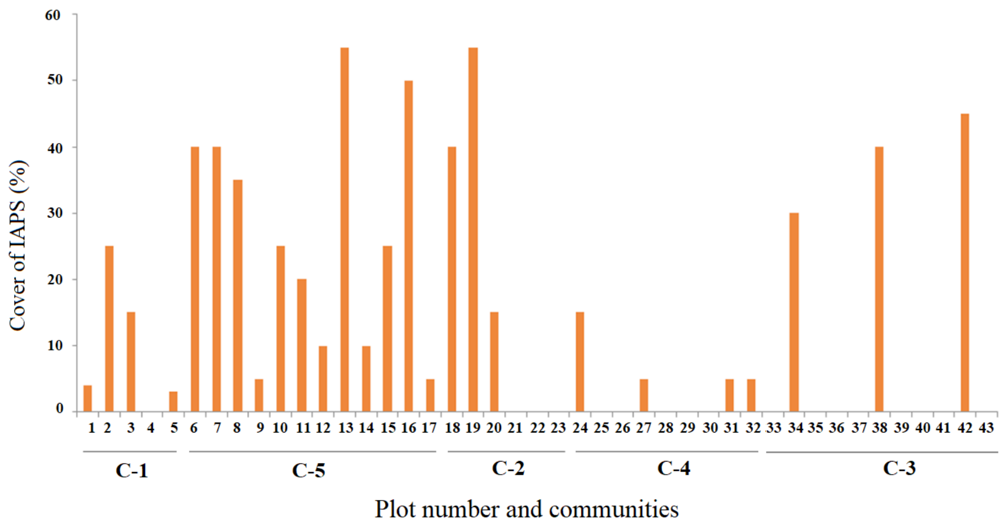

Figure 3: Cover of IAPS in plant communities of Kalika community forest, Kailali

The community forest is the main source of wild edible plants, fodders, medicines, firewood, etc. for the community people. It is always crucial to study the status of the forests and potential threats to the forest including IAPS invasion. The results indicate that the IAPS invasion in the community forest may create severe problems in future. Almost all the plots of *Terminalia-Shorea-Trewia* mixed community were invaded by *A. houstonianum*, *A. conyzoides, S. tora* and *A. mexicana*. As this community was nearer to the human settlement, the invasion might have occurred due to anthropogenic activities (Larson *et al.* 2001).

Ageratum houstonianum and *S. tora* were observed as the major invasive species invading the plant communities of the forest comparing to other IAPS reported. Thapa *et al.* (2015) also have reported that these two species and *A. conyzoides* were highly problematic species in the far-west region of Nepal. Three of the most problematic invasive species (*Ageratina adenophora, Chromolaena odorata* and *Mikania micrantha) in Central Nepal* (Thapa *et al.* 2016a, 2016b, Thapa *et al.* 2017, Shrestha *et al.* 2019; Thapa *et al.* 2020, Pathak *et al.* 2021) *have not reached to the Kalika community forest yet.*

According to the local people, *A. houstonianum* was confined to the agro-ecosystems for a long time, but from the last 8-10 years, the species has invaded forest ecosystems even under tree canopies. Previous studies have reported that *A. houstonianum* is poisonous to livestock (Shrestha *et al.* 2019, Bhatta *et al.* 2022). The community people of the current study site have also reported the livestock poisoning of this species. Also, both the species of the genus *Ageratum* (*A. conyzoides* and *A. houstonianum*) have negative impacts on crop plants through allelopathy (Pertin *et al.* 2018). Hence, it can be expected that they may harm native wild species in the forest. Additionally, the invasion of these IAPS from agricultural fields to forest ecosystems is a matter of concern.

The species *S. tora* usually invades roadsides, fallow lands, and forest margins. In the Kalika community forest, it was found growing abundantly in open canopy areas forming thickets inside the forest. Similar to *A. houstonianum, S. tora* is not consumable by livestock but the plant is reported as harmful to other species due to its allelopathic effect (Mushtaq *et al.* 2019). Therefore, potential impacts of these IAPS on native herbs and seedling recruitments of native shrub and tree species in the community forest should be evaluated and their invasions should be monitored.

Relationship between tree canopy and IAPS cover

Simple linear regression shows that the cover of IAPS gets reduced on increasing tree canopy (Figure 4, $P<0.001$). IAPS were absent where the tree canopies were above 80% and the plots having tree canopy cover <40% had the IAPS cover *≥40%* (Figure 4).

High tree canopy cover lowers the availability of light on the ground surface which is less favorable for the growth and reproduction of most of the IAPS (Yates *et al.* 2004). It suggests that the tree canopies should be maintained to reduce invasions (Thapa *et al.* 2016a). On increasing the IAPS cover, the native species richness and seedlings regeneration will be negatively impacted (Bhatta *et al.* 2020; Khaniya & Shrestha, 2020). The IAPS may compete with native species for nutrients, water, light and space (Gioria & Osborne 2014). Above and below ground parts of the IAPS release harmful allelochemicals that may inhibit growth and development of the native species and useful soil microbes (Chengxu *et al.* 2011; Thapa *et al.* 2017, Balami *et al.* 2017). Therefore, control and management of IAPS in the community forest should be initiated to conserve plant communities and native species diversity.

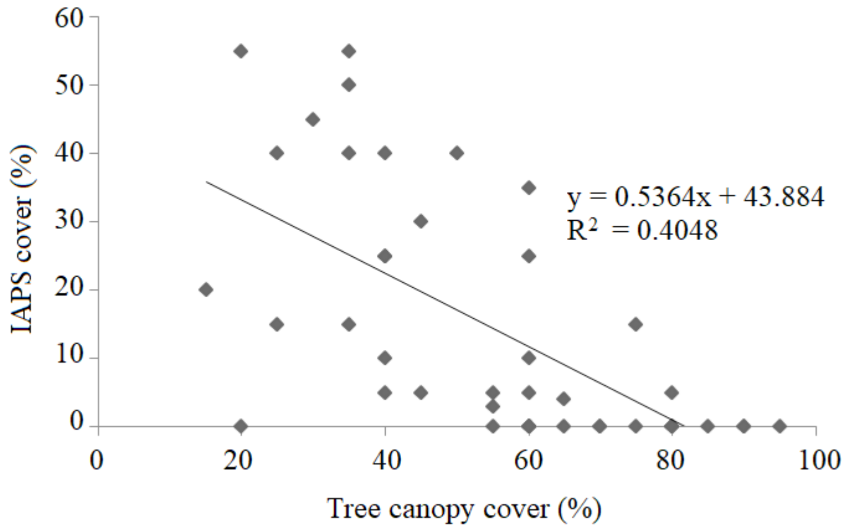

Figure 4: Relationship between tree canopy cover and IAPS cover

Conclusion

A total of 101 species of vascular plants belonging to 76 genera and 48 families were reported from Kalika community forest, Kailali district, Nepal. Five types of plant communities were identified by cluster analysis viz. (i) *Buchanania latifolia-Terminalia alata* community (ii) *Casearia glomerata-Mallotus philippensis* community (iii) *Shorea robusta-Terminalia alata* community (iv) *Adina cordifolia-Mallotus philippensis* community (v) *Terminalia-Shorea-Trewia* mixed community. The forest is invaded by the alien species *Ageratum houstonianum*, *A. conyzoides Bidens pilosa, Cassia tora* and *Argemone mexicana*. Higher cover of these IAPS was found in the *Terminalia-Shorea-Trewia* mixed community. Negative relationship of tree canopy with IAPS suggests that the tree canopy should be increased to reduce invasiveness. It is recommended that the community people should be aware about IAPS invasion in the forests, and control and management activities should be initiated for the sustainable conservation and management of the native biodiversity in the forests.

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