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Invasive Alien Species: Threats and Challenges for Biodiversity Conservation (A Case Study of Parsa Wildlife Reserve, Nepal)

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Abstract

The biodiversity in protected areas of Terai region in Parsa Wildlife Researve (PWR) of Nepal is now under serious threat due to rapid spread of Mikania micrantha, causing decline or even extinction of native species. This research focuses on impact of Mikanina micrantha in plant-diversity. The study was conceded in buffer zone community forest of PWR. On the basis of invasion by invasive alien species, forest was divided into high, medium and low severity area respectively. Total of 30 plots were chosen throughout the study site representing a variety of cover densities of Mikania micrantha. There was statistically significant between density of regeneration and level of severity (F= 10687.5 P>0.05). Simpson and Shannon diversity of Tree on different severity sites were insignificantly different on the basis of density of tree (P>0.05, chi-square =2.87). Similarly, There was statistically insignificant difference between the density of sapling and level of severity (p>0.05 chi-square 2.26). It revealed that presence or absence of Mikania micrantha did not affect the density of tree and sapling species.

Keywords: Invasive alien species, Biodiversity, *Mikania micrantha.*

Introduction

Change in bio-chemical cycle due to homogenization of the flora and fauna caused by bio-invasion result in biodiversity loss and species extinction. Not only these species threats native biological diversity but also has negative impact on smooth functioning of natural ecosystem. With their rapid growth, competitive abilities and novel growth forms, invasive species (IS) often have dramatic impacts on the native species within the habitats that they colonize[1]. APS has extreme negative impact on existing habitat, indigenous species diversity, nutrients composition in soil and forest fire cycle[2]. It is estimated that 57% of plant species identified by The Nature Conservancy as either "possibly extinct," "critically imperiled," or "imperiled" are threatened, at least in part, by predation or competition with exotic species (ES)[3]. Moreover, ES has high potentiality to change community structure and ecosystem process which in turn lead to a disastrous loss of forests, crops, fisheries and grazing territory[4]. It also becomes a threat to endangered or threatened plant species around the world[5]. Biological invasion around the world threatens biodiversity, ecosystems dynamics, asset availability, and national economy Furthermore human wellbeing. It is a pervasive and costly environmental problem[6]. Irreparable changes in existing habitat and biodiversity including extinction of local species are common phenomenon of invaded ecosystem[7]. As invasive species introduce parasites and pathogens causing diseases, it is considered as one of the most direct drives of biodiversity loss[8]. Besides killing and crowding out of NS and changing constituents of ecosystem, invasive species also mate with NS which brings genetical changes in invaded ecosystem [9].

It is the fact that IAS is second factor threatening to biotic nature globally and specially on island ecosystems. Connected with are furthermore prominent economic losses incurred due to impacts of invasive species. The Convention on Biological Diversity has understood the significance of worldwide issues and requests to contracting parties to "prevent the introduction of, control or eradicate those newcomer exotic species that threaten ecosystem, habitats and species" Article 8 (h)[10]. Impacts are observed at all spatial scales and no country and ecosystem is free from this menace[11]. The impacts are further compounded by climate change[12]. Often high level of IAS richness are related with warm climate, low attitude and disturbed habitats[13]. Invasive Species can bring landscape-level dynamic of forests through modifying disturbance regimes, nutrient cycling and both above and below ground ecosystem properties[14]. However there is little accord on the mechanisms connected with the establishment and success of invasive species or the magnitude and direction of their effects[15-17]. Different studies show that introductions of exotic species dramatically change the ecosystem and function of the native species and that led to threats the native species from the planet. On the other hand similar research on invasive species shows the controversy result that species invasions are rarely implicated as the cause of species extinction either locally or globally[18-20].

According to Di Castri[21] "A biological invader is a species of plant, animal or micro-organism which, most usually transported inadvertently or intentionally by man, colonizes and spreads into new territories some distance from its home territory". Invasions occur through three phases: invaders transport to new sites, establishment and population growth of the invaders in the new sites and their secondary spread from initial populations to other sites. For this all phases there is big role of human involvement who introduces these exotic species into the new community and also there are others environmental factors which play vital role to complete these all phases of invasions of exotic species on the new locality[22]. The rapid growth and development of exotic species take place in the gaps under the shade because there is low competition with native species. Introduction of exotic species not only reduce the health of native species but also impact on diversity and function of ecosystem[23-24]. What's more, it rule the understorey and suppress saplings and native species. Bio-invasions pose a major due to its nature of growing rates, however till now ineffectively tended to risk to sustainable forestry in the world[25]. Raghubanshi and Tripathi[26] indicate that species rich communities of the dry tropical forests are becoming species poor and less diverse not only by deforestation and forest fragmentation but also by IS[26]. Further concluded that Lantana invasion is changing the forest structure, leading to species diversity loss and creation of a homogeneous, mono-specific Lantana invaded understorey in the forest. The impacts of alien invasive species at the ecosystem level include changes to trophic structures, resources availability and disturbance regimes[27].

Nepal has 600 species of naturalized APS and these are considered as potential invaders[28]; out of these, many species have become aggressive and are rapidly colonizing different ecosystems. IAS is considered to be one of the major threats to native biodiversity and natural ecosystem. The human beings activates such as habitat destruction and over-exploitation are accompanied by introduction of exotic species that leading to habitat change and soil degradation which threats to the biodiversity of Nepal[29]. According to IUCN[30], 166 different non-native invasive plant species are found in both biologically rich areas as well as human dominated landscape such as forest, fallow land, grassland, croplands and wetlands[30]. Among them, 21 are identified as problematic and categorized as high, medium, low and insignificant are 6, 3, 7, 5 respectively and are categorized as risk invader[30]. Species like *Lantana camera, Mikania micrantha, Chromolaena orodata, Leucaena leucocephala* are invasive alien species (IAS) in Nepal[28]. *Mikania micrantha* is surveyed as one of the six high dangers postured IAS[28]. In spite of the fact that it is assessed that exclusive 1% of presented species really get to be invasive, *Mikania micrantha* is an extremely serious weed with an amazingly fast growth rate, to 27 mm a day and it justifiably has earned the common name of mile-a minute weed[31-32]. *Mikania micrantha* rapidly spreading from east to west of tropical zone of Nepal that invading the tropical terrestrial ecosystem. It is eight serious invasive alien species (IAS) of Chitwan National Park (CNP) of Nepal[33]. Small area with wide range of altitude variation makes favorable habitats and environment for easily acclimatization of exotic species in Nepal. IAS is very critical on such a poor economic country like Nepal where rural populations as rural community have high dependency on natural resources to run their daily livelihoods. Impact of IAS on native biodiversity is one of the complex topics so there is still lack of sufficient studies on this topic[34-35]. This type of study on the area will be fruitful since the area is highly invaded by *Mikania micrantha* and there is very limited study in impact of *Mikania micrantha* in terai's forest, one of the most productive ecosystems in Nepal especially from the dimension of biodiversity.

Materials and Methods

Study Area: Our research conducted at Parsa Wildlife Reserve (PWR), which was gazetted in 1984 with the aim of preserving of an Asian wild elephant. The Reserve includes tropical and sub-tropical forests of Nepal. Geographically, the PWR is located within north latitude of 27°15' to 27°33' and east longitude of 84°41' to 84°58'. The total area of PWR is 637.37 sq. Km[36]. The hottest month is the May when the mean maximum temperature reaches to 39.8o C while coolest month is January with the mean minimum temperature 5.80C. The annual precipitation (1720.51mm) is dominated by monsoon rain (83% precipitation occurring between June to October) with modest winter rain. The relative humidity varies from 49.7% to 94.2%. The dominant tree species of the reserve is *Shorea robusta* [37].

The study area of this research was conduct on Shree Rotomate Deurali Buffer Zone Community Forest (SRDBZCF). SRDBZCF located on ward number 5 and 6. It was established in 2009/November/9. The total user household of this buffer user community while established was 149. Total area of forest is 66.938 hectares and most of the forest is invaded by *Mikania micrantha* during inventory of SRDBZCF for fulfillment of above objective 1% intensity for sample plots were taken into consideration.

Data Collection: The condition of *Mikania micrantha* in forest was estimated via focus group discussion, key person interview and preliminary survey. Systematic random sampling was done to analyze the situation and condition of forest so that it represents variety of coverage by *Mikania micrantha* i.e. low, medium and high. A total of 30 plots were chosen throughout the study site representing a variety of cover densities of *Mikania micrantha*. As a result, 10 plots were taken for low severity, 10 for medium severity and 10 for high severity. 30 sampling plots of various sized quadrates; 20×20 m^2 for trees, 5×5 m^2 for shrubs and climbers and 1×1 m^2 for herbs were laid at 10 to 100m distance in adjoining forest from road and human settlement area. Nested plots 5×5 m^2 and 1×1 m^2 quadrates were allocated randomly in two corners of 20×20 m^2

plot[28]. Community consultations, individual interviews, field observations, literature review were conducted to collect data.

Data Analysis: Biodiversity Impact: Biodiversity index is one of the most suitable ways for measuring biodiversity. For species diversity, Simpson dominance and Shannon Weiner were used in this study.

Simpson's Dominance Index: Simpson's dominance index was computed to measure low, medium and high severity using following formula:

$$D = \frac{\sum ni(ni-1)}{N(N-1)} \quad (1)$$

Where: ni = the total number of individuals of ith species, N = the total number of individuals of all species.

The value of D ranges from 0 to 1. The value nearest to 1 indicates higher dominance and nearest to zero indicates lower dominance.

Shannon Weiner Diversity Index: Out of many diversity indices the most popular one is Shannon Wiener diversity Index.

This study makes a use of Shannon diversity index to compare the diversity of regeneration, sapling and tree in low, medium and high severity area. Combine function derived by Shannon and Wiener is known as Shannon index of diversity. The assumptions based upon the individuals are randomly sampled from an independently large population. The index considers the representation of all the species in the sample. In fact, biodiversity of ecosystem is measured via Shannon diversity index. Consideration of both the number of species present and species evenness is the major merit of this index. Formula employed to calculate Shannon index is as under:

$$D = \sum -(Pi * \ln Pi) \quad (2)$$

Where: H= index of species diversity, Pi= relative abundance of each species, i.e. the proportion of individuals of a given species relative to the total of individuals in the community.

Similarly, for density of regeneration, sapling and tree following formula was used:

$$Density(N/ha) = \frac{\text{No of Species}}{\text{Area of Plots}} x1000 \quad (3)$$

Results and Discussion

Regeneration Status on the Basis of Severity: There are verities of factors which play vital role on plants regeneration. On the basis of category of severity, regeneration density per hectare in low severity was 57000 and medium was 30000 and high 21000 respectively (Figure-1). Figure-1 indicates that regeneration in the study decrease with increasing severity level. There was statistically significant between density of regeneration and level of severity (F= 10687.5 P>0.05). Density of regeneration was not uniformly disturbed in all severity level thus it was impacted by severity level that was categorized into 3 categories (low, high and medium). In our study, regeneration were absent in several plots. The local species regeneration was unable to compete with *Mikanina Macrantha* especially in ground cover due to its carpeting nature. The sample area which was more prone to *Mikanina Macrantha* was prominently seen with reduced regeneration, evident by lower seedling.

The study carried out by Litton et al.[38] has clearly indicated similar type of result that the density of tree in native is higher than invaded. Engoke et al.[39] also concluded that seedling density declined with increasing cover of IAS. Dense growth of IAS modifies the micro-habitat in such a way that it becomes hostile for seed germination and seedling growth. Besides changing physical environmental conditions, the invasive species also release certain secondary metabolites (i.e. allelochemical) that make the chemical environment of soil unsuitable for germination of other species[40]. Again, Similar result were observed on study by Sapkota[41] and Ulak[42], which showed in their results that the regeneration of the forest was highly affected as the regeneration density per hectare in non-invaded area was higher than in invaded area. Ulak[42] illustrated there was no regeneration of *Dalbergia sissoo*, *Acacia catechu* and *Bombax cebia* in the study area. Very few regeneration of *Trewia nudiflora* and *Litsea monopetala* were found in invaded area. Brown et al.[43], also demonstrated the influence of exotic species (*Syzygium jambos*) on primary and secondary forest regeneration in the Luquillo Mountains of northeastern Puerto Rico, including the area in and around the Caribbean National Forest (CNF) and the Luquillo Long Term Ecological Research site (Luquillo LTER). Alvarez and Cushman[44] in Coastal California demonstrate that invasion by Cape-ivy reduced seedling recruitment in native and non-native seedling in plots by 88% and 92% fewer respectively. And shows that exotic species lessens availability of seedling by monopolizing limiting resources.

IAS obstructs and reduces the intensity and duration of light which prevent the establishment of native seedling species[45]. Lower the invasion sites, higher the availability of resources and vice-versa. The Shannon diversity index for regeneration showed inverse trends with severity level, which indicated that least severity facilitates species diversity (Table-1). From field survey, Shannon diversity of regeneration was higher in low severity area followed by medium and higher respectively (Table-1). Simpson's dominance was significantly greater in higher severity than in the least severity sites. Higher dominance was found in higher severity 0.42 and least in low severity area as compared to higher severity (Table-1). Its higher value among the invaded plant communities predicts the homogenous nature of the vegetation. This may be due to loss of intolerant species while favoring tolerant species. It is believed that the *Mikanina macrantha* releases substances that inhibit the growth of other plants.

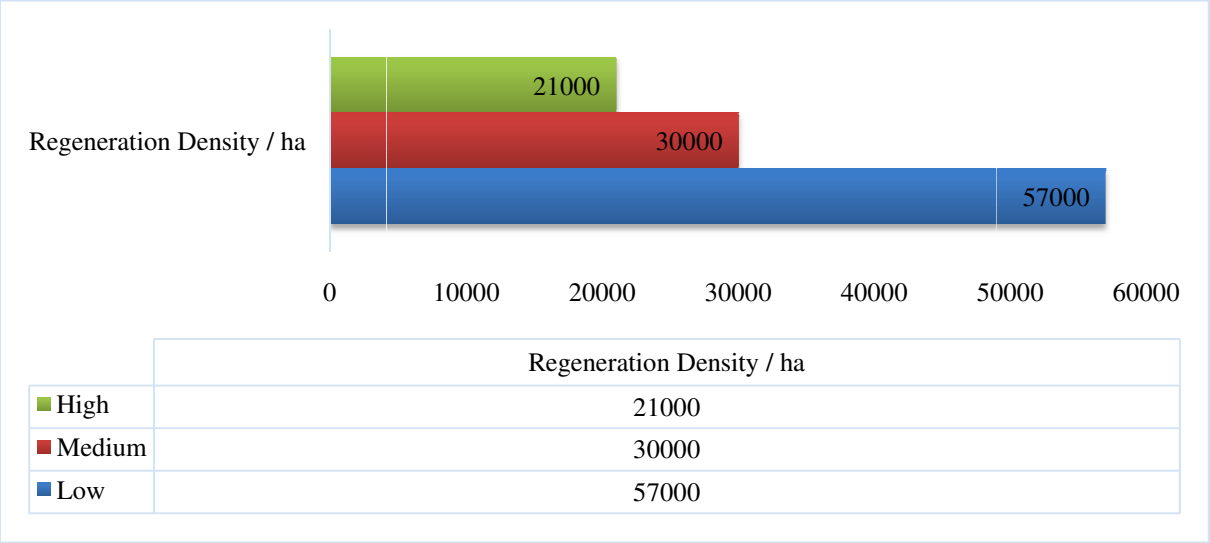

Figure-1
The regeneration density of forest in different level of severity

Ulak[42] demonstrated that regeneration diversity increases in invaded site than non-invaded site. In accord to other study like that of Siwakoti[46] conclude that the weed has been creating a serious threat in the protected areas such as the Chitwan National Park and the Koshi Tappu Wildlife Reserve by suppressing the growth of native plants and preventing the regenerations of other plants due to its high dispersal ability and adaptability to colonize in new habitat and difficult to control if once established. The strong invaders, in the invaders areas, reduce the density and diversity of species[2]. As per finding of Dogra[47] reduction in plant species and diversity species in invaded area was 32.10% and 41.21% respectively as compared to non-invader areas. In Chiwan NP, Sapkota[41] also reported high abundance of *Mikanina macrantha* in natural stands of *Bombax ceiba* and plantations of *Dalbergia sissoo* with negative impact to growth of seedlings (i.e. regeneration).In my study area also regeneration was impacted due to colonization of *Mikanina macrantha*, which was present in almost all the plots. According to Engoke et al.[39], the IAS are the passengers of deforestation and forest degradation at the early stage of colonization , which later change into divers by disrupting regeneration process. The IAS invades the forests and gradually colonizes sites.

Similar result found by Sapkota et al.[48] also indicated higher Simpson dominance index in heavily disturbed forest in comparison to least disturbed forest. Dogra[49] also found dominance index was increased in the invaded sites. Kohli et al.[50], demonstrated that higher value of index of dominance in the invaded areas and predict that dominance of single species over others and homogenous plant communities in the invaded areas.

Tree and Sapling: Ever since the studies reported by Elton[51] to those reported by Burke and Grime[52], researchers support that plant communities are generally more susceptible to invasion when they are subjected to some form of disturbance. The results in present study of tree diversity do not revealed any particular trend with increase in severity level (Table-2). Similarly, similar trend of Simpson dominance index was demonstrated. Highest dominance was observed in low severity least in medium severity (Table-2). Low, medium and high severity sites were insignificant different on the basis of density of tree (P>0.05, chi-square =2.87). The presence or absence of *Mikanina macrantha* did not differ the density of tree.

Table-1
Shannon and Simpson diversity index of regeneration at different severity level

Regeneration		
Severity	**Simpson dominance index**	**Shannon index**
Low	0.199	1.605
Medium	0.193	1.51
High	0.42	1.09

In case of sapling, diversity was higher in medium and low severity area as compared to high severity area (Table-2). Similarly Simpson dominance was higher (0.85) in high severity area followed by medium severity (0.44) and least (0.23) in low severity. The sapling diversity is not disturbed by *Mikanina macrantha* which have carpeting/ suppressing nature and vigorously colonizing. There was statistically insignificant between the density of sapling and level of severity (p>0.05 chi-square 2.26). It revealed that presence or absence of invasion did not affect the density of sapling size species.

Table-2
Simpson and Shannon diversity of Tree and Sapling at different level of severity

Variables	Severity					
	Low		Medium		High	
	Simpson dominance index	Shannon	Simpson dominance index	Shannon	Simpson dominance index	Shannon
Tree	0.28	1.53	0.18	1.86	0.24	1.65
Sapling	0.23	1.61	0.44	1.75	0.85	0.38

Trees are more robust and found to have less competition for food, nutrient, water and minerals in mature stage with *Mikanina macrantha* as compared to regeneration which are more vulnerable. Due to their long roots, trees can extract nutrient from deeper part of soil layer as compared to *Mikanina macrantha* whose roots are more superficial. Similar finding was interpreted on study by Raghubanshi and Tripathi[26] that diversity decrease as restriction of new growth of regeneration with increasing Lantana but tree species diversity was not affected. In sites where the plant is well established it has apparently remained for several decades and these sites have not yet begun to converge upon the pre-disturbance vegetation assemblage[43].

Saplings were lowest in the plots having the highest level of IAS infestation. It appears that growth of seedling into sapling is critical for tree regeneration under the influence of invasive species. Once the individual grows to sapling, the effect of invasive species would be insignificant. Engoke et al.[39], also conclude a similar trend of density of tree saplings, being not affected significantly by cover of IAS (linear regression, p=0.286) in the study area.

This may conclude *Mikanina macrantha* is not impacting in diversity of sapling size of plant species. The results were supported from study on invasive plants from other part of globe. According to Cabin et al.[53], recruitment of seedling to sapling – a transition period in which plants are competing greatly with invasive species like *P. setaceum* for limiting resources. Litton et al.[38] agreed with Cabin et al.[53] and further conclude that while presence of *P. setaceum* may not inhibit seedling germination, these new seedlings will not become established and survive to become the next cohort of canopy trees. And further concluded that sapling was affected by level of severity. As the severity level increases, the density of sapling and small diameter class tree were in decreasing. This is just opposite of our findings. This variation may be due to difference in climatic condition and management regime of the study area.

Conclusion

The negative roles of IAS can modify the structure, function and dynamics of an area. IAS is responsible for the loss of diversity of species productivity and result in landscape level changes. AS is the second worst threat after habitat destruction and set global priorities for management. The invasion of *Mikanina macrantha* is rapidly increasing in PWR.

Population structure in SRDBZCF - riverine mixed forest of Terai region of Nepal showed a considerable effect of invasion on regeneration as compared to sapling and tree species and shows the probable trend of change in future forest structure. Even the forest structure in terms of basal area and density was in better condition in low severity area than in higher. The invasion of alien species like *Mikanina macrantha* is jeopardizing the forest condition and compromising forest productivity of Terai forest by deteriorating forest.

Invasion of *Mikanina macrantha* also marked an impact on plant biodiversity with low diversity in regeneration. Higher the diversity of an ecosystem, higher will be its resilience and loss of such diversity makes it vulnerable. Invasive species creates unfavorable environment for growth of previously prevalent local species. The earlier stage of plant growth, especially regeneration, where plants lack robustness and are highly vulnerable, often fails in altered micro habitat created by aggressively colonizing invasive plants. Regeneration growth is highly impaired because of the carpeting nature of *Mikanina macrantha*. There was no effect in tree and sapling species as the trend of diversity index of both Shannon did not show any particular trend which was prominent for regeneration.

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