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"Mikania micrantha" is the most serious weed in protected areas, community forest, and agricultural land too. Mikania has invaded most of the rhino preferred habitat viz. Riverine forest, grassland, mixed hardwood forest and wetlands in Chitwan National Park. Mikania also has an adverse impact on wildlife habitat as well in agricultural crops (i.e. in Paddy field, sugarcane field, and Banana crop). This piece of work was carried out in Chitwan National Park, central Nepal to see the impact of Mikania on Rhinoceros habitat. This book has given a description of Mikania status in Nepal, its distribution and impact on Rhinoceros habitat in Chitwan National Park. This book also explored the details about vegetation study and different methods of calculating species diversity indices.

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ACRONYMS AND ABBREVIATIONS

CABI	: Centre for Agriculture and Bioscience International
CNP	: Chitwan National Park
CNPBZ	: Chitwan National Park and Buffer Zone
BZCF	: Buffer zone community forest
CNPBZMP	: Chitwan National Park and Buffer zone Management Plan
DNPWC	: Department of National Park and Wildlife Conservation
GISP	: Global Invasive Species Program
GPS	: Geographic Positioning System.
HMGN	: His Majesty's Government of Nepal
IAS	: Invasive Alien Species
ICIMOD	: International Centre for Integrated Mountain Development.
INGO	: International Non-Governmental Organization
IPM	: Integrated Pest Management
ISSG	: Invasive Species Specialist Group
IUCN	: The World Conservation Union
KFRI	: Kerala Forest Research Institute
NTNC	: National Trust for Nature Conservation.
SCOPE	: Scientific Committee for Problems of the Environment
USA	: United State of America

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ABSTRACT

The study entitled "Impact of *Mikania micrantha* on *Rhinoceros unicornis* habitat in Chitwan National Park (CNP)" was commenced between June & September, 2008 with aiming to assess the floral diversity, status and distribution of *Mikania* and its impact on rhinoceros habitat in five different research sites within and out side CNP. The sampling intensity for tree, shrub and herb, were 0.25%, 0.025% and 0.001% and plot size were 10*10m, 5*5m and 1*1m respectively. The riparian habitats, grasslands and afforested lands are highly invaded by the weed *Mikania*.146 plant species were recorded from 93 plots. The highest invasion was found in *Accacia catechu, followed by Dalbergia Sissoo and Bombax ceiba*.The floral diversity was assessed by using Shannon-Weiner index (H), Simpson Index of species (SI) diversity and important Value index (IVI) was calculated using Ms Excel 2003. The relative abundance was higher in Icharni greater floral diversity found at Sukhibhar and lesser diversity was seen in Baghanara BZCF. For status distribution the detail *mikania* distribution map, was prepared by using GIS and GIS software's Arcview 3.2, Arcview spatial analyst and cartalynx. An index of species reduction (ISR) was calculated to find out the impact of mikania on different tree species. ISR indicated that *Accacia catechu* followed by *Disoccilum binecteriferum were* most vulnerable tree species impacted by *mikania*. The over all impact of *mikania* was seen in grassland, riparian forest, wetlands, ecotones and riverine forest which are the potential habitats of rhinoceros.

Key words: *Mikania,* Species diversity, Impact, Rhinoceros, Habitat

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CHAPTER I: INTRODUCTION

1.1 Background

Mikania micrantha (L.) Kunth (here after Mikania) is a fast growing, perennial Central and South American climber, commonly called mile-a-minute weed, because of its vigorous and rampant growth habit. It has been reported to grow to 27 mm a day (www.issg.org/database). The plant is one of the major IAW in many tropical moist forest regions of Asia including Nepal and is still invading new areas, such as Northern Australia (www.cabi.org). The weed has been rapidly invading the different tropical ecosystems of Nepal (forest, cropland, grassland, and wetland) distributed Mechi to Lumbini zones (Ilam/ Jhapa to Rupandehi districts). The neotropical vine smother other plants and significantly reduces biodiversity by swamping vegetation and out competing native plants. However, it is rarely a weed in its native range in the Central and South America where natural enemies are seen to exert a significant pressure on the occurrence and abundance of the species (www.cabi.org). It is not reported west to Rupandehi. It is known by the various local dialects in different parts and community of Nepal, such as Pani lahara, Bire lahara, Tite lahara, Bakhre lahara, Pyangri lahara, Banlude jhar, Bahra mase, Lahare banmara (Tiwari *et al.*, 2005).

The weed was first collected from the Jogmai-Ragapani area of Ilam district of east Nepal in 1963 by a Japanese team, and scientifically reported in 1966 in the Flora of Eastern Nepal (Tiwari *et al*., 2005).So, it can be guessed that Mikania introduced to Nepal via north east India (Assam) and has been spreading towards west. The weed has been creating a serious threat in the protected areas too 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 greater one horned rhinoceros (Rhinoceros or Rhino here after) is listed as world's most endangered species of mega herbivore. It once inhabited most of the Indus, Brahamputra and Gangaetic floodplains and nearby foothills of south Asia (Laurie 1978).

The large body enables rhinoceros to consume large quantities of food and hence they are commonly referred as bulk feeder (Owen – Smith1988), as well as mixed feeder. As feeding is switching from a graminioid dominated diet during the wet season, proportion of woody browse is increased in the dry season (Lauri 1982).Due to illegal hunting and habitat clearance, rhinoceros are now restricted to isolated populations in protected areas on the Indian subcontinent mainly in Nepal and India. At present only three populations contained 408 individuals in Chitwan National Park, 22 individuals in Bardiya National Park & 5 in Shukla Phanta Wildlife Reserves (DNPWC, 2008).

1.2 Problem Statement and Justification

Mikania micrantha is an extremely serious weed with an exceptionally fast growth rate, 8-9 cm per day has been recorded (Choudhury, 1972). *M. micrantha* damages or kills other plants by cutting out the light and smothering them. In this respect it is especially damaging in young plantations and nurseries. It also competes for water and nutrients, but perhaps even more importantly, it is believed that the plant releases substances that inhibit the growth of other plants. *Mikania's* harm is unquestionable and it is an urgent but difficult task to control the plant. Chinese researchers are studying its eradication and the government gives much support to the study. Moreover, the public also take an active part in the plant's eradication. However, *Mikania* is so vigorous that we can't eliminate it completely by simple manual or mechanical means. Biological control is the best method but it is still a challenge in China at the moment (*Ye* and *Xia,* 2001).

Various efforts have been initiated and worked out in the field of *Mikania* and other IAS as well in the world including southeastern Asia. It seems to be very slow responding on *Mikania* problem in Nepal since the first national stakeholders' workshop on *Mikania* weed invasion in Nepal was held in 2004 after 15 years of invasion of the weed in Chitwan National Park. At present, the weed has vigorously invaded the core and buffer zone of the Park threatening to biological diversity and ecosystem. Many moist part of the park are seriously invaded by the weed. Being a climbing plant, it becomes a nuisance in forest suppressing forest under growth and saplings including those serving as egretories. The plant spread appallingly fast and becomes dense within 8-10 years according to local inhabitants (Tiwari et al, 2005), Whereas nature guides reported that the weed has unexpectedly invaded the area since last 4 years.

In addition, this weed has been nominated as among 100 of "world's worst" invader and further more, *Mikania micrantha* is one of the three worst weeds of tea in India and Indonesia and of rubber in Sri Lanka and Malaysia. In Samoa, incursions of *M. micrantha* have caused the abandonment of coconut plantations, and the weed has been reported to kill large bread fruit trees. It also causes serious problems in oil palm, banana, cacao and forestry crops, and in pastures. While it does not grow well in rice paddies, it can encroach from the edges to smother the crop (http://www.issg.org/database/welcome/).

Tiwari et al., 2005 have nominated the plant as among six of "high risk posed" weed and in addition, the first National stakeholders' workshop on Mikania micrantha weed invasion in Nepal was held on November 2004 in IUCN Nepal Hall by Himalayan Nature, IUCN-Nepal and CAB International, UK (Poudel et al., 2005). In this workshop, *Mikania micrantha* was considered as the most problematic in terrestrial ecosystem in eastern and central Nepal including Chitwan National Park (Baral, 2004). From the field study, eight invasive plant species were identified as problematic in CNP and out of which, *Mikania micrantha* was found to be highest invasive in terrestrial ecosystem (Sapkota, 2006). One day's Workshop on the Status of *Mikania micrantha* in Chitwan National Park concluded that, there is urgent to investigate the invasion of *Mikania* and formulate the strategy to overcome the problem of habitat degradation (Bhatta, 2006).

Despite the current situation of the weed, quantitative data on the impacts and scale of the problems are lacking for the country. This, together with a general lack of awareness, or differing perceptions of critical issues resulting from *Mikania* in different sectors, has in many cases still is, hindering appropriate responses at national and local levels. Stakeholders should have required information that is necessary to catalyze actions necessary to address the weed, such as cross-sectoral linkages, policy and support for appropriate measures. The most serious terrestrial plant weed is still spreading, unchecked. This is serious for our country where *Mikania* is compounding a multiple of problems affecting livelihoods, and is also undermining national and international program being implemented to improve livelihoods and national infrastructures (McNeely, 2001). In Chitwan National Park Mikania has invaded three habitat types viz. grassland, riverine forest and wetlands as well and still small amount of invasion in Tall grass land (themeda) and Sal forest. The major impact was on Dalbergia, Accacia,Bombax and different grasses eg Imperata cyllindrica and *Hemertheria comparusa* (ghode dubo)and

Eragrotis unioloids(Banso). It is also found that mikania was consumed by rhinoceros as stuffer food mixed with grasses, and still the impact on mikania is not studied, the present study "Impact of Mikania on rhinoceros habitat in Chitwan National Park, is justifiable here because it helps to know the major impacted area and major impacted plant species and also explore the consumption of mikania by rhinoceros and hence the study is justifiable.

1.3 Objectives

1.3.1 General Objective

The General Objective is to assess the impact of *Mikania micrantha* on *Rhinoceros* habitat in Chitwan National Park.

1.3.2 Specific Objectives

1. To assess the floral diversity in study area.
2. To assess the status and distribution of *Mikania*
3. To assess the impact of *Mikania micrantha* on *Rhinoceros* habitat

1.4 Research Questions

1. What is the status of *Mikania* on grassland, shrub land and woodland in CNP?
2. What types of food habitat is used by rhinoceros? Or what types of habitat is preferred by rhino?
3. Does *Rhinoceros* consume *Mikania* or not?
4. What is the impact of *Mikania* on rhinoceros habitat?

1.5 Limitation of the study:

Since the study time is very short, growth rate of mikania was not assessed because it needs at least one year for growth study. Similarly it was found that mikania was browsed by rhino in three different seasons as rhino's food habitat preference is changed according to season and sex. Therefore, to study the actual amount of mikania consumed by rhino it needs whole year study. Another limitation is budget and time constraint because this research is carried out for the partial fulfilment of Bachelor degree in Forestry.

CHAPTER II: LITERATURE REVIEW

2.1 Mikania invasion in Nepal

Mikania micrantha H.B.K. is a fast-growing perennial creeping vine belonging to the family Asteraceae and is native to Central and South America, where it is a weed of minor importance (Wirjahar, 1976; Holm et al., 1977). However, in its palaeotropic exotic range, it has become a major invader and notorious weed of agricultural land (Parker, 1972; Holm et al., 1977; Waterhouse, 1994; Cronk and Fuller, 1995; Zhang et al., 2004). It has been listed as one of the 100 worst invasive alien species in the world (Lowe et al., 2001), and it is considered the second most serious weed in the South Pacific (Waterhouse and Norris, 1987).

It has been found as an alien invasive species in 31 countries or states in the world including Asian country Nepal, India, China, Bangladesh, etc. (http://www.issg.org/database/welcome/). Mikania was reported first from IIam in 1963 by the name of *Kitamura* and later (1971) by the name of Mikania (Adhikari, 2004). After 10-15 years, National Trust for Nature Conservation (NTNC) first recorded the weed back in Chitwan. In Koshi Toppu Wildlife Reserve (KTWR), it was first seen in the northern part of the Reserve. The weed has now spread from Eastern Development Region to Central DR (extensive in protected areas like KTWR, Parsa Wildlife Reserve and Chitwan National Park). KTWR is covered by Mikania and the scale of escalation is very high. This plant is found mostly in the undisturbed riverine forest. *Mikania micrantha* is well established in the grassland and riverine forest in Chitwan National Park. High invasion of *Mikania* has been observed in the northern part of core and buffer zone of the park (Sapkota, 2007).The plant has very low use values except as fodder during the lean period-cattle only consume it if nothing else is available and people collect edible ferns that grow under the canopy of *Mikania* (Baral, 2004)

To reduce the damage caused by Mikania to tree crops or forest plantations, various management methods have been used, including cultural, mechanical, chemical, and biological controls (Parker, 1972; Cock et al., 2000; Ellison, 2001; Ellison et al., 2004; Zhang et al., 2004). Biological control is particularly attractive in controlling weeds in crops because biological agents applied do not adversely affect the non-target species as do chemical herbicides (CAB International Institute of Biological Control, 1987). It has been widely recognized as one of the

most promising methods of controlling exotic species, especially when native species are used to control exotic invasive weeds.

2.2 Distribution

2.2.1 Distribution in the world

The native range of the weed is central and South America but it has been spreading in various part of the world. It has been found as an alien invasive species in 31 countries or states in the world (http://www.issg.org/database/welcome/) which are American Samoa, Australia, Bangladesh, China, Cook Islands, Fiji, French ,Polynesia, Guam, India, Indonesia, Malaysia, Mauritius, Micronesia, Federated States of (FSM),Nepal, New Caledonia , Niue, Northern Mariana Islands, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Sri Lanka, Thailand, Tokelau, Tonga, Tuvalu Vanuatu,Wallis,Futuna

2.2.2 Distribution of Mikania in Nepal

This weed has been reported spreading from eastern to central Nepal in low altitude below 1400m.). The west boundary of mikania was found to extend as far west as Rupandehi district (Baral and Adhikari in press). A recent report has inidcated that it has already reached as far west as Kapilvastu District in the vicinity of Jagdishpur Reservoir (Siwakoti 2007).

2.2.3 Distribution of Mikania in Chitwan National Park.

Mikania micrantha is well established on the grassland and riverine forest in Chitwan National Park. High invasion of *Mikania* has been observed in the northern part of core and buffer zone of the park. The current distribution of Mikania in Chitwan National Park is given below (See Map 1, Page 27).

2.3 Ecology of Mikania

The English Name of Mikania is American rope, bitter vine, Chinese creeper, climbing hemp weed, mikania vine and mile-a-minute weed. It is a branched, slender-stemmed perennial **vine**. The **leaves** are arranged in opposite pairs along the stems and are heart-shaped or triangular with an acute tip and a broad base. Leaves may be 4-13 cm long. The **flowers**, each 3-5 mm long,

are arranged in dense terminal or axillary corymbs. Individual florets are white to greenish-white. The **seed** is black, linear-oblong, five-angled and about 2 mm long. Each seed has a terminal pappus of white bristles that facilitates dispersal by wind or on the hair of animals" (Csurhes & Edwards, 1998)."[A] fast growing, perennial, creeping or twining plant; **stems** branched, pubescent to glabrous, ribbed; **leaves** opposite, thin, cordate, triangular, or ovate, blade 4 to 13 cm long, 2 to 9 cm wide, on a petiole 2 to 8 cm long, base cordate or somewhat hastate, tip acuminate, margins coarsely dentate, crenate, or subentire, both surfaces glabrous, three- to seven-nerved from base; **flowers** in heads 4.5 to 6 mm long, in terminal and lateral openly rounded, corymbous panicles; **involucral bracts** four, oblong to obovate, 2 to 4 mm long, acute, green, and with one additional smaller bract 1 to 2 mm long; four flowers per head; **corollas** white, 3 to 4 mm long; **fruit** an achene, linear-oblong, 1.5 to 2 mm long, black, five-angled, glabrous; **pappus** of 32 to 38 soft white bristles 2 to 4 mm long" (Holm *et al.,* 1977; p. 322).

Habitat/ecology: A smothering vine usually occurs in disturbed forest, stream banks, roadsides, pastures, plantations and cultivated crops. It graos humid, sunny or shaded habitats; 0-2000 m altitude. It is thought to interfere with soil nitrification processes." (Waterhouse & Mitchell, 1998; pp. 27-28) and also a major weed in plantations, pastures, along roadsides and an intermediate weed in crops and forestry. It grows best where fertility, organic matter, and soil and air humidity are all high. Mile-a-minute tolerates some shade, and very rapidly overgrows abandoned areas" (Swarbrick, 1997; p. 17).

Mode of infestation:

Mikania can smother, penetrate crowns and choke and pull over plants. It thus causes a significant reduction in the growth and productivity of several crops. It successfully competes with trees and other crop plants for soil nutrients, water and sunlight. The weed can reduce light interception by covering the canopy of trees. Damage due to Mikania is high in young plantations compared to older ones since the weed can easily smother young trees. The adverse effect of Mikania on crops and soil properties is through the production of phenolic and flavanoid compounds.

Uses:

Economic gains due to Mikania are meager compared to the loss due to its infestation in various ecosystems. It is used as a fodder in many countries. Sheep preferentially grazed Mikania in Malaysia and other cattle also relish it. In Kerala,(India) the weed is utilized as a fodder in some parts of the state, especially during summer when availability of grass is scarce. However, Mikania is known to cause hepatotoxicity and liver damage in dairy cattle. Mikania is also reported consumed by rhinoceros as stress food in Jaldapada India (Ghosh C. et. al, 2007). The antibacterial effect of Mikania and its efficacy in wound healing has been reported. In Assam (NE India), Kabi tribes use the leaf juice of Mikania as an antidote for insect bite and scorpion sting. The leaves are also used for treating stomachache. Use of juice of Mikania as a curative agent for itches is reported from Malaysia. However, in all such cases therapeutic evidences are scarce or lacking. In Africa, Mikania leaves are used as a vegetable for making soups. The weed is used as a cover crop in rubber plantations in Malaysia. It is also planted on slopes to prevent soil erosion. Mikania green manure has been reported to increase the yield of rice in Mizoram, India. Recent studies have shown that Mikania is not suitable for mulching and composting due to its high water content.

Mikania propagates from branches and seeds, Seed dispersed by wind or in clothing or hair of animals. Vegetatively reproduces from broken stem fragments. Each node of the stem can produce roots. Use as cattle feed, cover crop, and a garden ornamental helps to spread the species.

Mikania is a genus which consists of about 250 species of herbaceous or slightly woody vines. The most commonly known species are *M. cordata* which is native to and distributed in some tropical countries. *M. scandens* is confined to North America whereas *M. micrantha* is native to tropical America. These species are rapidly growing, rampant vines which smother young tree crops and other plants. They cannot tolerate heavy shade, and contain substances which inhibit the growth of other plants and which depress nitrification rate in the soil. The presence of *Mikania spp*. in forestry and agriculture land, however, may also serve some advantages such as increasing soil macronutrients. Attacking fungus which causes white root-disease of rubber and as green fodder for cattle and other livestock. But these positive influences of Mikania spp. are less than their negative influences (Armantir, 1989).

M. micrantha takes about 5 days to develop from flower bud to full-flower, 5 days from flower to anthesis, and another 5–7 days to produce mature seed (Hu & But, 1994). Between 34 137 and 50 297 flower heads with 136 548–201 188 florets were counted in 0.25 m^2. Each floret contained between 1275 and 2377 pollen grains (Hu & But, 2000). *Mikania micrantha* influences act as a sink for plant reserves. Flower biomass made up 38.4–42.8% of the above-ground tissues and % dry matter of the flowers was 13.6–15.9%, which is higher than that of stems and leaves (Hu & But, 2000). The floret fruiting rate was measured as 68.4% during 12 h day length and the seed germination can reach 96.3% within 6–8 days of production at ambient temperature (Hu & But, 1994). Percentage germination was affected by temperature, the optimum temperature being 25–30C (Yang et al., 2003). Mean percentage germination of autumn and spring seeds differed being approximately 70% and 80%, respectively, suggesting that *M. micrantha* seeds have an after-ripening requirement (Yang et al., 2003).

In1990 Hu and But (1994) studied the life cycle of *M. micrantha* in Hong Kong and found growth could occur throughout the year peaking from March to August. Flowering occurs from September to October, and seed production is from November to February of the following year. In the Dongguan region it was found that the peak growing season was from March to October, flowering from October to December, seed production from November to December and senescence from December to February of the next year (Cao et al., 2003). In a 40m×10m plot beside a pond, six individual plants of *M. micrantha* were marked to monitor weekly growth. From 16 March 2001 to 22 March 2002 weekly growth increments were measured along the main stem. During the rainy season, *M. micrantha* maximum mean weekly growth occurred mid-October and was 47 cm.

The basic photosynthetic characteristics of *M. micrantha* and four associated species were measured and compared by Wen et al. (2000). The associated species included *Miscanthus floridulus* (Labill.) Warb., *Pueraria lobata* (Willd.) Ohwi, *Bidens bipinnata L. and Ipomoea cairica* (Linn.). The study showed that the net photosynthetic rate (Pn) of *M. micrantha* was 21.56 μmol CO_2 m^{-2} s^{-1} under full light. This was higher than that in the accompanying creeper *P. lobata*, and climbing herb, *I. cairica*, and was close to that of the annual herb *B. bipinnata*. Only the grass *M. floridulus*, had a higher photosynthetic rate than *M. micrantha*. This demonstrates that *M. micrantha* has a relatively high CO_2 fixation capacity. The photosynthetic rate and leaf stomatal conductance (Gs) of *M. micrantha* increased 30.7% before noon and

decreased 47.3% between 12:00 hrs and 14:00 hrs. Together with the high light compensation point of photosynthesis (1002 μmol m^{-2} s^{-1}), the time taken for photosynthesis to decline for *M. micrantha* was less than for other under storey shrubs. This suggests that *M. micrantha* is intrinsically a heliophylic species. Compared with *M. floridulus*, minimized to allow native biodiversity to increase. Increased habitat diversity of disturbed areas would provide places for natural enemies to survive and assist in natural biological control (Zhang et al., 2004).

Mikania micrantha grows in orchards, forests, along rivers and streams in disturbed areas, and along road-sides (Kong et al., 2000a). In open areas *M. micrantha* produces cushiony growth with twining roots up to 30 cm thick, while in forests and orchards it grows more than 20 m up and forms a heavy mat smothering the canopy. In Zhujian delta, *M. micrantha* has caused forests to degenerate. In aquatic habitats *M. micrantha* can spread onto ponds to cover or kill aquatic plants including *Eichhornia crassipes* (Mart.) Solm.-Laub. Unlike in its native range, in China this vine grows on dry soils and also on shady sites. *Mikania micrantha* appears to grow best where annual average temperature is usually higher than21^0C and soil moisture is over 15% (Huang et al., 2000). On Wutong Mountain in Shenzhen, *M. micrantha* was found growing above 600 m altitude (Huang et al., 2000).

Changes were studied in soil microbial communities where *Mikania micrantha* was invading a native forest community in Neilingding Island, Shenzhen, China. The results showed that the invasion of *M. micrantha* into the evergreen broadleaved forests in South China changed most of the characteristics in studied soils. Microbial community structure and function differed significantly among the native, two ecotones, and exotic-derived soils. They observed a significant increase in aerobic bacteria but a decrease in anaerobic bacteria in the *M. micrantha* monoculture as compared to the native and ecotones. It was concluded that *M. micrantha* invasion had profound effects on the soil subsystem, which must be taken into account when we try to control its invasions (Wei-hua et al., 2006).

The plants growing on less fertile soil produced fewer flowers, lower seed setting percentage and shorter flowering duration than those on more fertile soil. However, over-fertile soil also resulted in fewer flowers and low seed setting percentage. The plants growing in open habitat had more flowers with longer flowering duration, whereas under shade the grain weight was shown to have a slight increase. The seed setting percentage was highest at 10%-20% of shade

density. Moist soil had no significant effect on grain weight, but obviously led to more flowers, high seed setting percentage and longer flowering duration (Qi-he et al., 2003). On the other hand, with the increasing soil depth, vigor seed decreased. Seedlings mainly came from the seeds in upper layer soil. Seed production and soil seed bank of the three populations of *M. micrantha* were different due to different succession stage of the three communities. Density of seed bank in community in later succession stage was lower than that of in early succession stage of community (Wei-Yin et al., 2005).

Hsu and Chiang, (2003) compared the effects of temperature, pH, water potential, and planting depth on seed germination of the 2 *Mikania* species under controlled environments. Temperatures for seed germination ranged from 8^0 to 32^0 C for *M. micrantha* and 12^0 to 28^0C for *M. cordata*. Initial germination was around 6 days after planting, and accumulated germination reached a plateau at about 60% for both species 2 weeks after planting. Under an illuminated condition, more than 68% of seeds of both species germinated. In darkness, only 3.5% and 25% of seeds of *M. micrantha* and *M. cordata*, respectively, germinated. More than 50% of seeds of both species germinated between p^H 5.5 and 7.5. Seed germination of *M. cordata* was higher than that of *M. micrantha* when the water potential was 0, -0.2, or -0.4 MPa. Seeds of both species failed to germinate when the water potential was at -0.8 MPa or lower. Seedling emergence sharply decreased with increased burial depth, and maximum depth for emergence was between 2 and 2.5 cm. In the greenhouse test, from June through August, results showed that vegetative growth of *M. micrantha* was much stronger than that of *M. cordata* under similar conditions. The invasive *M. micrantha* had longer vines (1.8 times), more leaves (2.1 times), a larger leaf area (7.9 times), and more biomass (13.1 times by fresh weight) than those of the indigenous *M. cordata* at 11 weeks after seedling emergence. The data suggest that the invasive *M. micrantha* is capable of out-competing and displacing the indigenous *M. cordata* in natural habitats (Hsu and Chiang, 2003).

The effect of fire on growth and allocation of biomass and nutrients in *Mikania micrantha*, an early successional exotic weed, was studied in seral communities developed after slash-and-burn agriculture (jhum) in north-eastern India. In success ional fallows, plant vigor was stable in burnt plots, but declined with age in unburnt plots. Biomass and nutrient allocation to seeds was higher in burnt than unburnt 8-year old plots. Nutrient uptake efficiency was higher after burning and increased with age, but decreased with age in unburnt fallows, probably reflecting

differences in soil nutrient availability and competition. Nutrient-use efficiency was inversely related to uptake efficiency and may be a compensatory mechanism for survival. It is concluded that *M. micrantha* is adapted to survival after fire (Swamy and Ramakrishnan 1988).

Shade experiments revealed that seedlings of *M. micrantha* can not survive in light-limited forest under storey, but its root biomass increased significantly as light levels increased, indicating its shade-intolerant nature (Yau-Lun et al., 2002). Shading led to changes in the leaf histological characteristics of *Mikania micrantha*, leaves at higher light intensity being thicker than those at lower light intensity. Phenological observations showed that peak flowering of *M. micrantha* occurred in November and December with prolific seed production of 0.17X106/m^2 coverage. They developed an effective procedure to control *M. micrantha* by cutting the vines near the ground once a month for 3 consecutive months. By applying this procedure in summer and autumn, more than 90% of vines can be eliminated. However, this method was less effective during winter and spring. The allelopathic potential was tested in19 plants against *M. micrantha* seedlings and found that leaves and flowers of Delonix regia showed strong phytotoxicity against *M. micrantha*. Mulching 1-2 g of leaf or flower powder on the pot surface caused 75-90% mortality of *M. micrantha* seedlings within 3 weeks. Spreading a 4% aqueous extract of leaves of *D. regia* on leaves of *M. micrantha* seedlings also resulted in high mortality (Yau-Lun et al., 2002).

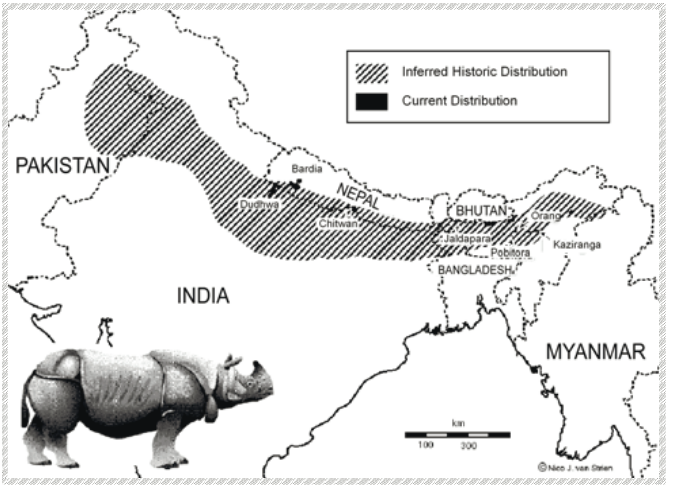
2.4 Distribution of Rhino

The Greater One-horned Rhinoceros (hereafter referred to as rhino or rhinoceros) were commonly ranging throughout the northern floodplain and nearby foothills of the Indian sub-continent between Indo- Myanmar border in the east and Sindhu River basin, Pakistan in the west. Destruction of appropriate habitats combined with poaching has led these animals to limit themselves to a few isolated pockets of protected areas of India and Nepal. Today only about 2,480 rhinoceros survive in the wild and about 136 in captivity (IUCN 1997).

The species now exist in some small population units situated in northern India and Nepal. The rhinoceros prefer to inhabit the alluvial floodplain vegetation of sub-tropical climate where water and green grasses are available all year round. They live on a diet of floodplain grasses, tree saplings, shrubs, aquatic plants, herbs and fruits. Annual monsoon floods altered the spatial distribution of these successional grasslands but maintained prime grazing habitat and high

rhinoceros densities. The study has revealed that a rhinoceros eats the fruits and seeds of at least 30 species of plants (Dinerstein and Price 1991). Populations of rhinoceros have decreased drastically over the last 400 years as a result of land clearing and poaching (Blanford 1988). Once abundant, rhinoceros are now battling for their survival due to heavy poaching and destruction of suitable habitats. This species is less threatened than the other Asian species. With the increase in the use of modern firearms, the farfetched value attached to rhinoceros horn, and the superstitious beliefs put on the magical power of the blood, urine and other parts have exerted tremendous pressure on the survival of this species.

Rhinoceros populations have increased and rhinos have been successfully translocated to re-establish populations in areas where the species had been exterminated in Nepal. The total estimated number of Greater One-horned Rhinoceros in wild is about 2,000 individuals and about 135 individuals in captivity in the world. The historic and current distribution of Asian rhinoceros is given in the following Map…2



Map 1: World distribution of Rhino **Source: Rhino Action Plan (2006-2011)**

2.4.1 Morphology & Ecology

A male may reach over 180 cm at the shoulder with a girth of 335 cm behind the withers. It is smaller than the African White rhinoceros but larger than the African Black rhinoceros. The

rhinoceros may exceed 2,000 kg in weight and have massive build because of their thick and solid bones. The skin is either thinly clad with hair or naked and the heavy hide in places in thrown into deep folds. The skin of rhinoceros is divided into great shields by heavy folds before and behind the shoulders and in front of the thighs. The fold in front of the shoulders is not continued right across the back, a distinctive character of this rhinoceros. On the flanks, shoulders, and hindquarters, the skin is studded with masses of rounded ubercles. With its grotesque build, long boat-shaped head, its folds of armor, and its tuberculated hide.

The rhinoceros is solitary animal and occupy the some patch of forest in Nepal. During the monsoon, they frequently enter into farmlands. They have particular places for dropping its excreta; so mounds accumulate in places. In approaching these spots a rhinoceros walks backwards and falls an easy victim to poachers. Breeding takes place all the time of the year and gestation period is about 16 months. The young at birth are about 105 cm in length and 60 kg in weight. The rhinoceros has among the lowest reproductive rates known for mammals. Inter-calving interval is about 4 years, and females first give birth as early as about 6.5 years. Females nurse babies to the age of 2 years, but by the age of 2 months the calves begin supplementing milk intake with grass shoots, and by 10 months they graze and browse freely. The rhino cows guard young calves intimately; calves become separated from their mothers when cows are chased by breeding bulls and occasionally during long grazing bouts (Laurie 1982).

2.4.2 Rhino habitat

Asiatic rhino species prefer to reside subtropical climate where water and green grass are available all year round. They are of special interest for conservation for their role in maintaining the Terai biodiversity, their phylogeny, ecology and nutritional energetic have evolved around these grassland ecosystems. Rhinos occur in highest densities along the floodplain grasslands and riverine forests bordering the Rapti, Narayani ,Reu and Dhungre rivers suggesting floodplain grasslands as the single mist critical habitat dominated by 4-6m tall *Saccharum spontaneum* (Dinerstein and Price,1991). Grasslands interspersed with patches of riverine forests together make about 30% of park area and are composed of *Saccharum spp, Narenga spp,* and *Themeda spp* (Shrestha, 1995). Due to the flood and vegetation succession the grassland may have substantially decreased. This grass species is the fundamental food resources of rhinoceros comprising more than 60% of the animal diet. Sal forest associated with

Syzigium cumini, Dillennia pentagyna, Lagestromia parviflora, Terminalia tomentosa,T. belarica comprise 70% of the park are seldom used by rhinoceros.

Rhinoceros live on a diet of floodplain grasses, tree, saplings, shrub, aquatic plants, herbs, and fruit. Annual monsoon flood altered the spatial distribution of this successional grassland but maintained prime grazing habitat and rhinoceros densities. The study has revealed that a rhinoceros eats fruits and seeds of at least 30 species of plants (Dinerstein and price 1991).

Population of rhinoceros has decreased drastically over the last 400 years as a result of land cleaning and poaching (Blanford 1988). Once abundant rhinoceros are now battling for their survival due to heavy poaching and destruction of suitable habitats, this species is less threatened than the other Asian species. With the increase in modern fire arms, the farfetched value attached to rhinoceros horn, and the superstitious belief put on the magical power of the blood, urine and other parts have exerted tremendous pressure on the survival of this species.

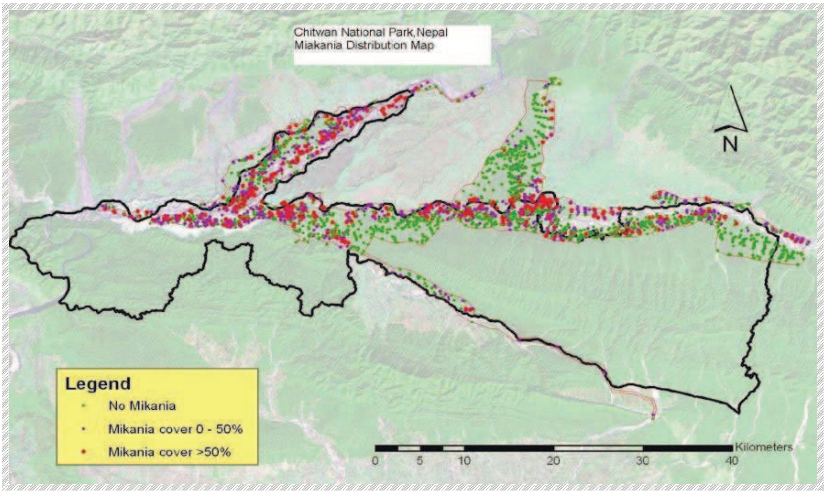
Rhinoceros used three types of grazing habits (Grazing, browsing, and others). The most preferred grass used by rhino is *Saccharum spontaneum, Narenga porphyrocoma, Sacchram bengalensis, pharagmatic karka, Imperata cylindrica, Themeda* sp. etc simultaneously).Similarly rhino used *Trewia nudiflora, Callicarpa macrophylla, Ehretia laevis, Clebrookia oppositifolia, Mallotus phillipinensis* as browsing species.(Jnawali,1995).

Jnawali (1995) identified five habitat types in Chitwan National Park viz. Riverine forest, Sal forest, Tall grassland, Bushy pasture and Cultivated land and in Bardiya ten types of habitat are used by rhinoceros ,viz. Sal forest, Riverine forest, Grassland, wooded grassland,, mixed hardwood forest, bushy pasture, wooded grassland, etc(Dinerstein 1979, Jnawali1995).

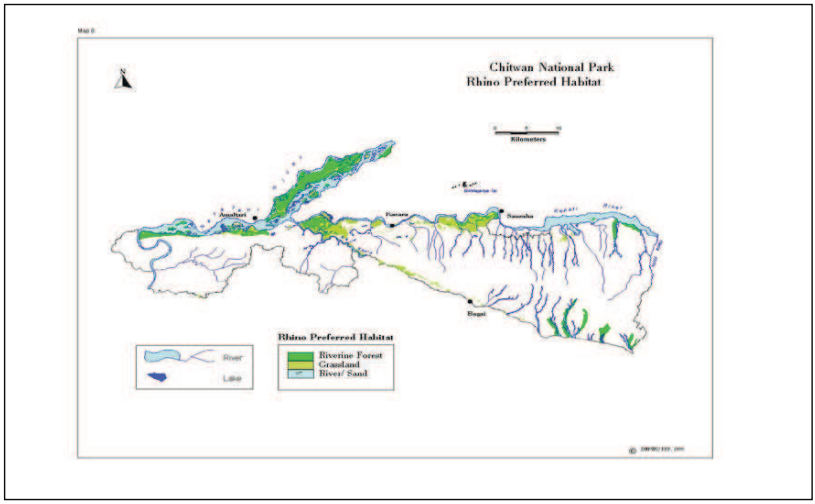
Habitat preference is changed on season basis. Rhino used grassland in hot season where as shrubs in winter season and trees as browsing. A study carried out in Bardiya shows that rhino preferred three types of habitat Khair sissoo forest, Riverine forest and Tall grassland and avoid Sal forest. Among preferred habitat riverine forest was highly preferred by rhinoceros jnawali, 1995). Habitat selection is also differing according to sex .Riverine forest was preferred in all the three seasons by females where as male preferred this habitat only during hot seasons. Khair –Sissoo forest is also preferred by female in all the seasons where as male preferred this habitat only in winter. Similarly Tall grasslands were preferred during hot and monsoon season by

females where as males preferred during the monsoon only. In the monsoon tall grassland are used by both sexes but different usage are found between males and females (jnawali, 1995).

Rhinoceros used more diverse diet in winter than in summer due to scarcity and quality of food, Laurie 1978 conclude that rhinos exploit higher variety of food plant to fulfill their nutritional requirement during the dry season when most of their preferred plant in the tall grassland have reached maturity and are less nutritional. Rhino spends about 8 hours/day in wallows or streams during the period of high humidity (August-September) but they spend at least an hour/day wallowing in December and January (Laurie 1978).



Map 2: Distribution of *Mikania* in Chitwan National Park *(Source: DNPWC)*



Map 3: Rhino habitat in Chitwan NP Source: DNPWC, 2008

CHAPTER III: STUDY AREA

3.1 Geographical location

Chitwan National Park lies between 27°20-27°40'N & 83°52'-84°45'E in the lowlands of southern central Nepal on the international border with India .The Dauney Hills lies on the west bank of the Narayani and Hasta and Dhoram rivers lie 78 km east wards. The park is bounded, north by the Narayani and Rapti rivers and south by the Panchnad and Reu rivers and a forest road. Parsa Wildlife Reserve is contiguous to the eastern boundary of the park and extends (27°15'-27°35'N, 84°45'-84°58'E) as far eastwards as the Bheraha and Bagali rivers (Sapkota, 2007)

3.2 Chitwan National Park

Chitwan National Park is first national park in Nepal, It is also a World Heritage Site, a tourist destination famous for exotic fauna such as the Greater one-horned rhino, tiger, bison, gharial,migratory birds and elephant and crocodile breeding centres. The Bishazari Tal (Lake) is declared as Ramsar site in 2003.Bikram Baba's temple, the Valmiki Ashram and other cultural sites. The Park is connected to Valmiki Tiger Reserve in India. The numbers of faunal species found in the Park include 58 mammals, 539 birds, 56 herpetofauna and 124 fish species. There are 234-recorded vascular plants in the area.

3.3 Buffer Zone

Protected area management approach has changed from protective to participatory and from species to landscape conservation. Nepal has always leaded in participating people in conservation and even sharing park revenue for local community development residing in the buffer zone. The National Parks and Wildlife Conservation Act was amended in 1993 with the provisions of Buffer Zone and sharing of the park revenue (30 - 50%) for community development and conservation activities. The Buffer Zone Management Regulations 2052 (1996) came into effect and as buffer zones CNP and BNP were declared as first bufferzones in Nepal which was the first action on proteced area management by sharing 50% park resource on community development. Since 1996, there are 11buffer zone declared in different protected areas.

Nepal Government has implemented Buffer Zone Management Program in CNP since March 1997, under the buffer zone regulations, the Management Committee received 50% of the park revenue for the implementation of conservation and community development programs in the buffer zone. The buffer zone implementation in CNP was the major intervention to protect the core area of the park through community based natural resource management in the periphery. The most conspicuous intervention of buffer zone promoted encouraging results in mobilizing public participation. The local inhabitants have turned from foes to friends of the park in about 25 years of time. The goal of buffer zone management is to develop CBOs for forging government community partnership for self sufficient supply of forest resources in the buffer zone and conservation of biodiversity in and around the park. The buffer zone management has been prescribed under a set of 17 specific objectives and 17 program components to ensure people's participation in resource management and community development contributing to biodiversity conservation in and around the park (DNPWC/MFSC, 2002& Sapkota, 2007).

3.4 Physical Feature

Chitwan is situated in a river valley basin or dun, along the flood plains of the Rapti, Reu and Narayani rivers. The Someswar and the Dauney hills form the southern catchments and both drain into the Narayani. The Churia Hills bisect the park, their northern face falling within the catchment of the Rapti and southern side forming the catchments of the Reu. The Rapti is bounded by the Mahabharata Range on the north. Both the Rapti and Reu flow westwards and drain into the Narayani, which meanders southwards for about 25km through a narrow gorge between the Someswar and Dauney hills until it reaches the Nepal-India border. There is a dam near Tribenighat. The Narayani is also called the Gandaki and is the third largest river in Nepal. It originates in the high Himalaya and, after joining the Ganges in India, drains into the Bay of Bengal.

3.5 Soil

The Churia, Someswar and Dauney hills constitute part of the Siwaliks which are characterized by outwash deposits carried from the north. All the rocks are of Pliocene or Pleistocene, fluviatile origin, and consist mainly of sandstones, conglomerates, quartzites, shales and micaceous sandstone. The Siwaliks show a distinctive fault pattern that has produced steep cliffs on the south-facing slopes, where vegetation cover is poorer than the northern slopes. The

Mahabharat Range consists of severely eroded pre-Siwalik quartzites, phyllites and sandstones. The flood plains comprise a series of ascending alluvial terraces laid down by the rivers and subsequently raised by Himalayan uplift. The terraces are composed of layers of boulders and gravels set in a fine silty matrix. There is a rough gradient from the higher-lying boulders and gravels to sands and silts and then to the low-lying silt loams and silty clay loams (Bolton, 1975; Laurie, 1978).

3.6 Climate

Chitwan harbors subtropical climate with a summer monsoon from mid-June to late-September and a relatively dry winter. Mean annual rainfall is 2400mm with about 90% falling in the monsoon from June to September. Monsoon rains cause dramatic floods and changes in the character and courses of rivers. Temperatures are highest (maximum 38°C) during this season and drop to a minimum of 6°C in the post-monsoon period (October to January), when dry northerly winds from the Himalaya and Tibetan Plateau are prevalent (Bolton, 1975; Laurie, 1978).

3.7 Vegetation

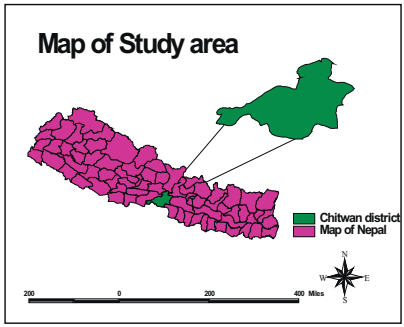
Shorea robusta forest is climax vegetation covers about 70% of the park (Laurie, 1978). However, floods, fires and riverine erosion combine to make a continually changing mosaic of grasslands and riverine forests in various stages of succession. Purest stands of sal occur on better drained ground. Elsewhere, sal is intermingled with chir pine *Pinus roxburghii* along the southern face of the Churia Hills and with tree species such as *Terminalia belerica*, *Dalbergia latifolia*, *Anogeissus latifolius*, *Dillenia indica* and *Garuga pinnata* on northern slopes. Creepers, such as *Bauhinia vahlii* and *Spatholobus parviflorus*, are common. The under storey is scant with the exception of grasses such as *Themeda villosa*. Riverine forest and grasslands form a mosaic along the riverbanks and maintained by seasonal flooding. Khair-sissoo *Acacia catechu-Dalbergia sissoo* associations predominate on recent alluvium deposited during floods and in lowland areas that escape the most serious flooding. *Bombax ceiba-Trewia nudiflora*, with understorey shrubs *Callicarpa macrophylla* and *Clerodendrum viscosum* represent a later stage in succession. Two other types of riverine forest (*Eugenia* woodland and tropical evergreen forest) occur in areas outside the core area of the park. Laurie (1978) identified seven major grassland types, which constituted about 20% of the park's area, but at present, it decreased to

less than 5% due to natural succession and invasion of unpalatable species as stated by Bhatta (2006). *Themeda villosa* forms a tall grass cover in clearings in the sal forest,*Saccharum-Narenga* associations grow as mixed and pure stands of tall grass (*Saccharum spontaneum* is one of the first species to colonize newly created sandbanks); *Arundo-Phragmites* associations form dense tall stands along stream beds on the flood plain and around lakes; *Imperata cylindrica* grows prolifically in areas within the park which were occupied by villages prior to their evacuation in 1964; various short grasses and herbs grown on exposed sandbanks during the dry months and become much more prolific with the outset of rain in May (e.g. *Polygonum plebeium*, *Persicaria* spp. and sedges such as *Cyperus*, *Kyllinga* and *Mariscus* spp.); *Cynodon dactylon* and *Chrysopogon aciculatus* and other short grasses grow in highest areas near riverine forest all the year round (http://www.unep-wcmc.org/sites/wh/chitwan.html). In addition, over 40 lakes identified within core area and several others in the buffer zone support various species of aquatic plants.

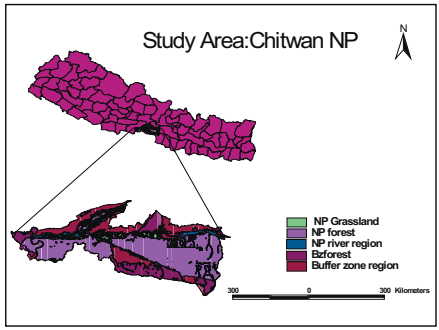
3.8 Fauna

CNP is an important habitat for a large number of endangered mammal's viz. Greater one-horned Rhinoceros, Royal Bengal Tiger, Asiatic Elephant, sloth Bear, Gaur and a number of birds like the Giant Hornbill, Bengal florican, lesser florican, and reptiles like the Gharial and the Mugger crocodiles. Altogether, The Park supports 50 species of mammals, 526 species of birds, 49 species of reptiles' ands amphibians and 120 species of fishes (DNPWC/MFSC, 2002).

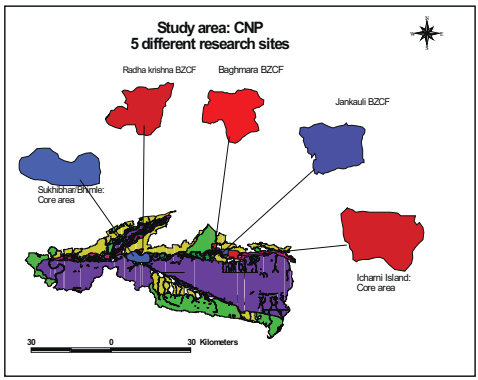
Study area selection showing in different maps.



Map 4 : Chitwan district



Map 5 Study area showing different habitat types



Map 6: Location of study area; different study sites

CHAPTER IV: METHODOLOGY

4.1 Research design

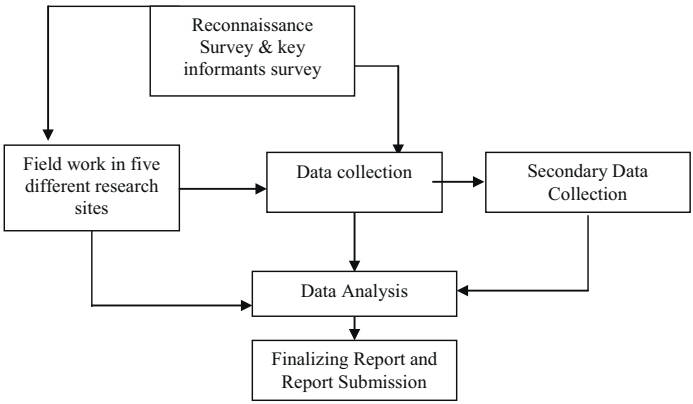


Figure 1: Research design

4.2 Site Selection

After the reconnaissance survey we knew about the habitat preference, *Mikania* invasion site, and finally assigned the research sites. The research sites cover the rhino preferred habitat invaded by *Mikania*. Out of five research sites, two sites were at park core area and next three in buffer zone. The random sample plots (size 10m*10m for trees, 5m*5m for shrubs and 1m*1m for herbs) were laid which covers all the five habitat types including riverine forest, grassland and Sal forest. The study was carried out in five research sites, viz: Baghmara community forest,Jankauli community forest in Bachhauli, Sauraha and Radha Krishna community forest in Meghauli bufferezone. Similarly two researches sites were allocated in the core area of CNP at Icharni Island and Sukhibhar/Bhimle area.

4.3 Methods of Data Collection

4.3.1 Quantitative Data Collection

4.3.1.1 Identification of invasion area and stratification

In reconnaissance, we identify the area of invasion and rhino preferred habitat. Reconnaissance field visits were made by elephants, on foot and by motor and the invaded areas allocated into blocks according to its habitat type.

4.3.1.2 Block Division and Sample Intensity

Each block was divided into various quadrates of 10*10m and these quadrates were randomly assigned, representing 0.25% sampling intensity for tree species and invasion ability of *Mikania*. Within this quadrate, 5*5m quadrates were allocated randomly in two corners for the shrubs and *Mikania* biomass representing 0.025% sampling intensity. Likewise herbs and regeneration were recorded from nesting sampling of 1*1m quadrate within the 5*5m quadrate representing 0.001% intensity. Following figure shows the distribution of nested sampling within main quadrate.

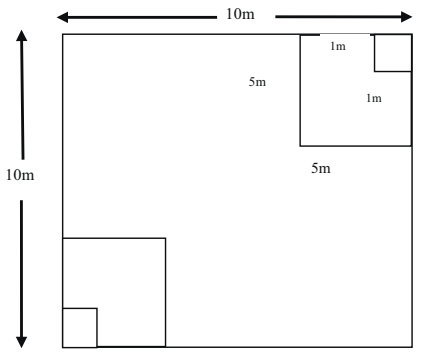


Figure 2: Lay out of quadrates

4.3.1.3 Data collection

All plant species within each quadrate were identified and counted. Due to the sufficient length & countless number of branches, climbing, creeping and highly spreading nature of Mikania and also entangled form of its associate climbers: the actual discrete number of all climber could not be assessed and indirect method as number of invaded tree and the climber species found in the tree were considered to be the number of plants and species accordingly. In case of grassland, *Mikania* was assumed to be $25m^2$/plant in 100% coverage as reported by Tiwari et al., (2005). The plant species were identified with the help of standard literature of plant identification in Nepal and visual inspection by taxonomists. Herbarium in National Trust for Nature Conservation in Sauraha, Chitwan was consulted for the further identification of the species. Invasion ability of *Mikania* on individual plant was ranked in 4 categories depending on percentage of smothering by the weed. Following criteria were considered for the ranking: non invasion (0%), low 0-50% and high above 50%.

4.3.2 Qualitative Data Collection

The qualitative data was collected on the view that either mikania consumption by rhino was seen by respondent oor not. It was also focused on impact of *Mikania on rhino habitat.* Mainly two types of data were collected, e.g. primary and secondary data.

4.3.2.1 Primary data collection

The primary data collection included the view from local key person, farmers, nature guides, park personnel and field observation. Open interview was used to know their ideas on control and management of the weeds.

4.3.2.2 Secondary data collection

The secondary data includes the existing research literature and document survey. Related INGOs such as GISP, CABI, IUCN, and ISSG, DNPWC annual report etc were consulted to receive literature and document on impact of mikania on rhinoceros habitat..

4.4 Statistical Treatment of the Data

4.4.1 Diversity Indices

To compare the distribution pattern in different blocks, either there is heterogeneous or homogenous & even or uneven distribution, Simpson's index was calculated using following formula Simpson's Index of diversity (Simpson 1949 as described by Krebs 1989) was applied for measuring floral diversity.

$$1 - D = 1 - \sum (p_i)^2$$

Where,

D = Simpson Index of diversity

P_i = Proportion of individual species in the community *i*.

4.4.2 Sorensen's Index of similarity (IS_s)

The Sorensen's Index of similarity (Sorensen1948) was employed to compare similarity of plant species in the two habitat types National park and bufferzone.

$$IS_s = \frac{2c}{a+b} \times 100$$

Where,

c = Number of species common to both areas

a =Total no of species in habitat a

b = Total no of species in habitat b

IS_s = Index of similarity.

4.4.3. Simpson's Index (D)

Simpson index measures the probability that two individuals randomly selected from a sample in to the same species (or some category other than species). There are two versions of the formula for calculating **D**. Strictly speaking; the first formula (1) should only be used to estimate an infinite population. The second version (2) is an adaptation of the formula to estimate a finite population. However, with a large sample there is practically no difference between these equations. Either is acceptable, but be consistent.

1. $D = \sum \left(\frac{n}{N} \right)^2$ 2. $D = \frac{\sum n(n-1)}{N(N-1)}$

Where, n = the total number of organisms of a particular species

N = the total number of organisms of all species

The value of **D** ranges between 0 and 1. With this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity. This is neither intuitive nor logical, so to get over this problem, D is often subtracted from 1 to give the species diversity.

4.4.4 Simpson's Index of Diversity (1 – **D)**

The value of this index also ranges between 0 and 1, the greater the value, the greater the sample diversity. This makes more sense. In this case, the index represents the probability that two individuals randomly selected from a sample long to different species.

4.4.5. Shannon-Weiner index.

Shannon-Weiner (S-W) provides a means of comparing the diversity between two or more ecosystems which goes beyond the most basic species-per-unit-area metric. While this simpler metric is useful, in some cases it is desirable to evaluate the equitability of the distribution of the species. An example is a disturbed habitat heavily dominated by a small number of species, but with a few individuals of the original habitat persisting at low numbers. In a more natural system, the native species could be more abundant and the ecosystem more balanced and resilient, despite comparable numbers of species.

S-W takes advantage of the mathematical properties of logarithms which can weight components of a system differently based on the numbers of individuals within a group. While you do not need to understand the theory that underlies this, it is helpful to remember that groups with small numbers contribute less to the S-W index than do more abundant groups.

If all groups contribute the same number of individuals to a community, S-W will be equal to the simpler species per unit area index. As soon as the species become unevenly distributed the Index goes down, depending on the scale of the inequality.

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

H'= index of species diversity

S= species richness (total # of species present)

Pi = proportion of total sample belonging to the ith species

ln= natural log (base e = not the same of log!)

4.4.6 Species richness index (d): It is no of species per sample

$$d = S / \sqrt{N}$$

Where,S= no of species in the sample and N = totalo of individuals.

4.4.7 Species evenness (e): It is degree of relative dominance of species in the sample.

$$e = \bar{H} / \log S$$

Where H= Shannon weinner index & S noof species in the sample.

4.4.8. Species heterogeneity: is reciprocal of SI

4.4.9 Important value Index (IVI)

The important value index (IVI) of each species was calculated by summing the percentage of relative dominance, relative density and relative frequency, each weighted equally for a species relative to a stand as a whole.

IVI= RD+RF+RDOM

Where

RD= Relative density

RF= Relative frequency

RDOM= Relative dominance

i) Basal area is one of the main characters determining dominance and nature of the community refers to the actual ground covered by the stems. It was calculated as following way.

$$\text{Dominance} = \frac{\text{Total basal area of the species}}{\text{Total area sampled}}$$

Basal area (BA) = $\pi (dbh)^2/4$

ii) Relative dominance is the proportion of a species to the sum of basal coverage of all the species in the area, which was calculated as:

$$\text{Relative dominance} = \frac{\text{Combined basal area (BA) of individual species*100}}{\text{Total basal area of all species}}$$

iii) Density refers to the number of individuals per unit area. Density is usually used for large plants that have discrete individuals (Zobel *et al.* 1987).

$$\text{Density of a species} = \frac{\text{Total number of individuals of a species}}{\text{Total number of quadrates sampled} \times \text{size of a quadrate}}$$

$$\text{Relative density} = \frac{\text{Total number of individuals of a species}}{\text{Total number of individuals of all species}}$$

4.4.10 Frequency and Relative Frequency

Frequency of a species is the percentage of quadrates in which the particular species occurs. It gives an index on the spatial distribution of a species and is a measure of relative abundance (Krebs 1978).

$$\text{Frequency} = \frac{\text{Total number of quadrates in which a particular species occurs}}{\text{Total number of quadrates sampled}} \times 100$$

$$\text{Relative Frequency} = \frac{\text{Frequency of a species}}{\text{Sum of frequency values for all species}} \times 100$$

4.4.11 Impact analysis of Mikania

4.4.11.1 Classification of impact and tree measurements

Mikania sign in the form of damage to the trees were classified as follows (Pradhan, 2007)

A killed: trees dead due to mikania

B totally invaded: tree alive but covered totally.

C: tree partially covered

D Other invaded in the ground cover of the trees.

The diameter at breast height (dbh) of all the impacted trees were measured >8cm dbh. The woody stems less than 8 cm dbh were not recorded, as these also invaded by Mikania.All recorded trees were assigned to 4cm intervals DBH size classes.i.e.8-11.9,12-15.9cm, up to 48.cm.

Mikania generally invaded the tree up to 20 m height. Hence classifying dead trees due to mikania was not difficult because mikania invasion was clearly seen. Similarly total invasion,

50% invasion and invasion on the ground were also be recorded. Also total coverage of mikania was recorded. Similarly cover of the other tree species also recorded.

4.4.11.2 Impact Analysis

Based on square plots, and Index of species Reduction (ISR) for major tree species was calculated using formula:

ISR= (A*B)/C

Where,

$$A = \frac{\text{Numbers of impacted species X}}{\text{Number of trees species X}}$$

$$B = \frac{\text{Number of killed species of X}}{\text{Number impacted trees of species X}}$$

$$C = \frac{\text{Number of pole sized trees (8-12.0cmdbh) of species X}}{\text{Number pole size trees of all species}}$$

4.4.12 Prominence value

To calculate the prominence value, the percentage cover of each species is assumed, estimated in each quadrates recorded in classes as follows. For high coverage =>50%, medium=26-50%,low =0-25%.These data were used to calculate prominence values for each species(Jnawali,1995) as follows. PV is used to calculate the availability of plants in the research sites.

$$PV_x = M_x(\sqrt{f_x})$$

PV_x = Prominence value of species x
M_x = Mean percentage cover of species x
f_x = Frequency of occurrence of species x

4.4.13 GIS and it use in habitat management.

Geographical information system (GIS) is a computer based technology that can store, manipulate, and produce a wide range of environmental, demographic and economical information to support resource management initiatives (Shrestha et. al 2000). GIS has unique ability to interrelate information stemming from range of sources and these capabilities can easily be transferred to the fingertip of the users. Therefore GIS can be a useful tool for Wildlife habitat inventory, mapping and analysis and also habitat management planning activities in reliable, faster and economic way.

In this study GIS soft wares were used to prepare the Mikania distribution map, with help of cartalinx, Arc view 3.2, and Arc view spatial analyst. Cartalinx was used for digitizing the base maps, Arc view 3.2 was used sorting and managing data and Arc view spatial analyst was used for analyzing spatial relationship.

4.4.14 Data analysis:

SPSS.12 version was used for analyzing the perception of people about mikania either mikania was consumed by domestic cattle as well the wildlife or not. Major concern was given to rhino either mikania was consumed by rhino or not. Similarly MS Excel was used to analyze different species diversity indexes.

CHAPTER V

RESULTS AND DISCUSSION

The Mikania weed has been proliferated rapidly in forest trees, grasslands and wetland areas of the Chitwan National Park and its buffer zone. Heavy invasion of the weed observed in the buffer zone forest (50-80%) followed by core area (20-50%). The core and buffer zone area was undisturbed where human pressure was minimal, so Mikania has got opportunity to spread rapidly covering a large area, and only peoples were permitted for cutting grasses in both buffer zone and core area.

5.1 Diversity of Species

5.1.1 Species individuals curve:

The species individual curve shows the area wise species richness and total no of the plant in the different research sites. Species- area curve is shown here in site wise as illustrated in the following figures.

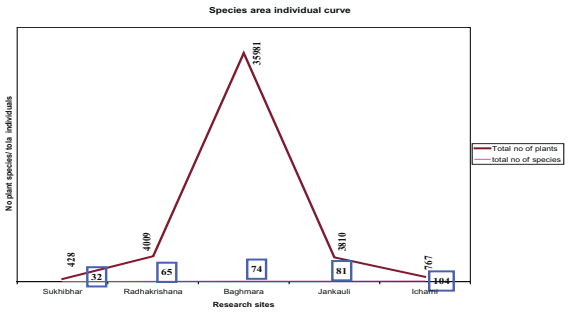


Figure 3: Study area wise species individual curve

5.1.2 Calculation of species diversity indexes

5.1.2.1 Shannon-wiener index diversity (H')

The diversity of species in each habitat types was calculated by using the Simpson diversity index and Shannon - Weiner diversity index. Shannon-Weiner (S-W) provides a means of comparing the diversity between two or more ecosystems which goes beyond the most basic

species-per-unit-area. Shannon-wiener index diversity (H') varied from Baghmara (H'=1.03) to Icharni(H'=2.52). it was much higher in three different study sites Icharni island , sukhibhar and radha Krishna BZCF.The maximum diversity was recorded (H'=2.52) in Icharni isaland and Minimum(H'=1.03) for Baghamara. Similarly the Simpson index is a measure of diversity. In ecology, it is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the abundance of each species.

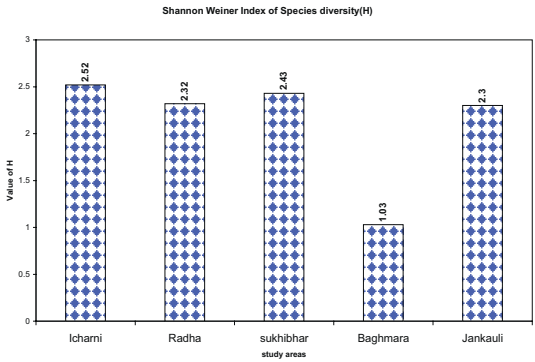


Figure 4: Shannon-Weiner index of species diversity for different study sites (see table 4.)

5.1.2.2 Simpson's Index of Diversity (1 – D)

Simpson's Index of Diversity (1 – D) and value ranges between 0 and almost 1, the greater the value, the greater the sample diversity. This makes more sense. In this case, the index represents the probability that two individuals randomly selected from a sample will belong to different species. The details of diversity indices are given below:

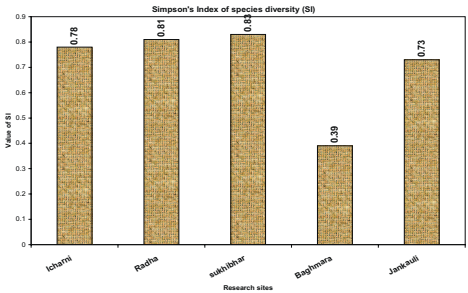


Figure 5: Simpson index of diversity for different study sites.

From the above figure it is clear that Sukhibhar has high Simpson diversity index (SI=0.83) followed by Radhakrishna (SI=0.81) and Icharni island (0.78). it was also seen that Baghamara has lesser Simpson diversity index value (SI=0.39).As we know greater the SI value the greater the diversity of abundance of the species, therefore it is clear that sukhibhar/ Bhimle area has greater diversity and Baghmara has lesser diversity. (see table:1)

5.1.2.3 Species richness Index (d): no of species per sample (See table: 1)

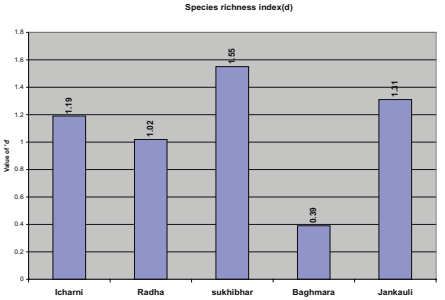


Figure 6: Species richness index

5.1.2.4 Species evenness (e): It is degree of relative dominance of the species.

5.1.2.5 Species heterogeneity: It is reciprocal of SI.

Table 1:Study area-wise species diversity index.

Research sites	species richness	Shannon Weiner Index(H')	Simpson's index (SI)	Species richness Index(d)	Species evenness (e)	Species hetrogenity(sh)
Icharni	104	2.52	0.78	1.19	0.005	2.13
Radha	65	2.32	0.81	1.02	0.008	5.37
sukhibhar	32	2.43	0.83	1.55	0.001	2.45
Baghmara	74	1.03	0.39	0.39	6.65E-06	1.28
Jankauli	81	2.3	0.73	1.31	0.00032	3.785

5.1.2.6 Sorensen Index (index of similarity (Iss) sorensen,1948)

The Sorensen Index (Index of similarity- ISS) shows that 74.33 percent of plant species are similar among two habitat types (buffer zone and National Park forest area) Although our study was concentrated in 5 different habitat types (2 sites were in core area and three sites were in

Buffere zone). The Sorensen index of similarity was used to compare the habitat composition between the bufferzone and core area and it shows that 73.33% similarity between the two habitats.

5.1.2.7 Important Value index (IVI)

We calculated the species diversity of research each sites for trees , vegetational data were collected following broad principle described by Misra (1968) and Muller –Dombois and Ellenberg (1974).The data were quantitatively analyzed for relative values of dominance. The sums of all the relative values are represented as important value index (IVI) in table 2. The IVI of a species indicates its dominance and ecological success, its good power of regeneration and greater amplitude; We concluded from the table, among five research sites major tree species *Accacia catechu,Bombax ceiba, Dalbergia sisso,Triwia nudiflora* were fond all in the five sites.

In Jankauli BZCF*, Triwia nudiflora* (IVI=53.80) was found most dominant followed by *Dalbergia sissoo*(IVI=27.43) and *Bombax ceiba* (IVI=18.18). In Baghmara BZCF *Albizia lucida (IVI=26.91)* was found most dominant followed *Triwia udiflora (IVI=23.10) and Dalbergia sissoo(21.91),* In Icharni island *Triwia nudiflora* (IVI=47.35) was found most dominant followed by *Bombax ceiba* (IVI=29.95) and *Dalbergia sisso* (IVI=10.87). In Radha Krishna BZCF the most dominant tree species was *Bombax ceiba*(IVI=54.36) followed by *Dalbergia sisso* (IVI=35.14)& *Litsea monopetala*(IVI=14.40) and finally in Sukhbhar/Bhimle area *Triwia nudiflora*(IVI=61.39) was most dominant followed by *Shorea robusta* (IVI=30.86) and *Litsea monoptala*(IVI=9.95).

It was seen that *Triwia nudiflora was* found most dominant in among all the sites, although it was also co-dominant in another sites. See in table (2)

Table 2: Study area wise Important Value index of some important tree species.

	study area wise Important value Index				
Name of the plant	Jankauli	Baghmara	Icharni	Radhakrishna	Sukhibhar
Accacia catechu	5.88	2.68	5.60	14.16	5.26
Albizia lucida	2.79	26.91	3.64	0	0
Bombax ceiba	18.18	6.22	29.95	54.36	7.73
Annona squamosa	1.00	0	0	1.00	0
Dalbergia sissoo	27.43	21.91	10.87	35.22	8.05
Litsea monopetala	4.20	4.46	6.099362	14.40	9.95
Shorea robusta	0	0	0	0	30.86
Disoccilum binecteriferum	0.34	0.04	0.76	1.15	1.33
Triwia nudiflora	53.80	23.10	47.35	31.52	61.39
Miliusa velutia	2.45	11.53	3.58	17.57	2.64
Ehretia elliptica	0	0.04	2.63	2.68	2.13
Cornea bichotoma	0	1.87	0.0031	1.87	1.33
Luculia gratissima	0.29	0.84	0.41	1.56	0
Adina cordifolia	0	1.35	0	1.35	1.33
Melia azedirach	0.85	1.35	0.87	3.083	0

5.1.2.7 Prominence value (PV):

To calculate the habitat preference and food habitat used by rhinoceros we calculated prominence value (PV). Prominence value gives the abundance of food plants(see in table 3) .It was seen that in grass species ,*Sacchrum spontaneum* was the most abundant species in tall grass land (PV=254.55),*Themeda* was common in Sal forest (PV=44.72) and in short grassland *Imperata cyllindrica* (PV=448.99)was most abundant. Among important brows species *Coffea bengalenslis* (PV=60) and callicarpa macrophylla (PV=32.31) found to be most abundant in riverine forest.Similarly in case of tree species *Litsea monopetala* (PV=15.49) and *Triwia nudiflora* (PV=326.31) are found to be most abundant in riverine forest. The food plants species of rhinoceros recorded in the field in dung sites and described by jnawali SR, are listed in the table . Among the species listed above, rhinoceros eat only the mature fruit of *Triwia nudiflora* fallen in the ground during the monsoon. Similarly, only seed bearing pods of Cassia torra and Cassia accidentalis and flowers of Bombax ceiba were recorded to be eaten. It was seen that highest proportion of wild food plants occurred in tall grass land and riverine forest. Wild animals in Chitwan foraged on larger proportion food plants than in Sal forest. (Jnawali, 1995).

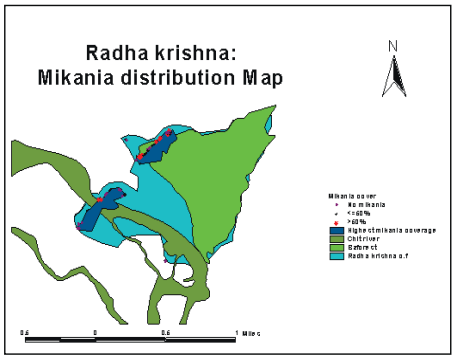
Table 3: Prominence value of some food plant species eaten by rhinoceros

Name of the plants	No of individuals	Frequency(fx)	Mean cover of individual species (Mx)	Prominence value(PV)
Litsea monopetala	54	60	2	15.49
Mallotus phillipinensis	50	60	5	38.72
Callicarpa macrophylla	173	116	3	32.31
Coffea bengalensis	78	100	6	60
Imperata cyllindrica	30509	56	60	448.99
Phragmatic karka	11	20	1	1.54
Saccrum spontaneum	1816	72	30	254.55
Themeda	320	20	10	44.72
Triwia nudiflora	73	220	22	326.31

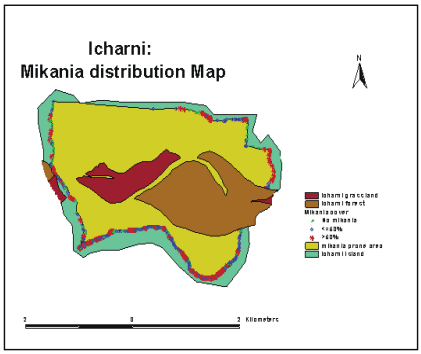
5.1 GIS Mapping of Mikania in different research sites

GIS Map was prepared by using GIS software. The detail Mikania distribution map is given below.

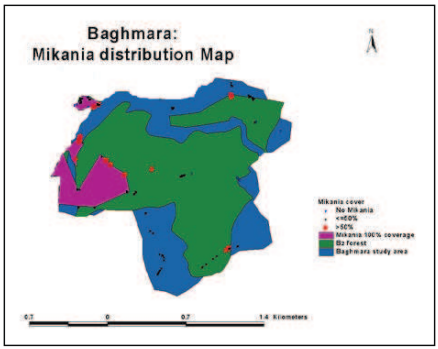
Mikania distribution Map of different study sites in Chitwan National Park and Buffer zone are as follows.



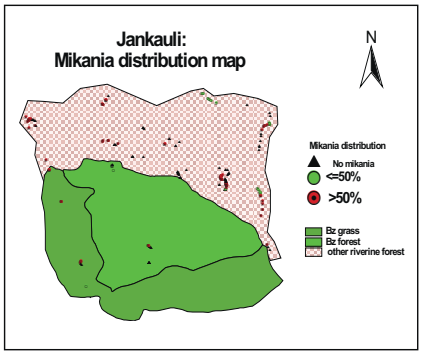
Map 7: Mikania distribution, Radhakrishna



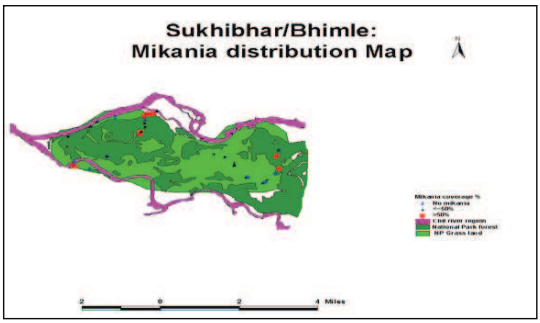
Map 8: Mikania distribution, Icharni Island



Map 9: Mikania distribution, Baghmara



Map 10: Mikania distribution, Jankauli



Map 11: Mikania distribution, Sukhibhar

5.3 Mikania impact assessment on rhinoceros habitat

5.3.1 Area of Invasion

5.3.1.1 Jankauli Community Forest

The total area of Jankauli Community Forest (JCF) is 65 hectares as assessed during the study and most of the woodland (except small piece in western block) is invaded by *Mikania*. Entire grassland of the Community Forest which lies in southern boundary along the bank of Dhugre Khola is free from the weed. The invasion was assessed as 56 hectares which comprises 86% of the total area. The major tree species found in the invaded woodland are *Trewia nudiflora, Litsea monopetala, Dalbergia sissoo, Ehertia elliptica* and *Bombax ceiba* followed by *Pogostemon benghalensis, Callicarpa macrophylla* and *Achyranthus aspera* etc in shrub, *Eragrostis unioloides, Aquisetum debile, Ageratum conizoides* and *Diplazium esculentum* etc in herb and associate major climbers are *Parthenocissus semicordata, Trachelospermum fragrans* and *Piper longum*. Mikania invasion map was prepared by using GIS. (See Map10 , page 49)

5.3.1.2 Icharni Island

The total area of the Island is assessed as 394 hectares comprising of 174 and 220 hectares of riverine woodland and grassland respectively. 60% and 35% as 104 and 77 hectares of woodlands and grasslands are affected by the weed invasion respectively. The invasion of *Mikania* was observed along the river bank, edge and low canopy area in case of woodland, whereas the grassland with sparse tree, shrub moist soil was found to be highly favorable for the weed. The southern part of the grassland is less invaded as compared to northern and western part. The major tree species of invaded area of woodland are *Ehretia elliptica, Myrsine chisia, Litsea monopetala, Trewia nudiflora* and *Murraya keinigii* followed by *Pogostemon benghalensis, Callicarpa macrophylla, Colebrookia oppositifolia*. Continuous block of *Mikania* invasion was not found in the area and *Coffea benghalensis* was found to be prominent shrub in absence of the weed. The herb species are *Eragrostis unioloides, Aquisetum debile, Diplazium esculentum, lepisorus bicolor* etc and the associate climbers are *Bredelia retusa, Parthenocissus semicordata, Trachelospermum fragrans* etc. Likewise, major tree species in grassland are *Trewia nudiflora* and *Litsea monopetala* followed by *Callicarpa macrophylla, Sida acuta* and

Solanum torvum etc in shrub and *Imperata cylindrica, Saccharum spontaneum, Diplazium esculentum* etc in herb. The associate climbers and creeper are *Coccinea grandis, Parthenocissus semicordata* etc. It was seen that 18 trees/poles were impacted due to mikania and average mikania cover was 40%.(See map 8, Page 49)

5.3.1.3. Baghmara Buffer zone community forest

The Baghmara community forest, located in the Southern plains of Nepal.In a initial stage Baghamara was highly degraded land and planted with fast growing fodder and timber species of sisoo (*Dalbergia sisoo*) and khair (*Acacia catechu)* and some fodder saplings. The total area is 215 hectare has already handed over to the Local User's Group Committee (UGC) for its management and utilization. The major tree species were *Albizzia lucida, Accacia catechu, Dalbergia sisso, Bombax ceiba, Litsea monopeta* etc,The major grass species found were *Sacchrum spontaneum, Imperata cyllindrica, Hemertheria comparusa* (ghode dubo), *Eragotis upioloids* (Banso) and other herb species dominant were *Coffea bengalensis* and *Pogostemon bengalensis*.

The major tree species impacted were *Accacia catechu* and *Triwia nudiflora* etc and the grass species smothered by *Mikania* were *Imperata cyllindrica*, *Hemartheria comparusa* and *Eragotis upiloids.*In sample area 14 tress and poles were found impacted in which five were killed due invasion of mikania.It was estimated that about 50% of forest area is smothered by Mikania.(See Map 9 ,page 49)

5.3.1.4 Radhakrishna Community Forest.

The total area Radha Krishna BZCF is 59 hactare and lies in Meghauli VDCc. The forest has already been handed over to the Local User's Group Committee (UGC) for its management and utilization. The major tree species were *Accacia catechu, Dalbergia sisso, Bombax ceiba, Litsea monopeta* etc,The major grass species found were *Sacchrum spontaneum, Imperata cyllindrica, Hemertheria comparusa* (ghode dubo), *Eragotis upioloids* (Banso) and other herb species dominant were *Coffea bengalensis* and *Pogostemon bengalensis* and fern species were *Tectoreia macrodonta,Diplazium esculenta* and *Pteris vittata.*This forest harbors good habitat for rhino. The other wildlife seen in the forest were Hog deer and barking deer.

The major tree species invaded by mikania were Bombax ceiba and Dalbergia sissoo including Accacia catechu and Triwia nudiflora.Out of 20 impacted trees 5 were found killed by mikania and there was also found that wetlands were also covered by mikania. In wetland mikania formed a mat like structure above Echornia specis.(See Map 7,Page 49)

5.3.1.5 Sukhibhar & Bhimle area

Sukhibhar/ bhime area is the core area of CNP. The total area covered during study was 150 hactare.Since the aim of the research is to cover all the *rhinoceros* habitat type that is covered by mikania this area is also inventoried. The major tree species are *Triwa nudiflora, Bombax ceiba,Dalbergia sissoo, Acciacia catechu, Litsea monopetala* in riverine forest and *Shorea robusta* in Sal forest.The major grass species were themeda in tall grassland and *Sacchram bengalensis* were found near the river site. It was also seen that *Sacharam bengalensis* is succeeded by *Imperata Cyllindrica a*nd *Imperata cyllindriaca* is succeeded by Rivereine forest. The major tree species invaded by mikania were *Accacia,Triwia and Bombax*.There were two poles size of tree of sisso were found dead due to mikania. The average invasion was about 25 % in sukhibhar/ bhimle area. (See Map 11 Page 49)

5.3.2. Invasion Ability

A single plant of Mikania can cover 20-25 sq.meter and it was also observed that 30-40 young plants were grown the suckeres of a single plant. The top part of mikania dries up every year but suckers of main stalk may serve for several years.

It was found that most of the small trees, shrubs and herbs were severely smothered in the invaded area and only some herbs like *Ageratum conizoides, Eragrostis unioloides, Aquisetum debile, Diplazium esculentum, Lepisorus bicolor* and *Tectoria macrodonta* were observed to be able to penetrate out through the entangled form of *Mikania*. *Imperata cylindrica* and *Saccharum spontaneum*, which are considered to be favorable grass for herbivores, were found to be dead and no new culms were sprouting from the rootstock in the invaded area. The invasion ability on major tree species were assessed and tabulated below

Table 4: Assessment of invasion ability on major tree species

S.N.	Species	Invaded Condition				Remark
		None	Low	Medium	High	
1	*Bombax ceiba*			√		DBH below 8-17 cm were killed .DBH above 30cm. were none invaded.
2	*Dalbergia sissoo*				√	DBH ranges from 10 to 20 cm were invaded and killed
3	*Trewia nudiflora*		√			No dead tree found, lower invasion on large trees
4	*Litsea monopetala*				√	No dead tree was found and all sizes trees were invaded
5	*Premna barbata*	√				No dead
6	*Ehretia elliptica*		√			No dead
7	*Acacia catechu*				√	8-24 cm were impacted and 12-19 dbh were found killed
8	*Myrsine chisia*	√				No dead
9	*Murraya koenigii*		√			No dead

The invasion of the weed decreases with the increase of canopy closure, which shows the intolerance of shade. Nevertheless, the grassland with sparse trees and shrub is observed to be highly prone to invasion by the weed. 100% open grassland shows the less favorable for the weeds. 0% canopy closure shows the 0-25% of invasion and >0-25% canopy closure receives 76-100% invasion by the weed. The relation between canopy closure and the invasion of the weed is illustrated in the following table.

Table 5: Relation between canopy closure and invasion of the weed (Sapkota, 2007)

Canopy closure	0%	>0-25%	26-50%	51-75%	76-100%
Invasion quantities	0-25%	100-76%	75-51%	50-26%	25-0%

So it is concluded that the invasion ability of the weed is same in 0% and 76-100% canopy closure and it is inversely proportional when 0% exceeds.

5.3.3 Presence or absence of Rhinoceros in relation to percentage coverage of mikania on different research sites.

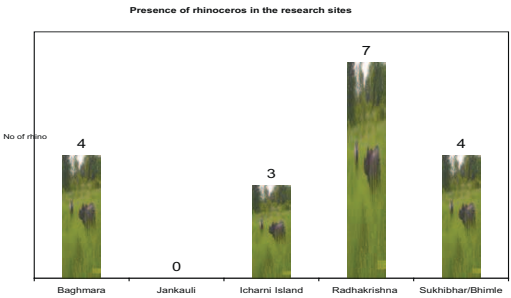


Figure 7: Presence of Rhino in different study area during research.

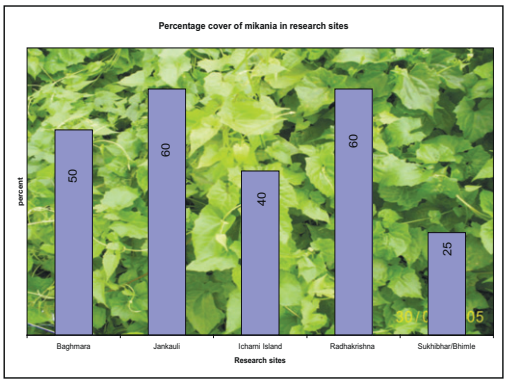


Figure 8: Research site wise mikania cover in percentage

From the above figure it is clear that presence of greater number of rhino was seen 7 in the Radha Krishna bufferzone community forest where Mikania coverage greater than 50% and followed by Sukhibhar number of rhino 4, mikania coverage is less than 50%,Baghamara buffer zone community forest 4, and mikania coverage about 50%,Icharni Island 3,mikania invasion about 50% and in there in no any rhino found in the Jankauli buffer zone community forest, where mikania coverage greater than 50%. Therefore it is clearly seen from the above figure that coverage of mikania also affect the presence or absence of rhinoceros in the research sites. (See figure 7, 8)

5.3.4 Distribution, density and frequency of Mikania in different research sites.

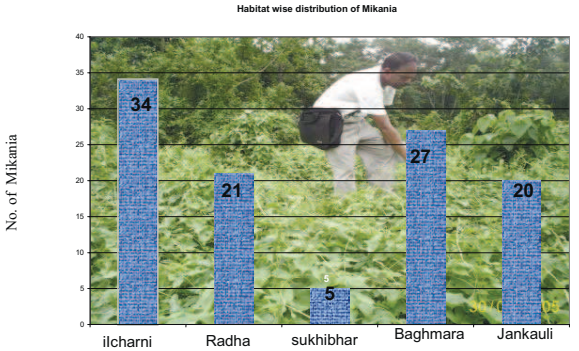


Figure 9: Numeric distribution of Mikania in research sites.

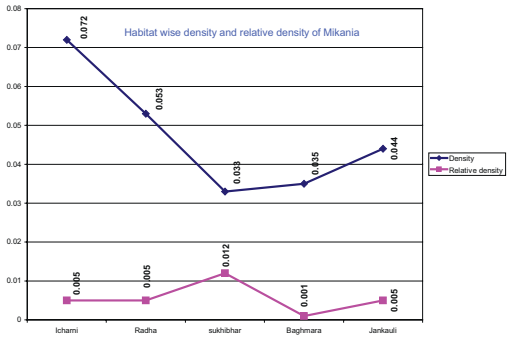


Figure 10: Habitat wise distribution of mikania (density and relative density)

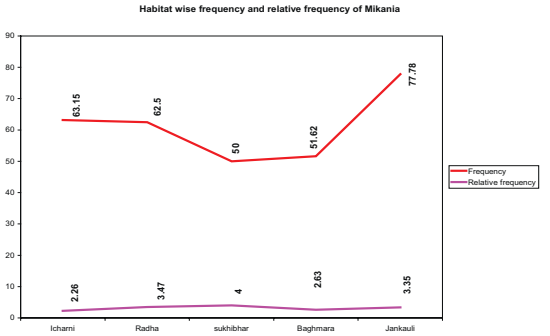


Figure 11: Habitat wise distribution of Mikania (frequency & Relative frequency)

Table 6: Distribution of Mikania according to habitat

Research sites	No of plants	Density	R. density	frequency	R. Frequency	no of Mikania / ha
Icharni	34	0.072	0.005	63.15	2.26	714
Radha krishna	21	0.053	0.005	62.5	3.47	
Sukhibhar	5	0.033	0.012	50	4	
Baghmara	27	0.035	0.001	51.62	2.63	
Jankauli	20	0.044	0.005	77.78	3.35	

5.3.4 Mikania impact on rhinoceros habitat.

Mikania impact on rhinoceros habitat depends upon type of habitat and moisture condition of the habitat. It was seen that floodplain, riverine forests, grasslands are found severely smothered by mikania where it was seen Sal forest were still safe from mikania. Though it was seen mikania slowly and gradually entering in to the Sal forest.In Sal forest, Mikania slowly penetrate with invading on *Themeda arundinaceae*.(khadai).*Themeda* was slowly pioneering in to the Sal forest and it was seen invaded by mikania.

Generally it was seen that, mikania invasion was in the undisturbed riverine forest, flood plains and grasslands, swampy areas and some of the wetlands. The major impact seen on vegetation are on trees, shrubs and herbs. In the tree species *Accacia catechu, Dalbergia sissoo* and *Bombax ceiba* was found severely impacted by mikania.To show the mikania impact on trees Index of species reduction is also calculated. See in the following chart.

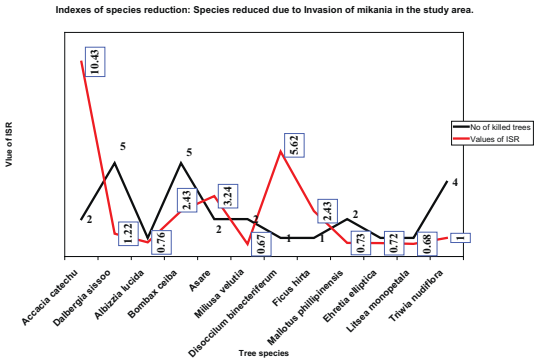


Figure 12: Index of species Reduction for tree species

The above figure represents indices of species reduction (ISR) value of different species and indicated that *Accacia catechu* (ISR=10.43) followed by *Disoccilum binecteriferum(ISR=3.24, Murraya koenigii(ISR=3.24,),Bombax ceiba(ISR=2.43)and Dalbergia sissoo(ISR=1.22) (see in table 7)* shows that the most vulnerable tree species impacted by mikania is *Accacia catechu* followed by *Disoccilum binecteriferuma*, *Murraya koenigi and Bombax ceiba.*

Table 7: ISR value of different tree species impacted in the study areas.

Species name	Killed	A	B	C	ISR=(A*B)/C
Accacia catechu	2	0.57	0.25	0.01	10.43
Dalbergia sissoo	5	0.97	0.17	0.13	1.22
Albizzia lucida	1	0.13	0.08	0.01	0.762
Bombax ceiba	5	0.8	0.25	0.08	2.432
Asare	2	0.53	0.25	0.04	3.242
Miliusa velutia	2	0.15	0.18	0.04	0.67
Disoccilum binecteriferum	1	0.38	0.2	0.01	5.62
Ficus hirta	1	0.4	0.17	0.02	2.4323
Mallotus phillipinensis	2	0.24	0.17	0.05	0.73
Ehretia elliptica	1	0.20	0.14	0.04	0.72
Litsea monopetala	1	0.092	0.2	0.02	0.67
Triwia nudiflora	4	0.12	0.444	0.05	1

Table 8: Study area wise impact seen in rhino habitat

Types of impact/ research sites	No of trees killed	Total poles impacted	Total tree/poles impacted	Impacted tree species	Mikania coverage in grassland %
Jankauli	6	8	18	*Accacia, Dalbergia, Bombax*	60%
Baghmara	5	3	14	*Accacia, Dalbergia, Bombax*	50%
Icharni Island	9	5	19	*Accacia, Dalbergia, Bombax*	40%
Sukhibhar	2	3	6	*Accacia, Dalbergia, Bombax, Triwia*	25%
Radha krishna	5	10	20	*Accacia, Dalbergia, ombax,Triwia*	60%

5.3.5 Impact analysis by comparing the Mikania invasion with rhinoceros habitat

Mikania impact on rhinoceros habitat is also analyzed by comparing the mikania invasion map (Map 1,page 27)and rhinoceros habitat map(see Map 3,Page 27).It is clear from the above figure that most of the rhino preferred habitat is invaded by mikania.

5.3.6 Population Trend of Rhinoceros in CNP

Population trend shows that in yearly stage there were lots of rhinoceros during 1950 but time being it was seen that population of rhinoceros was dropped down to 408 individuals. The population of rhinoceros was dropped down due to poaching and habitat alteration. One of the major causes for rhino habitat loss is shrinkage of grassland, riverine forest and wetland due to invasion of mikania. With the increase in habitat alteration due to mikania invasion, rhinos were compelled to move towards the buffer zone area and may be the victim of poaching and some time rhino might be the victim of poisoning and electrocuted in cropland. Therefore it was also seen an indirect impact on rhino by mikania. The population trend of rhinoceros shows the slows down pattern of rhinoceros in CNP.Details are given in the following figure 13.

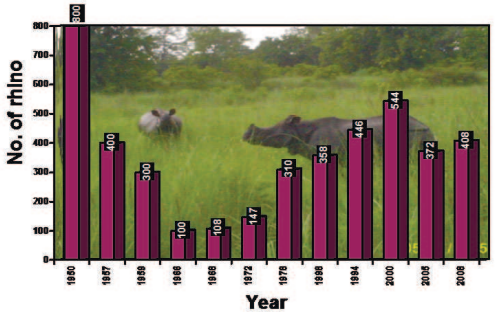


Figure 13: Population trend of rhino

5.3.7 Response of people regarding Mikania invasion and Rhinoceros habitat in CNP

To know about the perception of people about mikania on rhinoceros habitat we interviewed with park staff, Hotel staff (inside National park hotel),Naturalist and Nature guides, Local people (herder, grass cutter, Buffer zone committee members), National park authority, NTNC staff, Elephant stable staff of CNP and found the following results.

5.3.7.1 Response of people about mikania consumption:

It is seen from the figure that 69 % of respondent said that mikania is consumed by rhino and 31% people said that mikania was not consumed. It is clear here that only few people who were in contact with rhino (either in form of patrolling, guiding tourist, grass cutting, guarding the forest or Elephant staff) had seen that rhino ate mikania in small amount.(see figure 14) and the mode of eating was grazing only mikania, grazing with grass, browsing with grass. 12% respondents said that rhino eat mikania only,27% said graze with grass and 23% says mikania browsed with grass.(fig 15)

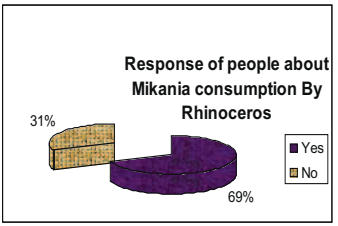


Figure 14: Response of people about mikania

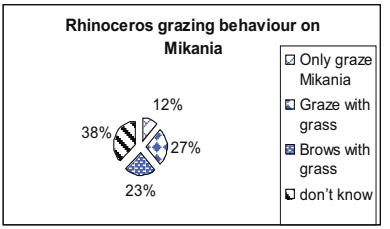


Figure 15:Rhino grazing behavior on mikania consumption.

5.3.7.2 Response of people about food habit of rhino on mikania:

It was found that majority of respondent respond that rhino ate mikania only as stress food and emergency food in lean period. The response of people is given in following figure 16.

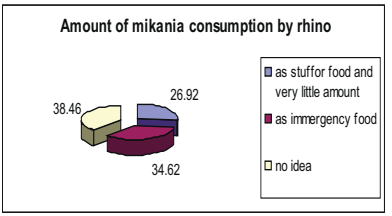
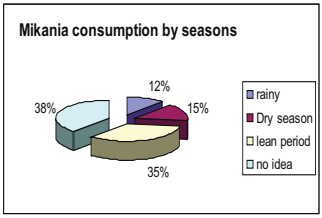


Figure 16: Amount of Mikania consumption by rhino.

5.3.7.3. Response about the season of mikania consumption by rhino & grazing pattern of rhinoceros.



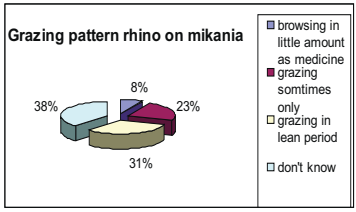
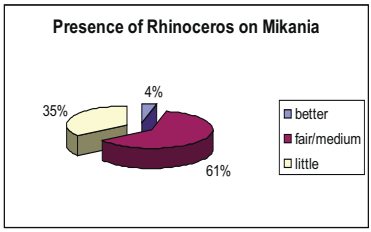


Figure 17: Mikania consumption by seasons.

Figure 18: Grazing pattern of rhino on Mikania.

It is seen from the response that rhino eat mikania in rainy season, dry season and winter season (lean period). The response is given in figure 17.

5.3.7.4 Response about the presence of rhino on Mikania habitat and destruction of rhino habitat by mikania.



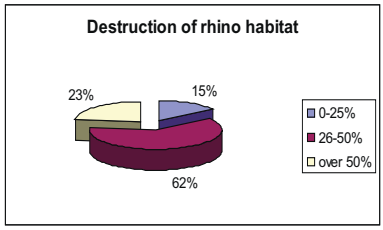


Figure 19: Presence of rhinoceros on Mikania.

Figure 20: Destruction of rhinoceros habitat by mikania according people's perception

5.3.9 Habitat Use by Rhinoceros

A rhino is expected to feed based in an area where its highly preferred food types are most abundant (Laurie,1982)they can not fully rely on only either grassland or mixed forest rather mosaics of all those including ecotone type of habitat are important for the one horned rhinos.

Considering total time spend in different habitats as habitat use, rhino clearly preferred riverine mixed forest and grassland. However, from the result of the compositional analysis for specific

activities, it is evident that rhinos have different habitat preference for different activities. For foraging they prefer grassland and ecotone, for resting there was clear preference for riverine mix forest. Thus, by just considering the overall habitat preference of rhinos, one would tend to miss out the critical needs of certain habitats for specific activities. It is evident that a landscape has a mosaic of grassland, ecotone and riverine mixed forest would be ideal for rhinos since these would, then meet all the various needs of the species.

Grassland is the most important habitat to acquire food and riverine mixed forest &ecotone are equally important side by side, though rhinos spend less time in those compared to grassland for foraging. Major portion of the rhino diet was composed *Sacchrum spontaneum.Imperata cyllindrica ,Phragmites karka* compared to other species, this shows that they largely rely on short grasslands (Litvaitis,1996,Peet et.al 1999) for obtaining food. Short grassland is the most suitable feeding ground during the winter as also(Laurie,1982& Owen smith,1988). Other species like *Cleroendendron viscossum,Tetrastigma serrulatum, Equisetum devile* are eaten but they contribute less than 1 percent dry matter to their over all diet due to their low availability and highly seasonal habit. Greater proportion of time was spend in riverine mix forest and ecotone where they get food, shelter and wallowing places as well. It was clearly observe that the animals spend time moving for assessing either food resources, resting places, water sources from one location to the next. It implies that the management of water resources in well dispersed manner is and essential variable for the appropriate management of rhino population (Kandel, 2003).

A mosaic of all habitats used by rhino is evident but they clearly avoided barren, open landscape feaures like rivers,sand/rocky beds and barren lands though these were easily accessible. None of the studies rhino visited agriculture fields or Sal forests that were in-close proximity. This is likely due to high risk of contact with humans and poor forage availability and quality in the Sal understory, *Sacchrum spontaneum* dominated grassland areas were regularly used by rhinos, where spoted deer, samber, hog deer and domestic sympatric ungulates were also seen abundantly such as intensive use by domestic and wild ungulates in a relatively small area could only be possible by spatiotemporal use as an ecological separation in habitats(Karkee,1997). Pattern of different habitat use is related to varying amount of nutrients affecting the forage quality during different seasons. All the focal animals were found using very short range of habitat that might be because of presence of all essential resources required for their sustenance.

From the compositional analysis based on direct observation, it seems that the use of grassland and ecotone is higher than its availability that is same as the result obtained for food habits and proportional use of habitats. Use of grasslands comes in the first rank followed by ecotone, riverine mixed forest, barren land and river bed. Simultaneous use of the riverine mixed forest is equally important as rhino could feel secure and can remain unseen from human disturbance and could escape from noon sun heat. The key factor of using different habitat is the motive of optimization by rhinos in maintaining a balance between nutrients intake, thermoregulation and seeking a secure place to rest (Sinclair, 1985)

Food habits

Rhino relied on areas with forage having high crude protein and low silica content (Banneree, 2001). Such food may be preferred because they are rich in nutrients and easier to digest. Other foods may be avoided because they contain toxic secondary compounds and are therefore difficult to digest. As large area of grassland is comprised of these species, such patches of short grasslands should be well preserved. Bell,1970 had investigated that study on food habits help to develop habitat and animal management programs, he had also focused that domestic of wild animals are compatible or complimentary.

High proportion of grasses in their diet of rhinos during the hot season in Chitwan was explained by the availability of high quality *Saccharum spontaneum* that keeps sprouting immediately after grazing and grass cutting (Dinerstein and Price,1991)and burning (Laurie,1978)due to high substrate moisture (jnawali,1195. Forage quality and accessibility are the determining factor for the use of a habitat by herbivores.Ungulates might not use all the available habitats and grass species equally(Grzimek and Grzimek,1960).Seasonal changes in forage quality cases shifts in habitat use(Schaller,1967;Klein,1984 and Dinerstein 1980). Flood also influences habitat use, creating mosaics and also redistributes the population density due to the destruction of grasslands, forest condition and shape of the ox-bow lakes.

Rhino ate a wide variety of food items but the bulk of the diet consisted mainly of relatively few types as also reported by Laurie (1982).Rhinos are considered as generalist bulk feeders (Oven-Smith,1988)but Indian rhinos are relatively selective of more preferable food species for nutrients and palatability due to that prehensile upper lip. Laurie(1978) recorded over 100 species of plants eaten by rhino during the year round study of a larger area from direct

observation. Jnawali (1995) reported 28 species based on fecal analysis with a Shanon-Weiner diet diversity in Sauraha area. Similarly Kandel (2003) had reported a higher diet richness of 42 species in the same area

Table 9: Food species of rhinoceros.

Sn	Species eaten by rhino	Grazing habit	Sn	Species eaten by rhino	Grazing habit
1	*Saccharum spontaneum*	grass	24	*Cleorodendron viscosum*	Brows
2	*Narenga porphyrocoma*	grass	25	*Coffea bengalensis*	Brows
3	*Sacchrum bengalensis*	grass	26	*Colebrrokea oppositifolia*	Brows
4	*Phragmites karka*	grass	27	*Cyperus rotundus*	Brows
5	*Imperata culllindrica*	grass	28	*Disoxylum binnectiforum*	Brows
6	*Themeda species*	grass	29	*Dryopteris cochleata*	Brows
7	*Sacchrum arundinaceum*	grass	30	*Equisetum debile*	Brows
8	*Cyaanodon dactylon*	grass	31	*Eupatorium adenophorum*	Brows
9	*Vetiveria zizanoids*	grass	32	*Flemengia strobilifera*	Brows
10	*Setaria sp*	grass	33	*Lantenna camera*	Brows
11	*Desmostachia bipinnata*	grass	34	*Litsea monopetala*	Brows
12	*Chrysopogon aciculatus*	grass	35	*Michenia chinensis*	Brows
13	*Typha elephantina*	grass	36	*Mucuna nigricans*	Brows
14	*Cymbopogon sp.*	grass	37	*Murraya paniculata*	Brows
15	*Panicum sp.*	grass	38	*Pogostemon bengalensis*	Brows
16	*Ageratum conyzoids*	Brows	39	*Scoparia dulis*	Brows
17	*Albizzia jullibrissib*	Brows	40	*Sellaginella monospora*	Brows
18	*Artemisia dobia*	Brows	41	*Spiranthes sinensis*	Brows
19	*Bombax ceiba*	Brows	42	*Tetra stigma serrulatum*	Brows
20	*Caesalpinia decapetala*	Brows	43	*Vallaris solanaceae*	Brows
21	*Callicarpa macrophylla*	Brows	44	*Triwia nudiflora*	Brows
22	*Cannia bichotoma*	Brows	45	*Mikania micrantha*	Brows, as stress food
23	*Clematis gouriana*	Brows			

5.3.10 Threat and damage of Mikania

Mikania reduces growth and productivity of several crops such as oil palm, rubber, citrus, cassava, teak, eucalypt, acacia, albizia, pineapple, coconut and plantain in its introduced regions. The annual cost of controlling Mikania in rubber, oil palm and cocoa plantations in Malaysia is estimated to be around 8-10 million dollars. Besides the effect on crop yield, Mikania also makes harvesting difficult because of its creeping and twining habit. It was estimated that Mikania reduces 20% of the oil palm yield in Malaysia during the initial five years of

production. Retardation of tree growth in Mikania infested plantations is attributed to production of allelopathic substances by the weed. Infestation by the weed in natural forests in northeastern India caused a reduction in species richness, habitat destruction, species monopolization and new micro site formation. The weed renders collection of non-wood products (e.g., reed extraction) from natural forests less profitable, since heavy overgrowth of the weed disrupts collection. In CNP the major threats and damages by mikania is habitat alteration, wildlife population decrease, scarcity of food for mikania, crop raiding in buffer zone, loss of endangered species, nutrient loss resulting decrease breeding potential resulted poor offspring ,Ecosystem may collapsed and loss of prey and predator may occurred.

5.7 Control and Management Measures

Nepal has not, so far, taken any significant intervention on control and management of *Mikania* except some documentation on the weed even though it is highly invading most prevalent habitat. So it is urgent to take immediate action on control of the weed using already tested alternative measures. Following methods are used to control mikania in Kerala (India) and China.

Mechanical:

Sickle weeding, uprooting and digging are the main mechanical control methods in practice. Sickle weeding before flowering and seed setting gives temporary control. But quick re-growth from cut stumps frustrates this method. Uprooting during the initial stages of growth (before flowering and fruiting) is the most effective mechanical control method. The slash and burn technique is also practiced widely. However, the weed stock may survive burning and produce young shoots in a couple of months. Mechanical control method is very labour intensive and uneconomical. One advantage of this method is that it reduces the vegetative propagation of Mikania. In Indonesia, the cost of mechanical control of Mikania is estimated to be 125-175% higher than that of herbicidal control.

Chemical:

Both pre-emergent and post-emergent herbicides are generally used for Mikania control. Pre-emergence application of oxyflourfen (0.06 kg ha-1) + paraquat (0.24 kg ha1) is reported to be

effective if applied before flowering or seed setting. Glyphosate is widely used in many countries against mikania, especially in forest plantations. The dosage used varies widely (0.5 to 4.5 kg ha1 or 0.75 to 8 l ha-1) depending on the intensity of infestation and number of applications required for effective control. In general, the application of glyphosate @ 2.5 - 5 l ha-1 may take care of even heavy infestations. This herbicide can also inhibit germination of seeds of the weed. Application of diuron at the rate of 1-2 kg ha1 is also reported to be equally effective as glyphosate. Herbicides triclopyr + picloram (commercial name Grazon DS) @ 1.75 l ha-1 and triclopyr (commercial name Garlon 600) @ 500 ml ha-1 also gives excellent control of Mikania.

All herbicidal applications should preferably be carried out before flowering and seed setting. It should also be borne in mind that though a single and thorough application of any one of these herbicides may control the weed for about an year, re-growth will occur in most areas through wind-borne seeds, especially after the onset of the monsoon. It may therefore be necessary to repeat annual applications for the next few years, depending on the severity of re-infestation.

Biological:

Biological control using a natural insect enemy, viz., *Liothrips mikaniae* from Trinidad, was attempted in the Solomon Islands and Malaysia but successful establishment was not achieved. Recent studies carried out by CABI Bioscience (UK) in collaboration with Kerala Forest Research Institute (India) and institutions under the Indian Council of Agricultural Research have shown that a highly damaging microcyclic rust, viz., *Puccinia spegazzinii*, which naturally occurs and causes damage to Mikania in the neotropics, has great potential as a bio control agent against the weed. The fungus was tested for host specificity against closely related members of Asteraceae and a number of economically important plants and proved highly specific to Mikania. It was released recently in tea plantations in northeast India and agricultural systems in southwest India and preliminary results on spread of the pathogen in the field has been encouraging *Puccinia spegazzinii*- infection at released sites, Kerala, India

Discussion

Out of 146 plant species recorded in the study area, tree species were 32, shrub species 27, and herb species were 23, fern 4, climber and creeper 15 and other are 44. Among 32 tree species, 11

species were found invaded and incase of grass species *Imperata cyllindrica,Themeda arundinaceae*, *Hemertheria comparusa(Ghode dubo),Separis verticulata,(*Banso)were found mostly smothered by mikania.

In the western part of Baghmara forest, major invasion was found in *Accacia catechu, Dalbergia sissoo* and least in *Triwia nudiflora*, In Baghamra ,*Hemartheria* and *separis verticulata* were mostly invaded in grassland area small invasion was found in *Imperata cyllindreica.* In a grassland patch *Hemertheria comparusa(Ghode dubo),Separis verticulata,(*Banso) and mikania was found in composition 50/50(grass/mikania),In Jankauli forest, Major invasion was seen in *Accacia sissoo,Dalbergia sissoo,and Bombax ceiba* as well in the *Litsea monopetala* saplings and poles are found severly invaded and *Imperata cyllindrica* in grassland were found smothered, Similarly it was found as same as Jankauli in the Icharni island, fern species *Pteris vitata,Tectoria macrodonta,Duiplazium esculentum* and *Lepisorus bicolar*were found smothered in the ratio 60:40.and in the Radhakrishna Buffer zone community forest,major invasion was seen in *Bombax ceiba ands Accacia catchu* and in case of grasses,*Hemartheria and separis verticulata* were found most invaded by mikania and in this forest concentration of rhinoceros was also found higher. Similarly in the Sukhibhar /Bhimle area lesser invasion was found in comparison to other sites. The major invasion on tree species was seen in *Triwia nudiflora, Litsea monopetala, Accacia catechu* and *Bombax ceiba* and in case of grassland *Imperata* in short grassland and *themeda* in tall grassland were found invaded. Mikania impact is also determined by the presence or absence of rhinoceros in the mikania invaded area.

Mikania impact was higher in flood plain than other habitat The flood plains are also the preferred habitat of mega herbivore (Pradhan, 2007), therefore the higher the invasion of mikania in the flood plain, higher the impact in the rhinoceros habitat. Except the flood plains mikania impact was also seen in grassland, wetlands and agricultural land .Mikania smothered habitat that is preferred by rhinoceros. The presence of rhinoceros in Mikania invaded area is satisfactory and it was also seen by researcher, that mikania was browsed by rhinoceros with *Hemertheria comparusa(ghode dubo)* and *Eragrostis unioloides(* Banso) in very small amount I in the Radha Krishna bufferzone community forest.

One of the naturalist of Tiger mountain (Tharu lodge) Mr Dhan bahadur chaudhary and other hoteliers had also seen mikania grazed by rhinoceros in Tiger Tops area.They saw mikania

grazing by rhino in December/January which is also lean period for availability of grass. In this season grasses got maturity and mikania becoming pale yellowish color after flowering/seeding, it is assumed that due to scarcity of food, rhino may graze on mikania.

According to Bed bdr Khadka(Ranger CNP), he saw that Rhino consumed Mikania intentionally during dry season April (2006). He further added that; it was hot summer, rhino came from the sun into the *Triwia nudiflora* shade and intentionally eaten the tips of mikania which was newly sprouted and it was assumed that rhinoceros eat mikania to over come their body temperature as medicine as some time Tiger eats tips of *Imperata* to overcome the health hazard. He further added that habitat condition was riverine and none other grasses were present during that season while rhino eat mikania in very amount and soil is sandy loam.

From the respondent survey it was also concluded that majority of the respondent said that mikania was browsed by rhinoceros in little amount with grass. According to respondent survey not only the rhino but also the other mega herbivore elephant and gaur consume mikania. Similarly domestic cattle i.e. cow, buffalo and goat graze on mikania and it was also found that people cut mikania as fodder and feeded their cattle in KTWR and KERALA.

Although mikania has bitter-sower taste, the researcher saw the domestic elephant of CNP,Sauraha and khorsor had grazed mikania with grasses. from the above discussion it is clear that Mikania is consumed by domestic cattle as well the domestic elephant. Similarly it is also clear that rhino consumed mikania in little amount in lean period, rainy season and dry season but it is not studied that in what amount mikania was consumed by rhinoceros. Therefore it is difficult to describe preference of mikania by rhinoceros.

Mikania grows luxuriantly wherever the canopy is open in the forest area. Invasion ability of weed is generally low in high altitude (area<1000m asl).The average number of seed per milligram is 108 ± 12 .The are minute and bear pappus. The seeds of Mikania are dispersed by wind, water animal contact. The high level of mikania infestation was seen in moist deciduous habitat of CNP may be due to illicit felling of trees during insurgency period, grazing and resultant opening of canopy.

Availability of water may be the limiting factor for growth of mikania in dry deciduous forest. The weed dries during summer (March –may) wherever water availability is poor.

CHAPTER VI
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Among five research sites, It was seen that Buffer zone forest were (Baghmara,Jankauli & Radhakrishna BZCF) severely invaded by mikania than National park forest (Icharni and Sukhibhar-Bhimle area).Out of five sites Jankauli and Radhakrishna BZCF are seriously invaded. It was seen that most of the small trees, shrubs and herbs are severely smothered in invaded area of all habitat types and some herbs of invasive nature were observed to be exposed out from the entangled form of *Mikania*. The associate climber as *Parthenocissus semicordata* showed the same nature of *Mikania*. Shannon-Weiner (S-W) provides a means of comparing the diversity between two or more ecosystems which goes beyond the most basic species-per-unit-area. Shannon-weiner index diversity (H) varied from Baghmara (H=1.03) to Icharni (H=2.52).It was much higher in three different study sites Icharni island, Sukhibhar and radha Krishna BZCF. The maximum diversity was recorded (H=2.52) in Icharni isaland and Minimum (H=1.03) for Baghamara. The comparison among researches sites shows that Icharni had highest diversity than those of others. Similarly the Simpson index is a measure of diversity, and often used to quantify the biodiversity of a habitat and gives the dominancy of the species. It takes into account the number of species present, as well as the abundance of each species. The value of Simpson's Index of diversities ranges between Sukhibhar (SI =0.83 and Baghmara (SI=0.39) and it shows that greater abundancy of plant species Sukhibhar and lesser abundancy was seen in Baghanara BZCF.It was also concluded that Sukhibhar has greater diversity according to simpson index of diversities.

Indices of species reduction of five different study area shows that Accacia catechu (ISR=10.43) is most vulnerable tree species followed by *Diissocillum binectiferum* (ISR=5.61). The tree species killed due to mikania were *Accacia catechu,Dalbergia sissoo* and *Bombax ceiba*.Among the diet plant species *Sachhrum bengalensis,Coffea bengalensis,Litsea monopetala* and *Triwia nudiflora* are found most abundant in the study sites.

Forest edge, riparian vegetation, afforested land and grassland with sparse trees and shrubs are being degraded due to high invasion of the weed. It is reported that, the coverage of grassland in CNP is very low and furthermore, it is being invaded by *Mikania,* the nature of invasion of the

weed and its preferred habitat shows the serious threat to the Rhino habitat as well as its management. So the weed is compounding a multiple of problems affecting livelihoods and environment, and there is no doubt that *Mikania micrantha* should be categorized as "most serious weed" of Chitwan National Park and it needs to take immediate action to control the weed.

It was also concluded that mikania invasion is relatively lesser in grazing area than in grazing restricted area. Fire doesn't play any role to control mikania but it was found after firing of mikania it regenerated well.

In jankauli forest Agro forestry crops were cultivated as a practice of controlling mikania.During cultivation of agro-crops they plough the area and then cultivated crops.

It was also concluded that mikania was concentrated on rhino habitat in large amount. It was flourishing after the massive flooding of Rapti River in 1993. Seeds of the plant, which is a native of Central and Latin America, might have been brought here by the flood. It was also concluded that rhino consumped mikania as stress food (during lean period) in rainy season, winter season (after the fruiting of mikania December and January recorded by Dhan bdr Chaudhary, Tiger mauntain , tharu lodge) and also found during mid march (Bed khadka, Ranger CNP).Although researcher got eaten mikania by elephant and rhino during rainy season only in little amount mixed with *Hemertheria comparusa* (ghode dubo)and *Eragrotis unioloids* (Banso)

In Baghmara, it was seen that massive tourism, rhino habitat is found disturbed, the rhino presence in Baghmara behaves like domestic animals. The annual earning of baghmara was found to more than five millions. Similarly in Radhakrishna BZCF, Meghauli,Tourism was promoted by constructing infrastructures viz. Mahan(Tower for viewing wildlife) and Waterholes for wallowing rhinos.

It was found in Jankauli BZCF and near Tiger Tops Jungle lodge, *Cascuta comprestis*(Cascuta reflexa) in a small pocket dominating mikania, and it was also seen in many experiment mikania was also controlled by using another vine *Cascuta reflexa.*

Mikania invasion was found to be in grasslands and reverie forest. But there is no invasion till now in Sal forests. There is also no invasion of Mikania where grass lands that are being continuously managed since last 3-4 years. In pure *Sacchrum sponteum* grasslands and sandy area also there is no invasion. Further investigation of Mikania invasion and strategy to overcome this alien species are urgent (Bhatta, 2006).

Mikania is a perennial climber but it dries once in every summer. In CNP it was found that Mikania regenerate after mid march and fully regenerated with monsoon (Jun-July).The flowering time of mikania is Sep-Nov and fruiting occurs between Sep- Feb.

Due to inherent properties of efficient nutrient uptake and use efficiencies Mikania invade the disturb land and even loss in native bio-diversity and it impacts upon ecosystem. (Ramakrishnan, 2001).

Biological invasion of mikania altered the ecosystem complexity would impact on sustainable livelihood concern of community and altering in bio-diversity change the biological cycle and leads the global change in context of biological invasion.

If Mikania infestation in rhino habitat will not controlled, Chitwan National Park will be converted in to green desert Park

The over all impact of Mikania was seen in wetlands, grasslands, riverine forest. Mikania invasion in wetlands impacts on water birds and weed invasion on short grass land effect on the roosting and breeding of grass land bird i.e Bengal florican (globally threatened and protected birds of Nepal) etc. Finally it in concluded that not only the birds but also the mega herbivore depends upon wetland, grassland and riverine forest and they are impacted by the Mikania. Especially it is concluded that grassland, wetland and riverine forest is the prime habitat of rhinoceros, and it is seriously infested by Mikania and it is serous threat for rhino habitat management and maintaining the rhino population.

6.2 Recommendations

- Rhinos are specialist of flood plains (Laurie, 1972). They are fond of resting in the water or in a clay wallow which helps to keep their skin in good condition, besides this they like well formed of grass land with mixed forest in their proximity in reality rhino preferred habitat (grassland, wetland and riverine forest) is mostly smothered by mikania. Therefore it is strongly recommended that a national level policy and control mechanism will be prepared for the control and management of mikania for endangered species conservation.

- In Koshi Tappu wildlife reserve, local people tried to control mikania themselves through mechanical control by allocating little budget. Therefore it is also recommended for CNP, that prepare a mechanism for allocating little amount of the BZCC budget for controlling mikania.
- It was seen in Jankauli community BZCF, buffer zone people were trying to control mikania by cultivating the Agro-forestry crop by ploughing and digging the forest and remove the mikania mechanically. Therefore it is recommended that agro-forest cropping should be extended to another BZCF.
- Mikania invasion was seen lesser in the grazing prone area than grazing prohibited areas, it is recommended that in BZCF, allow the control rotational grazing for livestock ,it may result the control in Mikania invasion in rhinoceros habitat
- Promote local people to prepare compost manure from mikania; Mikania compost was prepared and used Vishnu NTFP herbal nursery, Meghauli, Chitwan, therefore it is recommended for preparing compost.
- Develop proper mechanism to use mikania as fodder to feed their livestock locally.
- In Kerala (India), Biological method (Using *Puccinia spegazzinii*) of control the mikania was found to be more successful, there fore it is recommended to introduce the biological control method using *Puccinia spegazzinii* in Buffer zone (only in small pocket for trial)
- Involve local users for mechanical interventions in Buffer Community Forests,
- Initiate cattle grazing in some BCF on a trail basis because it was seen less mikania in heavy grazing areas.

- Continue on going grassland management program
- There is a need for national invasive alien species experts to coordinate with other stakeholders of society who are directly and indirectly affected by mikania (Baral and Adhikari in press).

- There is a need for mechanisms to enable stakeholders in biodiversity, forestry, agriculture and environmental agencies (governmental and nongovernmental) to work together in solving the problem of IAs at national level.

6.3 Future research thrust:

- Mikania was found to be consumed by rhinoceros in little amount with grass as browse in rainy season, mikania consumed solely in lean period (during scarcity of grasses) and also eaten by mikania during its first regeneration in April but the real amount mikania eaten by rhinoceros is not studied, therefore the detail study regarding the dung test will be carried out through out the year for the actual mikania consumption by rhinoceros.
- Study on "Survey for dominance and growth of mikania in different ecosystem" will be recommended.
- Study on the effect of different environmental factors on infestation and distribution of mikania.
- Use of GIS to assess the pattern of spread of weed mikania.
- Study on the "Identification and evaluation of Bio-control agents".

Some photo plates

Regeneration of Mikania

Mikania at flowering stage

Branches with flowers and mature seeds of Mikania

Mikania bearing pappus seed

Mikania cuts with grass as Fodder

Mikania infestation on Bombax

Research site inventory

Mikania regeneration on Rhino dung

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