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Impact of *Mikania micrantha* H.B.K. Invasion on Diversity and Abundance of Plant Species of Chitwan National Park, Nepal

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ABSTRACT

This research investigated the invasion of the alien plant *Mikania micrantha* H.B.K. and its impact on plant species richness and abundance in Chitwan National Park (CNP) forest. Stratified sampling technique was used to collect the information using the nested quadrats in the *Mikania* invaded and not invaded sites in July 2011. The study revealed that the invasion highly related with the vegetation structure of the habitat; higher the tree crown cover lower the invasion. On the other hand, the invasion in terms of cover percent of *Mikania* irrespective of the biomass (fresh weight) decreased plant species richness. Species richness showed unimodal response to the *Mikania* cover percent with the decrease after 35% of *Mikania* cover.

Keywords: Alien plant, species richness, biomass, unimodal response

INTRODUCTION

Invasion by non-native species represents one of the major threats to biodiversity (Tilman 1999, Davis 2003). The association between the global climate change and species invasion pattern suggests that the invasion rate by the alien species will not decrease soon (Cheung *et al.* 2009). The consequence of the augmenting invasion includes an array of ecological, economic and health impacts (Pimentel *et al*. 2005, Reaser *et al*. 2007, Groom *et al*. 2006). Even though Elton (1958) first raised the alarm of the impact of invasive species in the 1950s, the concern on the problem has increased only recently because of its serious impacts on global biodiversity (Tilman 1999, Sala *et al*. 2000, Davis 2003).

Mikania micrantha H.B.K. (hereafter called as *Mikania*) is also one of the worst invasive plants in the world (Lowe *et al*. 2000). Originating in Central and South America, its invasion has been reported throughout the tropical Asia including Nepal. It exhibits an exceptionally fast growth rate and a high sexual reproductive capacity (Choudhary 1972, Swamy & Ramakrishnan 1987) and thus has earned the common name 'mile-a minute weed' (Holm *et al*. 1977). This perennial, sprawling vine damages or kills other plants by cutting out the sunlight and smothering them. It has been listed as one of the six worst invasive alien species that poses the highest risk to native ecosystems in Nepal (Tiwari *et al*. 2005).

When the *Mikania* first invaded in Nepal is not clear, however the first record of the *Mikania* could be found in the herbarium collected by Kitamura in 1963 (Tiwari *et al.* 2005). This plant has now invaded the forests, grasslands, wetlands, fallow lands and even in the croplands of tropical parts of Eastern to Central Nepal (Tiwari *et al*. 2005, Siwakoti 2007). The Chitwan National Park (CNP), a World Heritage Site is also found to be adversely affected by its invasion (Sapkota 2007, Shrestha *et al*. 2008). The extent of invasion and its impact on biodiversity is increasing each year and it is reported to be invaded that of about 20% area of the CNP (Khadka 2010).

The forest ecosystem in CNP is globally important for maintaining the invaluable biodiversity. This is one of the most important habitats for the remaining population of one horned rhinoceros and Bengal tiger and other important biological diversity. But it is so unfortunate that the problem of conservation is augmenting because of addition of the invasion by *Mikania* along with other factors. The problem is so drastic and increasing that even the immediate prime minister also observed the problem and initiated in the uprooting program in 2009. The forests and grasslands in CNP were free of Mikania micrantha in 2005 study, but the repeated study in 2007 recorded the invasion of Mikania (Shrestha *et al*. 2008). There are very little information on the ecology and impact of the invasive species in CNP. A detail study on Mikania was carried out in the invaded area of CNP (Sapkota 2007). However, to identify the more detail information on impact of invasion, a comparative study on invaded and non-invaded area is very crucial. On the other hand, the gradient of species diversity as well as abundance along the extent of invasion is required to assess the impact of invasion on native species. This study examined the impact of *Mikania micrantha* H.B.K. on diversity and abundance of plant species in CNP and identified factors responsible to inhibit the invasion success.

MATERIALS AND METHODS

Study Area

This study was conducted in the Chitwan National Park, particularly in the eastern sector called Sauraha, Chitwan (Fig. 1). The forest close to the rivers is the riverine forest type with *Trewia nudiflora* L. and *Bombax ceiba* L. as the dominant tree species. However, the vegetation of inner part of the park is dominated by Sal (*Shorea robusta* Gaertn.) forest and it covers the 70% of the park area. Sal is intermingled with chir pine (*Pinus roxburghii* Sarg.*)* along the southern face of the Churia Hills and with the trees *Terminalia bellirica* (Gaertn.) Roxb., *Dalbergia latifolia* Roxb., *Anogeissus latifolius* (Roxb. ex DC.) Wall. ex Guill. & Perr., *Dillenia indica* L. and *Garuga pinnata* Roxb.on northern slopes. The riverine forest covers 10% of the park area and is dominated by Khair-Sissoo (*Acacia catechu* Willd.- *Dalbergia sissoo* Roxb. ex DC.*)* associations as well as Simal - Bhellar (*Bombax ceiba - Trewia nudiflora*). The remaining 20% of the area is covered by the grasslands, where *Themeda villosa* (Poiret) A. Camus*, Saccharum spontaneum* L., and *Imperata cylindrica* (L.) Beauvois are the major plant species.

The Chitwan National Park is a home to 50 species of mammals, including the globally important species as one-horned Asian rhinoceros (*Rhinoceros unicornis*)*,* tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Wild elephant (*Elephas maximus*), etc (Bhuju *et al*. 2007). A larger number of birds (489 species), snakes (19 species including king cobra *Ophiophagus hannah* and Indian python *Python molurus*), crocodiles (2 species as mugger *Crocodylus palustris* and gharial *Gavialis gangeticus*) and 113 species of fish are also found due to the diversity in habitat (Bhuju *et al*. 2007).

The climate is subtropical with a summer monsoon from mid-June to late-September when 90% of the 2,400mm of rain falls, and a relatively dry winter from October to February. The monsoon rains cause dramatic floods and alterations to the character and courses of rivers. Temperatures are highest during the monsoon period, with a maximum of 38°C, and drop to a minimum of 6°C after the monsoon when dry northerly winds from the Himalaya and Tibetan Plateau are prevalent.

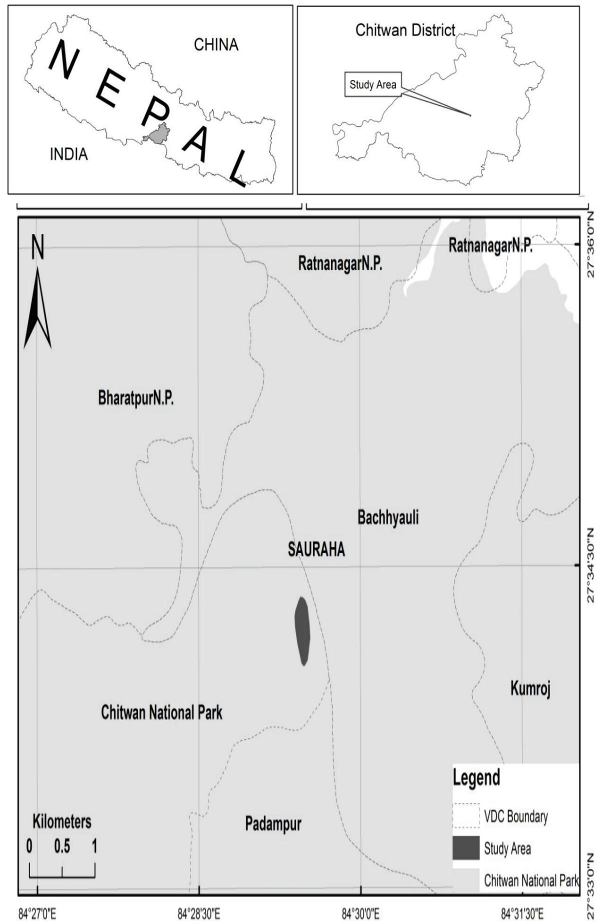

Fig. 1. Map of the study area

Sampling

The study was carried out by the standard systematic sampling methods making definite size quadrats in both invaded and not invaded areas. Based on the invasion pattern, 5 parallel transects were made starting from the edge of the forest towards the core region and hence covered the areas from invaded to invasion free areas. The distance of transects were maintained at 50 meters and similarly the plots in each transects were also established at a distance of 75 meters. The first plots in each transect was located at the edge of the forest and close to the river where as the last plots at the invasion free core area of the forest. The remaining two plots were made in between them at equal distance of 75 meters.

The size of the sampling plot was identified using the species area curve method. 10m x 10m plots were used for the study of tree species and *Mikania* cover percent while 2m x 2m plots in the mid of the larger plots were used to study the shrubs and saplings while three 1m x 1m plots were held randomly inside the larger plots to study the *Mikania* biomass, herbs and seedlings.

Data Analysis

Within each sampling plots, GPS coordinates were recorded using GPS (GARMIN), name and population of plant species, cover percent by visual estimation and fresh weight of *Mikania* using the digital weighing machine. The univariate statistics was used to describe the data in the form of minimum value, maximum value, mean, and standard deviation for each variable. The bivariate relationship with *Mikania* cover and fresh weight and other vegetative characteristics have been analyzed using the Correlation Coefficient analysis. The impact of invasion (*Mikania* Biomass) on species richness and plant population (both total population and population of individual species) was analyzed by the Regression (Ordinary Least Square OLS) method. All the statistical analysis of Univariate, Bivariate and multivariate analysis has been performed using SPSS (IBM SPSS Statistics 19).

RESULTS

Vegetation composition

The first study area (the riverine forest) was dominated by the *Trewia nudiflora* L. tree species. *Bombax ceiba* L. and Dhatrung (*Ehretia laevis* Roxb.) were the associated species but had the very scarce distribution. The vegetative composition and their quantitative data are shown in the Table 1. On average, only 2 trees were recorded in a plot (100 square meters) while the crown covered about 49% areas of each plots on average. A total of 44 plant species were recorded, however the average total species richness in a plot was just 5.73 with the maximum records of 12 species in a plot. The species richness of the shrub and herbaceous layers were 3.84 and 3.15, respectively. *Mikania micrantha* H.B.K. invaded in such a way that it covered almost 45% of the research plots on average. The extent of invasion was also reflected by the cover percent of the plant that varied from 0% (*Mikania* free) plots to the 90% in the highly invaded plots. While the biomass in terms of fresh weight was recorded as 395.36 grams per square meter, it also varied a lot among the plots with the standard deviation 426.44.

The correlation analysis in between the different variables is shown in Table 2. The analysis shows that total species richness as well as shrubs and herbs species richness though negatively correlated with the biomass and cover percent of *M. micrantha*, the relationship is not significant. However, the correlation coefficient between the *M. micrantha* cover and tree population (-0.62**) as well as *M. micrantha* and tree crown cover percent (-0.74**) are strongly negative.

Table 1. Univariate statistics

Variables	Min.	Max.	Mean	Std. Dev.
Biomass (grams) of *Mikania micrantha*	0	1386.66	395.36	426.44
Mikania micrantha cover (%)	0	90	43.68	32.99
Total species richness	0	12	5.73	4.05
Tree population	0	4	1.94	1.47
Tree crown cover (%)	0	90	48.42	32.78
Shrub species richness	0	9	3.84	2.94
Shrub population	0	144	50.31	47.19
Herbaceous species richness	0	11	3.15	2.87

Table 2. Pearson correlation coefficient among the variables

Variables	Mikania micrantha	
	Fresh weight	Cover
Total species richness	-0.08	-0.39
Tree population	-0.21	-0.62**
Tree crown cover	-0.43	-0.74**
Shrub sp. richness	-0.12	-0.19
Shrub population	0.16	0.07
Herb species richness	0.02	-0.29

Invasion dynamics

Mikania was found to be affected by tree population, crown cover and the distance from the edge of the forest. The regression analysis showed the significant linear decrease of invader cover percent with the measured variables. As explained by the regression model, increase in one individual tree decreased the *Mikania* cover percent by about 15 % while increase in tree cover by 1 % decreased the invasion cover by 0.75%. Similarly, when we move from the edge to the core parts of the forest the invasion gradually decreased and absent at certain distance. The result showed that as we move 1 meter inside the forest from the edge, *Mikania* cover percent decreases by half percent (Fig. 2).

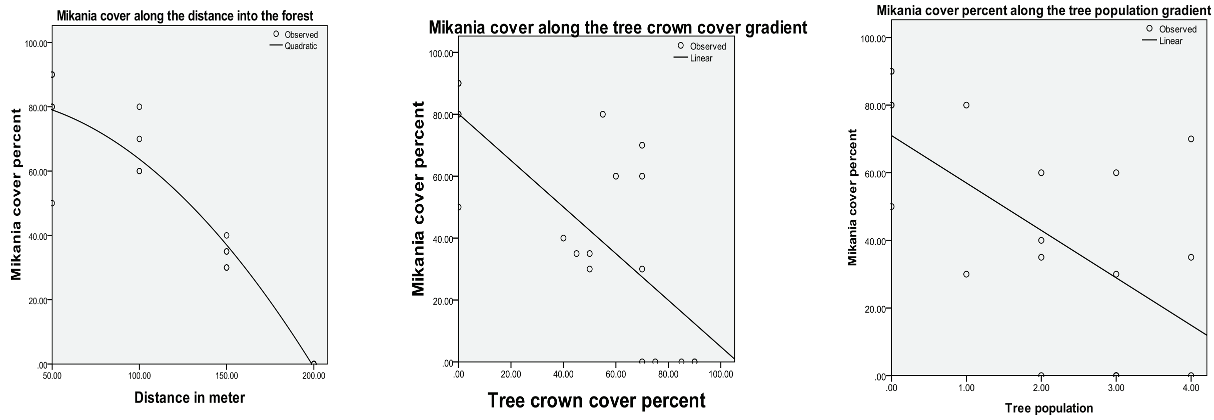

Fig. 2. Invasion dynamics along the environmental gradient

Table 3. Result of the Regression analysis with Mikania cover as dependent variable (Model 1 = linear effect and Model 2 = unimodal effect)

Predictors	Reg. Coeff.	Adjusted R^2	t -value	Sig. (*p*)
Tree population				
Model 1 (F=10.92, p=0.004**)	-14.027	0.355	-3.305	0.004**
Model 2 (F=7.79, p=0.004)	6.22	0.43	1.8	0.091
Tree crown cover				
Model 1 (F=21.58, p= 0.000**)	-0.753	0.534	-4.646	0.000**
Model 2 (F=11.32, p=0.001)	-0.007	0.534	-1.014	0.326
Distance into the forest (Strata)				
Model 1 (F=137.85, p= 0.000**)	-0.531	0.884	-11.74	0.000**
Model 2 (F=93.86, p=0.001)	-0.002	0.912	-2.523	0.023*

Invasion and species richness

The study of invasion dynamics showed that the invasion in terms of plant cover is inhibited by the tree crown cover but not by the tree population. But it is very interesting to find that shrub population has also the positive effect on the *Mikania* cover percent. As found in Model I, increase in shrub population by one individual increase the invasion by 0.38 percent. In Model II, when the disturbance gradient (where human interference with walking trails and river flooding is higher) was included the effect of tree characters faded away and showed significant negative impact on *Mikania* cover percent. As we move from the non-invaded plots to the edge of the forests, invasion increased by 31.68 percent in each stratum. When both the factors shrub population and disturbance gradient were fitted along with the tree characters, both of the variables showed accelerating effect on *Mikania* invasion.

Table 4. OLS regression estimates of the impact on Mikania cover percent

Variables	Model I	Model II	Model III
Shrub population	0.388**		0.16*
Disturbance gradient		31.68**	25.75**
Control			
Tree population	- 7.389	0.895	- 2.42
Tree crown cover (%)	- 0.712**	0.181	0.02

The ordinary least square (OLS) regression analysis shows the unimodal response of species richness with the invasion cover. The optimum number of species was recorded at about 35% of invasion and it decreased thereafter as shown in the figure. Almost no other species existed when the invasion cover is more than 90%. But the multivariate analysis showed that species richness decreased significantly with the increase of invasion cover percent when the effect of tree population, crown cover and shrub population remain constant (Fig. 3).

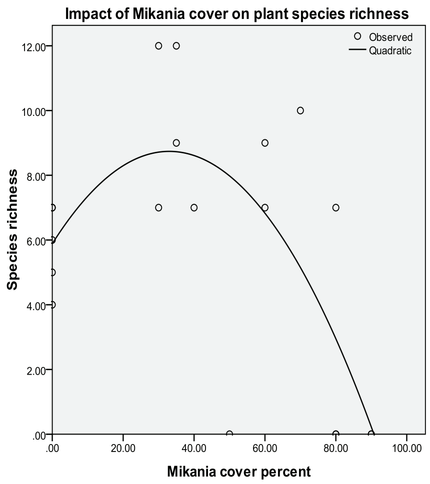

Fig. 3. Impact of *Mikania* cover on plant species richness

Table 5. OLS regression estimates of the impact of *Mikania* biomass and cover percent on species richness

Variables	Model I	Model II	Model III
Mikania biomass	-0.001		0.001
Mikania cover (%)		-0.047*	-0.057*
Control			
Tree population	1.274*	0.877	0.728
Tree crown cover (%)	0.006	0.022	-0.019
Shrub population	0.049**	0.066**	0.067**

DISCUSSION

Vegetation Composition

The first study areas was dominated by Bhellar (*Trewia nudiflora* L.) tree species in major association with Simal (*Bombax ceiba* L.) and Dhatrung (*Ehretia laevis* Roxb.). Though the total number of species recorded in the study area was higher, the average total number of plant species per plot was just 5.73. It could be because of two reasons; first the study was carried out in plots. And smaller areas always show lower number of species compared to larger areas (Rosenzweig 1995). The second study area was very disturbed due to human as well as natural interferences (flooding) and higher disturbance degraded the habitat and made it unsuitable for many species and brought about the variation in species composition even in a small area. In addition the encroachment and increasing *Mikania* cover is the another reason for lower plant species diversity (Kaur *et al*. 2012). This is also supported by the correlation analysis between invasion and species richness. Though the output is not significant the negative sign of correlation reflects the relationship pattern between the variables. When the invasion extends and dominates an area, it alters the ecosystem structure and function (Vila *et al*. 2011). Then the species with lower or no resistive strength are excluded easily (Hejda *et al*. 2009). Here, the species mostly the herbaceous species could be considered as the resistive plants to invasion as they are surviving in the invaded areas.

Invasion Dynamics

Mostly, the alien species invade and dominates where the native vegetation is dwindled by either natural or human disturbances (Elton 1958, Primack 1995). *Mikania* invasion is also recorded to be higher along the forest edge towards the riverside and go on decreasing as move into the core areas. The cover percent up to 90% of the research plot along the forest edge shows the severe invasion problem in more disturbed area. Such severity is because invasive plants located near a vector pathway, such as road, trail or waterway; increase their chances of being dispersed by the vector using that pathway (Davies & Sheley 2007). Proximity to waterways greatly increases the likelihood of water dispersal. For example, wind dispersal appendages, such as plumes and wings, would aid water dispersal by increasing buoyancy (Cousens & Mortimer 1995).

In addition, such areas have lower plant population and provide the opportunity for invasion with lower competition for light and nutrients. As shown by the regression analysis, the invasion dynamics is significantly affected by both tree population as well as tree crown cover. Increase in tree population decreased the invasion cover percent by about 15%. Disturbance in the form of resource use decreases either tree population or crown cover or both and that creates better condition for the invasion as well as rapid expansion of invasion. Higher tree population leaves narrow space for invasion and increase competition for the resources while higher crown cover reduces light availability which is also one of the inhibitor factors for the invasion. Hence, availability of space and light are the important factors for *Mikania* invasion and its growth. The linear negative effect of tree characteristics on invasion cover percent suggest that we have to maintain the optimum tree population as well as crown cover to protect the forest from the invasion vulnerability. Care should be given to protect the trees both from logging and lopping. As ecologically sustainable methods of control for invasive plants have not been invented yet, protection of the existing trees from logging and lopping could decrease further invasion while plantation of native tree species and its growth after certain years could bring a good results in invasion management and habitat restoration against the invasion problem.

Invasion and species richness

The invasion of alien species is considered to be a great threat to native biodiversity (Tilman 1999, Davis 2003) due to its negative impacts. Many studies have already recorded that the alien invasion is harmful for the native species diversity (Kaur *et al*. 2012). This study also found similar results for the invasive plant *Mikania micrantha* H.B.K. This plant is known to have exceptionally fast growth rate and a high sexual and vegetative reproduction capacity (Choudhary 1972, Swamy & Ramkrishnan 1987) and hence affects the native plants by limiting sunlight and nutrients. In addition, it retards the growth of other species due to the allelopathic effect (Ye & Zhou 2001).

The bivariate analysis with *Mikania* cover and fresh weight with total species richness, shrub species richness and herbaceous species richness showed negative correlation. Though the result was not significant, it showed the direction of impact. It might be associated with other variables rather than *Mikania* invasion alone. But it is due to the unimodal response which was found from the regression analysis. Species richness increased from no invasion to 35% of *invasion* coverage and then decreased gradually as the plant cover increased. The native plants species have their competitive ability to resist up to 35 % of the invasion, more than this cover percent is unsuitable and hence could not grow and survive there. Thus, the negative impact of invasion does not hold true up to 35% of *Mikania* invasion cover. But the problem is that we can't manage the invasion cover up to this level as the plant has very fast growth rate. This result thus has a very significant implication in park management as it reveals that decreasing the invasion extent to lower extent could maintain the plant diversity in spite of the invasion. Hence, absolute removal is the best way however park managers should not wait for time and resources for such programs rather start partial removal to maintain the diversity and habitat condition.

On the other hand, the multivariate analysis showed that invasion extension in the form of plant cover increases with the shrub population and distance closer to the forest edge. The regression model I and II taking shrub population and Distance separately showed positive impact to invasion, if we keep the tree characteristics as tree population and crown cover as constant. Similarly, combining both variables in a model (III) also showed independent impact on invasion increment. The effect of shrub cover could be the indirect effect of tree characteristics. Areas where tree population and crown cover is lower, obviously the shrub population becomes higher. When *Mikania* invaded such areas, it found a good environment for establishment and growth. Since the lower height of the shrubs, *Mikania* could find the better anchorage and opportunity to expand than on trees. In addition, distance closer to the edge is more disturbed because of natural (flooding) as well as anthropogenic factors (resource collection and tourism) which created the forest edge more suitable for invasion growth and expansion. So the result also accords the results of the previous studies which showed that the disturbed sites are not only prone to invasion but also have severe impact to native species diversity after invasion.

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