1. INRTODUCTION

Nepal remarkably rich in species and ecosystem diversity has high degree of autochthony and ecosystem. The global extent and rapid increase in invasive species are homogenizing the world's flora and fauna (Mooney and Hobbs 2000) and is recognized as a primary cause of global biodiversity loss (Wilcove and Chen 1998). Bio-invasion may be considered as a significant component on global change and of the major causes of species extinction (Drake et al. 1989). There are altogether 166 alien plant species naturalized in Nepal (Tiwari et al. 2005).

1.1 Invasive Alien Species

A biological species introduced in an ecosystem other than its natural home is called alien, exotic, or non-native. There exists a long list of alien species throughout the world, which make a valuable part of the livelihood and economy of the modern world. If these organisms became aggressive or spread beyond the manageable boundaries and vie native species in the ecosystem then these are considered as Invasive Alien Species (IAS). Invasive alien species are any species introduced in areas where they do not occur naturally but causing enormous damage to the ecosystem. Invasive alien species may be plants or animals.

The Global Invasive Species Programme has defined IAS as follows: "IAS are organisms that have been moved from their native habitat to a new location where they cause significant harm to the environment, economic systems and/or human health"(http://www.gisp.org). Invasive alien species spread outside their natural habitats have affected native biodiversity in almost every ecosystem type on earth and are one of the greatest threats to biodiversity. Since the 17^{th} century, invasive alien species have contributed to nearly about 40% of all animal extinctions for which the cause is known (CBD 2006).

An introduced species might become invasive if it can emulate native species for resources such as nutrients light, physical space, water or food. If these species evolved under great competition or predation, the new environment may host few competitors, allowing the invader to proliferate quickly. The effects of invasive plants on natural habitats are more complex than the direct negative impacts. Their additional potential positive impacts such as providing economic and ornamental values have sparked a

controversy as to whether they are friends or foe, pest or providence, and weed or wonder (Pasiecznik 1999, Foster and Sandberg 2004).

The impacts of invasive alien species are more in disturbed area than natural undisturbed areas. High invasion of *Mikania micrantha* has been observed in the northern part of core and buffer zone of the park (Sapkota 2007).

1.1.1 *Mikania micrantha* Kunth

Mikania micrantha is commonly called mile-a-minute weed because of its exceptionally fast growth rate (Holm et al. 1977). *Mikania micrantha* is a fast-growing perennial creeping vine belonging to the family Asteraceae and is native to Central and South America, capable of producing large amount of biomass, and is highly invasive in humid tropical and subtropical regions of Asia and the Pacific (Waterhouse 1994). *Mikania micrantha* is a fast-growing climber with a high reproductive rate (sexual and asexual) and is fire-adapted. Asexual reproduction is from roots that develop from nodes on small sections of the stem. Whereas these natural biological characteristics give the plant the potential to spread, anthropogenic factors can either cause or greatly exacerbate the actual spread and growth of *Mikania micrantha*; this is in common with some other invasive plant species in the Indian subcontinent (Murphy 2001). It has been listed as one of the 100 worst invasive alien species in the world (Lowe et al. 2000).

It is known by the various local names 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).

1.1.2 Distribution of *Mikania micrantha* in the World

Native range: Central America, Guadeloupe, Martinique, South America (http://www.issg.org).

Alien Range: American Samoa, Australia, Bangladesh, British Indian Ocean Territory (BIOT), China, Christmas Island (Indian Ocean), Cook Islands, Fiji, French Polynesia, Guam, Hong Kong, India, Indonesia, Malaysia, Mauritius, Micronesia, Nepal, New Caledonia, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Sri Lanka, Thailand, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna. (http://www.issg.org)

1.1.3 Distribution of *Mikania micrantha* in Nepal

Mikania micrantha has been reported spreading from eastern to central Nepal in low altitude below 1400m. The west boundary of *Mikania micrantha* was found to extend as far West as Rupandehi district. A recent report has indicated that it has already reached as far West as Kapilvastu District near Jagdishpur Reservoir (Siwakoti 2007).

In Chitwan, this weed is well established on the grassland and riverine forest in Chitwan National Park. High invasion of *Mikania micrantha* has been observed in the Northern part of core and buffer zone of the park. The urban, semi urban and cultivated lands of Terai region are also seriously invaded by this weed.

1.1.4 Host Range

Mikania micrantha is a serious weed of plantation crops including tea, teak, rubber, oil palm and coconut. It is also a weed of bananas, coffee, and other tree crops, especially in moist locations. Some major hosts are *Bambusa vulgaris* (common bamboo), *Camellia sinensis* (tea), *Cocos nucifera* (coconut), *Coffea* (coffee), *Elaeis guineensis* (African oil palm), *Hevea brasiliensis* (rubber), *Musa* (banana), *Polyphagous* (polyphagous), *Tectona grandis* (teak), *Theobroma cacao* (cocoa) etc.(Holm et al. 1977).

1.1.5 Habitat

Mikania. micrantha is a tropical vine usually found in damp, lowland clearings or open areas. It also grows along streams and roadsides, in or near forests, forest plantations, pastures, fence lines, tree crops (immature rubber, oil palm and cocoa, and to a lesser extent tea, coffee and fruit trees) and waste areas (Adams et al. 1972). It may be common in areas affected by slash and burn agriculture (Rawat 1997). In Singapore, it spreads on coastal reclaimed sand-filled areas (Lee et al. 1997).

1.1.6 Means of Movement and Dispersal

Natural Dispersal (Non-Biotic): Dispersal of *Mikania. micrantha* is mainly by wind, but water dispersal is possible.

Vector Transmission (Biotic): Not documented, but highly likely that it is dispersal by animals.

Accidental Introduction**:** Being wind-dispersed, the seeds may be carried on any article that is transported through an area where the weed grows. Vehicles and equipment

moving through areas infested with *Mikania. micrantha* are likely carriers that should be cleaned before travelling long distances to avoid spread of the weed.

1.2 Greater One-horned Rhinoceros

Greater One-horned Rhinoceros (*Rhinoceros unicornis*) belongs to family *Rhinocerotidae*. *Rhinoceros unicornis* Listed as vulnerable species. It is one of the members of mega herbivore known as flag species of Chitwan National Park. The Greater One-horned Rhinoceros is a heavily built species and males have average head and body length of 368–380 cm with a shoulder height of 170–185 cm while females have an average head and body length of 310–340 cm and have a shoulder height of 147–173 cm. (Macdonald 2001). Females typically weigh about 1,600 kg and males weigh 2,000–2,130 kg. The largest sized specimens can range up to 4,000 kg (Boitani 1984)

The Greater One-horned Rhinoceros has thick, silver-brown skin, which becomes pinkish near the large skin folds that cover its body. Its upper legs and shoulders are covered in wart-like bumps. It has very little body hair, aside from eyelashes, ear-fringes and tail-brush. Males develop thick neck-folds (Laurie et al. 1983).

The Greater One-horned Rhinoceros is primarily found in part of Northeastern India and in the Terai of Nepal. Where the population are confined to the riverine grasslands in the foothills of Himalayas (Talukdar et al. 2008). Typically weighing between 1600 to 3500kg. In Nepal, 375 individuals of rhinos were estimated in 2007. Most of them were found in Chitwan National Park, 35 in Bardiya National Park, 6 in Suklaphanta Wildlife reserve (Syangden et al. 2008). In March 2008, 408 are found in and around Chitwan National Park, 22 in Bardiya National Park and 5 in Suklaphanta Wildlife Reserve (Department of National Parks and Wildlife Conservation, 2008). In 2012, a total of 534 rhinoceroses were found during the census, with 503 in Chitwan National Park (density 1 km^{-2}), 24 in Bardia National Park (0.28 km^{-2}) and seven in Suklaphanta Wildlife Reserve (0.1 km^{-2}) (Subedi et al. 2013)

Distribution of rhino completely depends up on the habitat parameters like availability of food plants, distance from water body, and distance from road, distance from human settlement, elevation and so forth (Sharma et al. 2011). Rhinos were predominantly solitary, although temporary aggregation at wallows and feeding ground were frequent .The most common type of groups consist of sub adults mainly sub-adult males (Laurie 1983). The Greater One-horned Rhinoceros is grazer. Their diet consists of almost

entirely the grasses but rhino is also known to eat leaves, branches of shrub and trees, fruits and submerged and floating aquatic plants (Laurie et al. 1983).

Feeding occurs during morning and evening. The rhino uses its prehensile lip to grasp grass stems, bend the stem down, bite off the top and then eat the grasses. With the very tall grasses or samplings, the rhino often walks over the plants with its legs on both sides using the weight of body to push the end of the plants down to the level of mouth. They drink for a minute or two at a time. Potential food plant species of rhinos are short grasses (*Cynodon dactylon, Paspalidium flavidum, Imperata cylindrica* etc.), tall grasses (*Saccharum spontenum, Saccharum munja, Narenga porophyrocoma, Themeda villosa,etc.),*sedges, herb, creeper (*Cyperus digtatus, Cyperus pilosus, Ageratum conyzoides, etc.),* trees (*Trewia nudiflora , Litsaea monopetala, Premna integrifolia etc.*), aquatic plants (*Hydrilla verticellata, Vallisneria speralis, Pistia stratiotes,etc.)* (Laurie et al. 1983).

1.3 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). *Mikania micrantha* damages or kills other plants by cutting out the light and smothering them. In this respect, it is 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. Its harm is unquestionable and it is an urgent but difficult task to control its invasion. 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 micrantha* is so vigorous that we cannot eliminate it by simple manual or mechanical means. Biological control is the best method but it is still a challenge in China (Ye and Xia 2001).

Various efforts have been initiated and worked out in the field of *Mikania micrantha* and other IAS as well in the world including Southeastern Asia. It seems to be very slow responding on *Mikania micrantha* problem in Nepal since the first national stakeholders' workshop on *Mikania micrantha* 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. The weed seriously invades many moist part of the park. Being a climbing

plant, it becomes a nuisance in forest suppressing forest under growth and saplings. The plant spread appallingly fast and becomes dense within 8-10 years according to local inhabitants (Tiwari et al. 2005). It was nominated that the plant is among six of "high risk posed" weed. 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 2007). 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).

In Chitwan National Park and its buffer zone area, *Mikania micrantha* has invaded three habitats 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 e.g. *Imperata cylindrica* and *Hemertheria comparusa* (Ghode dubo) and *Eragrotis unioloids* (Banso). It is also found rhinos consumed that *Mikania micrantha* as stuffer food mixed with grasses, and still the impact on *Mikania micrantha* is not studied. The potential habitat of rhino is riverine forest and the Baghmara Buffer Zone Community Forest is a representative part of whole habitat of rhino. The study "Impact of *Mikania micrantha* on *Rhinoceros unicornis* habitat in Baghmara Buffer Zone Community Forest" is justifiable here because it helps to know the major impacted area and major impacted plant species and explore the consumption of *Mikania micrantha* by rhino and hence the study is justifiable.

1.4 Hypothesis

1. The presence of *Mikania micrantha* greatly reduces the species richness.
2. The presence of *Mikania micrantha* greatly reduces the food species of *Rhinoceros unicornis.*

1.5 Objectives

General Objective

The General Objective is to assess the impact of *Mikania micrantha* on habitat of *Rhinoceros unicornis* in Baghmara Buffer Zone Community Forest.

Specific Objectives

1. To assess the floral diversity in study area
2. To assess the status and distribution of *Mikania micrantha*
3. To make GIS mapping of distribution and invasion of *Mikania micrantha* in BBCF
4. To assess the impact of *Mikania micrantha* on *Rhinoceros unicornis* habitat

2. LITERATURE REVIEW

2.1 *Mikania micrantha* Invasion in Nepal

Mikania micrantha 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 per day (www.issg.org).

The plant is one of the major IAW in many tropical moist forests of Asia including Nepal and is still invading new areas, such as Northern Australia. The neotropical vine smothers 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).

Mikania micrantha is one of the well-established invasive alien weeds in the tropical part of eastern and central Nepal. The weed has been causing serious problems in the forests, grasslands, fallow lands, croplands and wetlands of the Koshi Tappu Wildlife Reserve and its buffer zone. It kills other plants by blocking sunlight and smothering them. The Reserve has initiated to manage the weed with local community in the buffer zone. The paper attempts to highlight the problem of *Mikania micrantha* in the Koshi Tappu area and the efforts of community to manage the weed. 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. Ilam is famous for tea gardening and Assam (Northeast India) is the main centre for supplying the tea saplings or seeds to Ilam. Therefore, it can *Mikania micrantha* be guessed that *Mikania micrantha* introduced to Nepal via Northeast 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 colonise in new habitat. It is difficult to control if once established and it is assessed as one of the six high risk posed invasive alien species in Nepal (Tiwari et al. 2005).

Later on (Poudel et al. 2005) considered it as most problematic in terrestrial ecosystem in eastern and Central Nepal.

A recent report has indicated that it has already reached as far west as Kapilvastu district near Jagdishpur Reservoir (Siwakoti 2007).

2.2 Invasion in Chitwan National Park

In Chitwan National Park (CNP), *Mikania micrantha* was found to be the most serious weed among the eight invasive alien species (IAS) in terrestrial ecosystem. *Mikania micrantha* is well established on the grassland and riverine forest in Chitwan National Park. High invasion of *Mikania micrantha* has been observed in the northern part of core and buffer zone of the park (Sapkota 2007).

A survey conducted as part of a census of the Greater One-horned Rhinoceros (*Rhinoceros unicornis*) in May 2008, concluded that *Mikania micrantha* is currently found across 44% of habitats sampled and almost 15% of these have a high infestation (50% coverage). Highest densities were recorded from riverine forest, tall grass and wetland habitats and this is where the highest numbers of rhinos were recorded in the habitats surveyed during the census (Murphy et al. 2013).

2.3 Impact of *Mikania micrantha*

2.3.1 Economic impact

M. micrantha is widespread throughout South and Central America, but is considered a weed in only a few places. Following its introduction to the Old World from South America, it has become a serious weed of plantation crops including tea, teak, rubber, oil palm and coconut, from India to Oceania (Cock 1982).

In India, *M. micrantha* is a serious weed of tea plantations, particularly in areas with high soil moisture. As a climbing vine, it quickly covers and smothers other plants, including other weeds (Dutta 1977).

The annual cost of controlling *M. micrantha* was estimated at US$9.8 million for rubber, oil palm and cocoa crops in Malaysia (Teoh et al. 1985).

In one study, 54 species of weeds were collected from a 3-month-old bamboo *(Dendrocalamus asper)* plantation in Lampung, Indonesia, which had been previously planted with cassava. Its climbing habit enabled it to cover the crop plants, suppressing their growth and in some cases killing them (Widjaja and Tjitrosoedirdjo 1991).

A study in Malaysia has shown that *M. micrantha* competes with teak, merkus pine (*Pinus merkusii*) and manila copal (*Agathis loranthifolia* = *A. dammara*) for nutrients,

space and light and causes mechanical damage to the trees (Suharti and Sudjud 1978). It is also a serious weed of rubber and oil palm plantations (Teoh et al. 1985).

2.3.2 Impact on Biodiversity

M. micrantha was observed in the Neilingding Island (Shenzhen, Guangdong Province, China) in 1997, yet two years later, it has covered 40-60% of the total land killing local plants. The site is famous for its large population of macaques (*Macaca mulatta*) and these are now under threat (Xie et al. 2001).

A study in Southern China showed that *M. micrantha* has a major impact on forest communities once established. It smothers native vegetation and eventually kills much of the standing vegetation including trees. In southern China, it is a considered to be a major threat to the local biodiversity (Xie et al. 2001and Zhang et al. 2004).

In a study conducted in buffer zone of Chitwan National Park, Chitwan, Nepal, correlation between the coverage of *Mikania micrantha* and species richness showed its high negatively significance with species richness at 0.01 level. Which means when the coverage of *Mikania micrantha* is high, number of species is lower (Sharma 2009).

In Nepal, a study shows that some important fauna are very selective in feeding e.g. *Rhinoceros unicornis* is very selective species and is the keystone of CNP. Increasing invasive alien plant species, *Mikania micrantha* may directly affect the important faunal species (Sapkota 2007).

2.4 Distribution of Greater One-horned Rhinoceros

2.4.1 Historic Distribution

Greater One-horned Rhinoceros once range across the entire Northern part of the Indian sub continent along the Indus, Ganges and Brahmaputra river basins from Pakistan to Indian-Burmese border including parts of Nepal, Bangladesh and Bhutan. They may have also existed in Myanmar Southern China and Indochina (Foose et al. 1997).

2.4.2 Present Distribution

By Nineteenth century, they only survived in the grasslands of southern Nepal, Northern Uttar Pardesh, Northern Bihar, and Northern Bengal and in the Brahmaputra valley of Assam. This huge animal is found in Terai of the foot of the Himalaya from Bhutan to Nepal. It is more common in eastern portion of Terai in than in the western and mostly abundant in Assam and Bhutan Dooars (Choudhury 1985).

The populations of the Greater One-horned Rhinoceros are now confined in few fragmented forest and grassland patches, mainly in the protected areas of India(Kaziranga NP, Assam,Politora WS, Assam, Orang NP, Assam, Jaldapara WS, West Bengal, Gorumara WS, West Bengal and Dudwa NP, Uttar Pardesh) and in Nepal (Chitwan NP, Bardiya NP, Shuklaphanta WR (DNPWC 2009).

2.5 Habitat of Greater One-horned Rhinoceros

Greater One-horned Rhinoceros 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).

Rhinoceros unicornis lives 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 rhino densities. The study has revealed that a rhinoceros eats fruits and seeds of at least 30 species of plants (Dinerstein and Price 1991).

Rhinoceros unicornis used three types of grazing habits (grazing, browsing, and others). The most preferred grasses used by rhino are *Saccharum spontaneum, Narenga porphyrocoma, Saccharum bengalensis, pharagmatic karka, Imperata cylindrica, Themeda* sp. Etc. Similarly, rhino uses *Trewia nudiflora, Callicarpa macrophylla, Ehretia laevis, Clebrookia oppositifolia, Mallotus phillipinensis* as browsing species (Jnawali1 995).

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 (Jnawali1995).

Habitat preference is changed on season basis. Rhino uses grassland in hot season where as shrubs in winter season and trees as browsing. A study carried out in Bardiya showed 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 (Janawali 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 unicornis used diet that is more diverse in winter than in summer due to scarcity and quality of food and 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).

3. MATERIALS AND METHODS

3.1 STUDY AREA

3.1.1 Geographical location

The study was conducted in Buffer Zone of Chitwan National Park called Baghmara Buffer Zone Community Forest in Chitwan District. Chitwan District is one of the seventy-five districts of Nepal, which is a landlocked country of South Asia. It lies in the lowlands or Inner Terai of Southern Central Nepal on the international border with India. It covers an area of 2,218km² (http://en.wikipedia.org).

3.1.2 Chitwan National Park

CNP, covering the total area of 1682 km^2 (core area 932 and buffer zone area 750 km^2), lies in the lowlands of central Nepal and is located between 27°16' 56" N to 27°42' 13"N latitude and 83°50' 23" to 84°46' 25"E longitude. The park established in 1973 as the first protected area in Nepal has a long history of over 3 decades in park management and rich experiences in nature conservation (Shrestha 2006). It is an important habitat for a large number of endangered mammals like 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. The park has over seven types of forest, six types of grassland, three main river systems, a number of oxbow lakes and wetlands, which support 50 species of mammals, 526 species of birds, 49 species of reptiles and amphibians and 120 species of fishes. Floral diversity encompasses over 600 species of which 50 are grasses, 16 orchids and 73 ferns. It provides a natural linkage to the Mahabharat range on its north, the Siwaliks hills and the Terai forests towards the south and the Parsa Wildlife Reserve in the east. The Terai of Chitwan bordered with Indian Territory making the Trans boundary linkage with the Valmiki Tiger Sanctuary, Udaipur Sanctuary and Sohagibarwa Sanctuary (DNPWC/HMGN 2002). In recognition of its unique biological resources of outstanding universal value, United Nations Educational Scientific and Cultural Organization (UNESCO) designated, the park as a World Heritage Site and the Beeshazari Tal contained within the park system is included in a Ramsar Site (Shrestha 2006).

3.1.3 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, quartzite's, shale's 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 Mahabharata Range consists of severely eroded pre-Siwalik quartzite, 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).

3.1.4 Climate

The climate of the study area is sub-tropical monsoon type with high relatively humidity. Monsoon rain prevails from late June to September (Tamrakar 2002). Heavy flooding occurs during the monsoon. The average daily maximum temperature of the area in hot summer days is about 36.8˚C. Spring starts from March and is immediately followed with summer and that ends in June (Pant 2003). The minimum temperature is about 7.8˚C in cool dry winter during October to February (Nepal Conservation Research and Training Center 1997).

3.1.5 Buffer Zone

Buffer zone conservation approach is more participatory approach than protective approach. It helps in promotion of local people participation in conservation programs. As of March 1997, the Nepal government has implemented Buffer Zone Management Program in CNP under the NPWC Act 1973 as amended in 1993 and the Buffer Zone Management Regulations 1997. Under the regulations, the Management Committee receives 30% to 50% of the park revenue for the implementation of conservation and community development programs in the buffer zone. To protect the core area of the park through community based natural resource management in the periphery is the major intervention of implementing the buffer zone program.

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 by the time of buffer zone program had been implemented. 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).

3.1.6 Baghmara Buffer Zone Community Forest

Baghmara Buffer Zone Community Forest (BBCF) is located in Bachhauli Village Development Committee of Chitwan District, Nepal. It is situated in buffer zone area of Chitwan National Park at its eastern sector. It is located in subtropical lowland region covering 215 ha area in between 27˚34.78'-27˚35.53' Northern Latitude and 84˚28.43'-84˚29.40' Eastern Longitude at 170 meter of elevation. (Baghmara Buffer Zone Community Forest 2003).

It is situated at the North border of Chitwan National Park; the forest was heavily degraded in the seventies and eighties following the nationalization of forest and eradication of malaria in the southern Terai of Nepal. In 1990, acknowledging the importance of conservation and usefulness of natural resources in livelihood of people, the locals gathered to protect and conserve the forest and its biodiversity leading to the beginning of community conservation of this forest. On June 26 1995, with collective voice from community, this forest was officially handed over to the community user group as Baghmara Buffer Zone Community Forest under Forest Act 1993. The forest covers an area of 215 hectare of which 163 hectare. was naturally regenerated through community efforts. This forest user group consists of 956 households as members and constitutes more than half of the population of Tharus (one of the indigenous groups). Besides this, other indigenous/ethnic groups such as Magar, Gurung, Tamang, Newar, Mushahar, Dalits and Brahmin and Chhetri also inhabit this area (source BBCF 2008).

This community forest is located on the floodplain of Rapti River with majority of the riverine forest species. The vegetation consists of partly planted (52 ha) and the rest regenerated type with dominant species. The total grassland or savanna area of this forest

is nearly 45 ha. The dominant species of the forest are Simal (*Bombax ceiba*), Bhellar (*Trewia nudiflora*), and Padke (*Albizia julibrissin*). The Baghmara Community Forest has provided an excellent habitat for many wildlife species. It harbors carnivores such as the Bengal Tiger (*Panthera tigris*) as frequent visitor, Common Leopard (*Panthera pardus*), Rhino (*Rhinoceros unicorn*is), Spotted Deer (*Axis axis*), Sambar Deer (*Cervus unicolar*), Barking Deer (*Muntiacus muntjack*), Hog Deer (*Axis porcinus*), Wild Boar (*Sus scrofa*), Mugger Crocodile (*Crocodylus palustris*), and Rhesus Monkey (*Macaca mulatta*) (Pant 2003).

The detail of map of my study area Baghmara Buffer Zone Community Forest with its different habitats is given below in figure1.

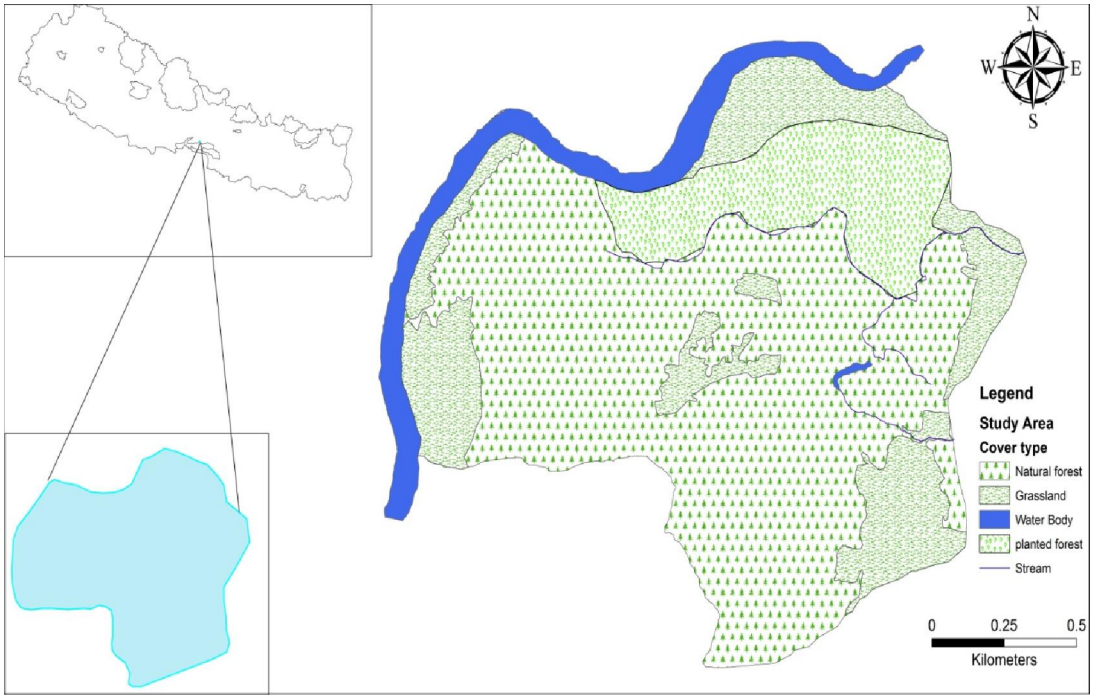

Figure 1: Map of study area, Baghmara Buffer Zone Community Forest showing different research sites.

3.2 Data Collection Methods

This section describes on how data were collected including sampling strategy, data collection methods and analysis methods. Various formulae on data analysis and statistical procedures are explained in this section too.

3.2.1 Sampling Strategy and Plot Division

The study area was divided in to three different parts based on vegetation types and habitat types. The three parts are naturally regenerated forest (54.88%), partially planted forest (24.19%), grassland, and savanna (20.93%). The data were collected by belt transect method in the onset of monsoon, in each research site belt transects were laid and within each transect various quadrates were nested of size 20×20m, 5×5m and 1×1m for trees, shrubs and sapling, and herbs and ground vegetations with sampling intensity 0.8%, 0.1% and 0.004% respectively at interval of 50m. The layout of quadrates is given in figure 2.

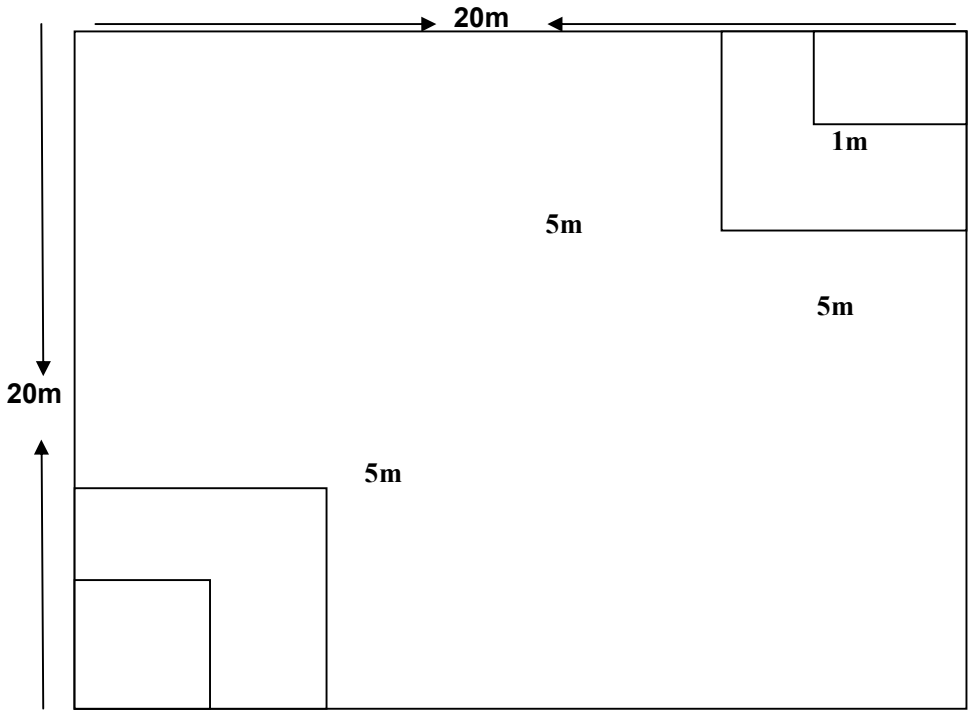

Figure 2: Layout of quadrates

3.2.2 Quantitative Data Collection

All plant species within each quadrate were identified then counted and estimated their cover percentage. The quantitative data such as density, frequency and coverage were collected from sampling plots. The plant species were identified with the help of standard literature of plant identification in Nepal and visual inspection. National Trust for Nature Conservation in Sauraha, Chitwan and Central Department of Botany, Kirtipur, Kathmandu was consulted for the further identification of the plant species.

3.2.3 Qualitative Data Collection

The qualitative data was collected from nature guide forest guard national park personal grass cutter etc. and it was focused on impact of *Mikania micrantha* on rhino habitat. Mainly two types of data were collected, e.g. primary and secondary data.

3.2.3.1 Primary data collection

The primary data were collected from local key person, farmers, nature guides, park personnel and field observation. Geographical Positioning System and direct field observation gained geographical data.

3.2.3.2 Secondary Data Collection

The secondary data includes the existing research literature and document survey. The main source of secondary data were different books, literatures, journals of different national and international publications , the main institutes visited for obtaining secondary data were DNPWC, NTNC, library of CDZ and CDB, TU Central Library, community forest office etc.

3.3 Statistical Treatment of Data

3.3.1 Diversity Iindex

The huge range of size and life expectancy of different plant species complicate floral diversity particularly in forest ecosystems. The different diversity indices were given below.

3.3.1.1 Shannon-weiner Diversity Index (H)

It combines two quantitative measures;

1. The species richness (the number of species in the community) and

2. Species equitability (how even are the numbers of individuals of each species). The higher the number, the higher is the species diversity. The Shannon Wiener index for diversity was calculated according to (Michael 1990) and it is as follows:

$H=\sum_{i=1}^{s} pilnpi$

Where,

H'= index of species diversity

S= species richness (total no. of species present)

Pi = proportion of total sample belonging to the ith species

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

3.3.1.2 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 = total no. of individuals.

3.3.1.3 Simpson's Index (SI)

Simpson's index is commonly used to evaluate different trends in plant diversity (Reich et al. 2001). Simpson's index is not logarithmic in nature and therefore is more sensitive to shifts in dominant plant species. In essence, equal value is given to the presence of any species, allowing the abundance of those species to increase the diversity value for a given plant community.

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.

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 zero and one. With this index, zero represents infinite diversity and one, 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 one to give the species diversity.

3.3.2 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) = π (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

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

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).

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

$$\text{Relative density} = \frac{\textbf{Total number of individuals of a species}}{\textbf{Total number of individuals of all species}} \times 100\%$$

3.3.3 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).

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

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

3.3.4 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.

$PV_X = M_X (\sqrt{f_x})$

Where,

PVx = Prominence value of species x
Mx = Mean percentage cover of species x
fx = Frequency of occurrence of species x

3.3.5 Abundance Frequency Ratio (A/F)

The ratio of abundance to frequency (A/F) for *Mikania micrantha* was determined for eliciting the distribution pattern. This ratio has indicated regular (<0.025), random (0.025 to 0.05) and contagious (>0.05) distribution patterns (Whitford 1949).

3.4 Impact Analysis of *Mikania micrantha*

3.4.1 Classification of Impact and Tree Measurements

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

A: killed (trees dead due to *Mikania micrantha*),
B: totally invaded (tree alive but covered totally),
C: tree partially covered and
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 micrantha*. *Mikania micrantha* generally invaded the tree up to 20 m height. Hence classifying dead trees due to *Mikania micrantha* was not difficult because *Mikania micrantha* invasion was clearly seen. Similarly, total invasion, 50% invasion and invasion on the ground were also being recorded. In addition, total coverage of *Mikania micrantha* was recorded. Similarly, cover of the other tree species also recorded.

3.4.2 Index of Species Reduction

Based on square plots, and Index of species Reduction (ISR) for major tree species was calculated using formula as done by (Pradhan 2007)

$$ISR = \frac{A \times B}{C}$$

Where,

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

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

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

3.5 GIS Mapping of *Mikania micrantha* Distribution and Rhino Preference Habitat

For GIS mapping of *Mikania micrantha* distribution in Baghmara Buffer Zone Community forest field data were collected with the help of GPS and field survey. With the help of data gained by direct field study and GPS location, GIS mapping of *Mikania micrantha* distribution and rhino preference habitat of study area was done by using ArcMap 9.3 software and Google Earth.

3.6 Data Analysis:

SPSS 16 version was used for testing Spearman's rho correlation between species richness and *Mikania micrantha* and between number of food species of rhino and *Mikania micrantha* coverage in Baghmara Buffer Zone Community Forest since the data was not normal. Similarly, MS Excel 2007 was used to analyze different species diversity indexes and ArcMap 9.3 software and Google Earth 10 were used to for analysis of spatial data.

4. RESULTS

To meet the objectives of the study following results were made with the installation of the aforementioned methods.

4.1 Floral Diversity

4.1.1 Species- individuals Curve

The species individual curve shows the area wise species richness and total number of the plants in the different classified habitats.

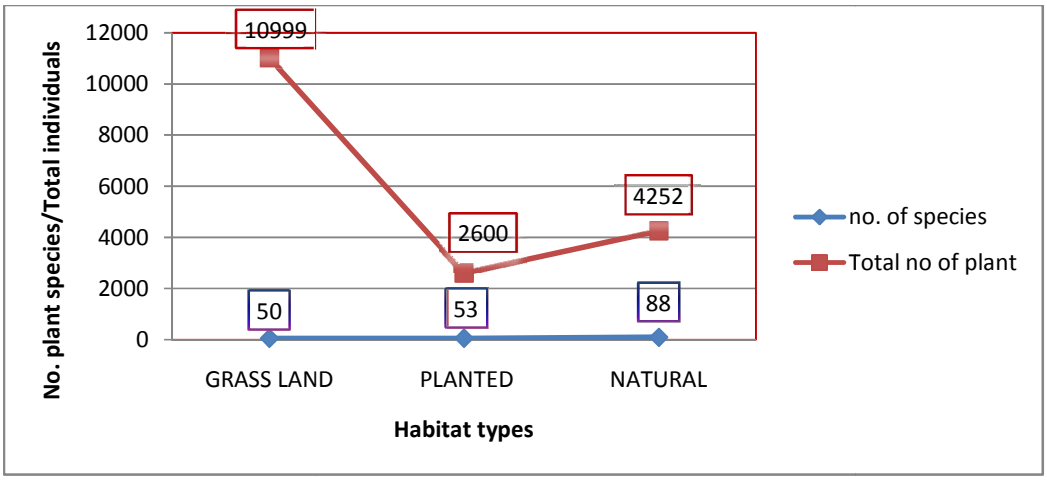

Figure 3: Study area wise species-individual curve.

The above figure 3 clearly indicates that natural forest harbors more species than planted forest and planted forest harbors more number of species than grass land.

4.1.2 Calculation of Species Diversity Indexes

Table 1: Study area-wise species diversity index.

Habit types	Species richness	Shannon-Weiner Index(H')	Simpson's Index (SI)	Species richness Index(d)
Natural forest	88	3.410	0.0557	1.3495
Plantation forest	53	3.258	0.0608	1.0394
Grass land	50	1.886	0.3039	0.4768

From the above table1 it is obvious that based on all four parameters of measurement of diversity (Species richness, Shannon-Weiner index, Simpson's index and Species

richness index) are highest in natural forest and which is followed by planted forest and grassland.

4.2 Important Value Index (IVI)

The species with highest IVI in Natural forest was *Albizia julirissin* (84.73) followed by *Trewia nudiflora* (58.14) and *Bombax ceiba* (44.76). On the contrary, the least dominant tree species was *Murraya koenigii* (1.45). In planted forest, the leading dominant tree species was *Dalbergia sissoo* (109.97) followed by *Trewia nudiflora* (80.56) and *Tectona grandis* (28.030). On contrary tree species with least IVI was *Mesoneuron cuculata* (3.03).The IVI of tree species are shown in following table 2.

Table 2: Habitat wise IVI of tree species

SN	Scientific name	Habitat-wise Important Value Index	
		Natural forest	Plantation forest
1	*Trewia nudiflora*	58.14	80.56
2	*Albizia julirissin*	84.73	22.84
3	Lali*	3.23	0.00
4	*Physalis divaricata*	3.45	0.00
5	Kaijal*	2.71	0.00
6	*Ehretica elliptica*	20.89	23.81
7	Rato kath*	6.95	0.00
8	*Bombax ceiba*	44.76	0.00
9	*Dysoxylum binecteriferum*	7.83	0.00
10	*Mesoneuron cuculata*	3.01	3.03
11	*Dysoxylum gobera*	1.50	0.00
12	*Litsea monopetala*	5.70	0.00
13	*Dalbergia sissoo*	13.28	109.97
14	*Milusa veluta*	5.66	3.05
15	*Murraya koenigii*	1.45	0.00
16	*Myrsine chisia*	4.80	3.08
17	*Acacia catechu*	12.26	3.37
18	*Duabanga grandiflora*	1.49	0.00
19	*Syzygium cumini*	3.28	0.00
20	*Melia azedirachta*	2.90	0.00

21	*Leucaena leucocephala*	1.53	0.00
22	*Ficus hirta*	2.20	0.00
23	*Albizia lebbeck*	2.19	0.00
24	*Alstonia scholaris*	2.26	0.00
25	*Premna barbata*	1.92	7.786
26	*Mallotus philippensis*	1.89	7.655
27	*Tectona grandis*	0.00	28.03
28	*Xeromphis spinusa*	0.00	6.810

4.3 Food Species of *Rhinoceros unicornis*

Based on (Jnawali1995) and (Kandel 2008) total 41 food species of *Rhinoceros unicornis* were recorded in Baghmara Buffer zone Community Forest. The list of the food species is shown in the following table 3.

Table 3: Food species of *Rhinoceros unicornis*

SN	**Scientific name**	**Grazing patterns**
1	*Trewia nudiflora*	Browsing
2	*Albizia julirissin*	Browsing
3	*Bombax ceiba*	Browsing
4	*Litsea monopetala*	Browsing
5	*Ehretica elliptica*	Browsing
6	*Murraya koenigii*	Browsing
7	*Dysoxylum binecteriferum*	Browsing
8	*Mallotus philippensis*	Browsing
9	*Clerodendron viscusum*	Browsing
10	*Lantana camara*	Browsing
11	*Cllicapra microphylla*	Browsing
12	*Colebrookia oppositifolia*	Browsing
13	*Coffea bengalensis*	Browsing
14	*Cirsium walichii*	Browsing
15	*Ageratum conyzoides*	Browsing
16	*Pterish vittata*	Grazing

17	*Cynodon dactylon*	Grazing
18	*Eragrostistis uniolodes*	grazing
19	*Hermertheria comparusa*	grazing
20	*Elusine indica*	grazing
21	*Themeda species*	grazing
22	*Setaria species*	grazing
23	*Imperata cylindrical*	grazing
24	*Cyperus species*	grazing
25	*Digitaris species*	grazing
26	*Narenga porphyrocoma*	grazing
27	*Saccharum spontaneum*	grazing
28	*Desmostachium bipinata*	grazing
29	*Cymbopogon sp.*	grazing
30	*Vitex cerdivus*	grazing
31	*Scoparia dulis*	grazing
32	*Vetiveria zizanoids*	grazing
33	*Flemingia strobilifera*	grazing
34	*Chrysopogon aciculatus*	grazing
35	*Equisetum debile*	grazing
36	*Themeda species*	grazing
37	*Phragmites karka*	grazing
38	*Saccharum bengalensis*	grazing
39	*Saccharum arundinaceum*	grazing
40	*Dgitaris species*	grazing
41	*Mikania micrantha*	brows as stress food

4.4 Prominence Value (PV)

To know the abundance of plant species PV of shrubs and herbs species were calculated in all three different habitat types. *Mikania micrantha* is most abundant species in natural forest and planted forest and the PV are 276.132 and 292.578 respectively. In case of grassland *Imperata cylindrica* was found to be the most abundant grass species (PV=276.684) followed by *Saccharum spontaneum* (PV=139.550) and *Mikania micrantha* (PV=49.338). *Imperata cylindrica* and *Saccharum spontaneum* are potential

food species of *Rhinoceros unicornis* so grassland was found to be preferential habitat of these mega herbivores.

Table 4: Habitat wise PV of shrubs and herbs food species of *Rhinoceros unicornis*

SN	Scientific name	Habitat-wise prominence value(PV)		
		Natural	Planted	Grassland
1	*Mikania micrantha*	276.132	292.578	49.338
2	*Clerodendron viscusum*	25.592	9.575	4.112
3	*Lantana camara*	4.861	0.000	1.371
4	*Cllicapra microphylla*	34.857	85.916	27.619
5	*Colebrookia oppositifolia*	19.815	5.156	1.371
6	*Coffea bengalensis*	2.372	0.000	0.000
7	*Pterish vittata*	4.841	4.755	0.000
8	*Cynodon dactylon*	36.895	9.623	36.962
9	*Eragrostistis uniolodes*	13.311	74.846	9.751
10	*Hermertheria comparusa*	22.002	5.156	26.112
11	*Elusine indica*	16.390	12.028	0.000
12	*Ageratum conyzoides*	37.081	47.735	16.446
13	*Themeda villosa*	1.118	7.753	7.753
14	*Setaria species*	4.706	0.000	2.518
15	*Imperata cylindrica*	22.943	5.156	276.684
16	*Cyperus species*	3.660	3.402	10.964
17	*Digitaris species*	0.198	0.000	0.000
18	*Narenga porphyrocoma*	1.581	0.000	9.495
19	*Saccharum spontaneum*	4.861	1.203	139.550
20	*Desmostachium bipinata*	1.581	0.000	3.876
21	*Cymbopogon sp.*	3.162	11.482	1.371
22	*Vitex cerdivus*	0.198	0.000	0.000
23	*Scoparia dulis*	1.581	0.000	0.485
24	*Vetiveria zizanoids*	0.198	1.203	2.518
25	*Flemingia strobilifera*	0.559	6.250	1.371
26	*Chrysopogon aciculatus*	0.559	16.839	0.000

27	*Cirsium walichii*	0.000	1.203	36.927
28	*Equisetum debile*	0.737	0.737	5.417
29	*Themeda species*	0.000	0.000	4.196
30	*Phragmites karka*	0.000	0.000	36.775
31	*Saccharum bengalensis*	0.000	0.000	19.187
32	*Saccharum arundinaceum*	0.000	0.000	7.121
33	*Dgitaris species*-1	0.000	0.000	0.485

4.5 Status and Distribution of *Mikania micrantha*

4.5.1 Density and Relative Density

The density and relative density of *Mikania micrantha* were recorded highest in planted forest (0.742 and 17.12 per meter area respectively) and which was followed by natural forest (0.61 and 14.28) and the density and relative density of *Mikania micrantha* were recorded lowest in grassland (0.14 and 0.71) per square meter respectively as shown in figure 4.

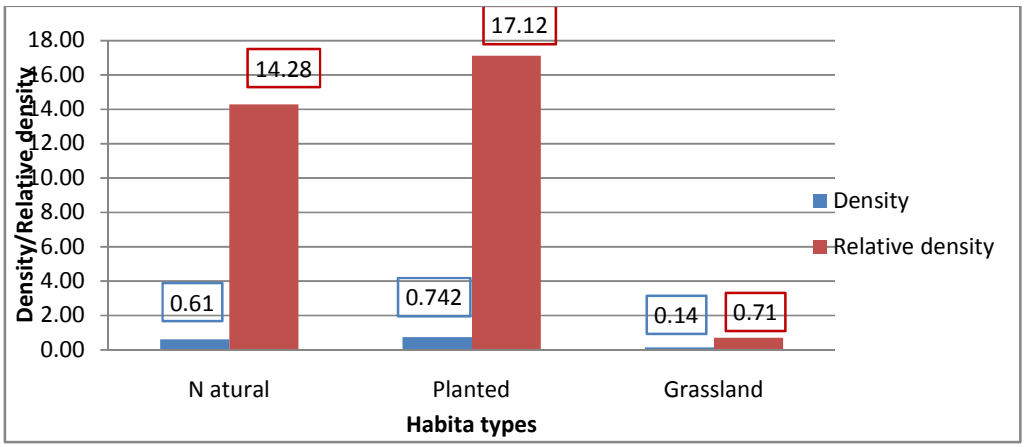

Figure 4: Density and relative density of *Mikania micrantha* in different habitats

4.5.2 Frequency and Relative Frequency

The frequency and relative frequency of *Mikania micrantha* were found to be highest in planted forest and which was followed by natural forest and grassland as graphically presented in figure 5.

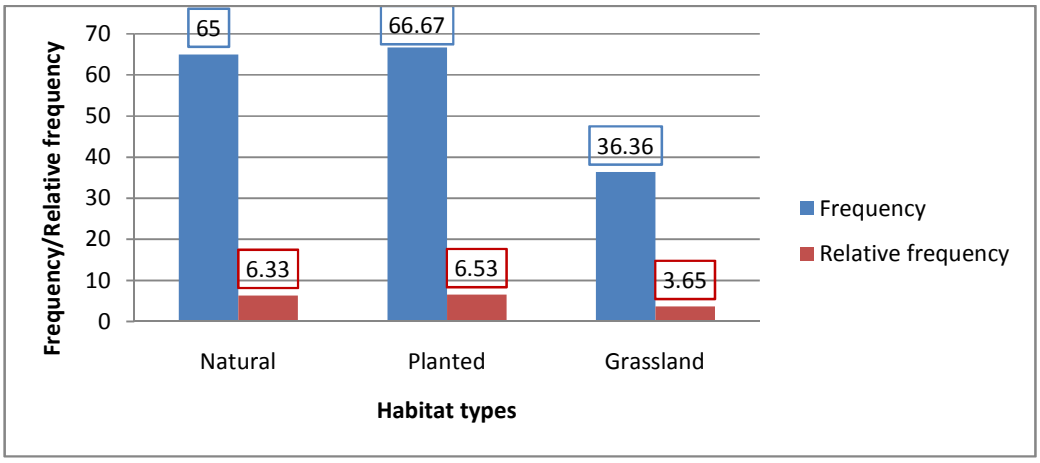

Figure 5: Frequency and relative frequency of *Mikania micrantha* in different habitats

4.5.3 Distribution Pattern

Here, the distribution pattern of *Mikania micrantha* was calculated by using the process given by (Whitford 1949). The ratio of abundance to frequency (A/F) for *Mikania micrantha* was determined for eliciting the distribution pattern. This ratio has indicated regular (<0.025), random (0.025 to 0.05) and contagious (>0.05) distribution pattern. In all three habitats, the distribution of *Mikania micrantha* was found to be contagious or clumped as shown in table 5.

Table 5: Distribution pattern of *Mikania micrantha* in different habitats

habitat types	A	F	A/F	Range of A/F value	Distribution pattern
Natural	23.35	65	0.36	A/F >0.05	Contagious
Planted	27.81	66.67	0.42	A/F >0.05	Contagious
grassland	9.75	36.36	0.27	A/F >0.05	Contagious

4.6 Assessment of *Mikania micrantha* Distribution and Abundance

The assessment of *Mikania micrantha* distribution and level of invasion was done throughout the whole study area. From the vegetation analysis, the percentage of coverage of *Mikania micrantha* was found to be the highest in planted forest (35.83%) and which is followed by natural forest (34.25%) and grassland (8.18%) as presented in figure 6

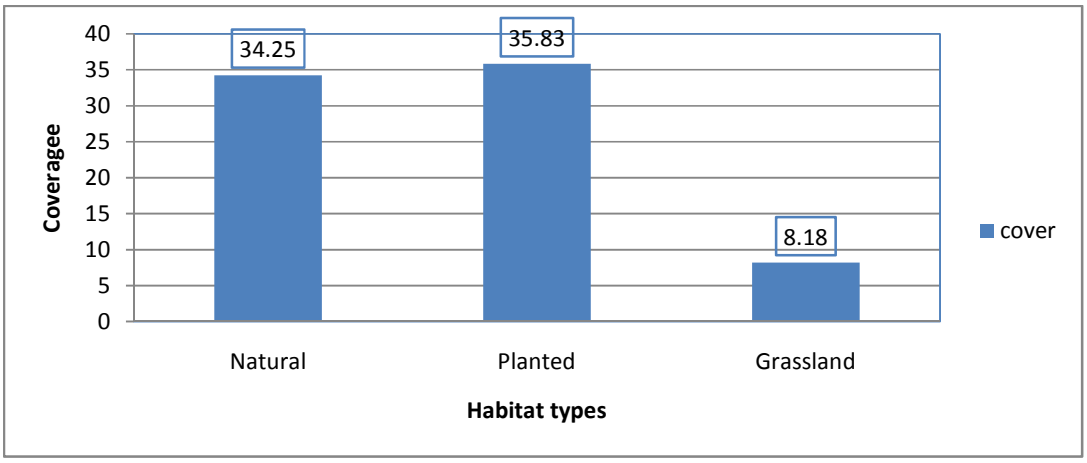

Figure 6: Coverage of *Mikania micrantha* in different habitats

For GIS mapping of invasion of *Mikania micrantha*, the invasion were classified as 0% coverage, <50%, 51 to 75% and >75%. The GIS mapping of *Mikania micrantha* invasion is shown in fig 7. In which higher invasion is recorded in damp areas around the water bodies and more disturbed area like edge of the community forest.

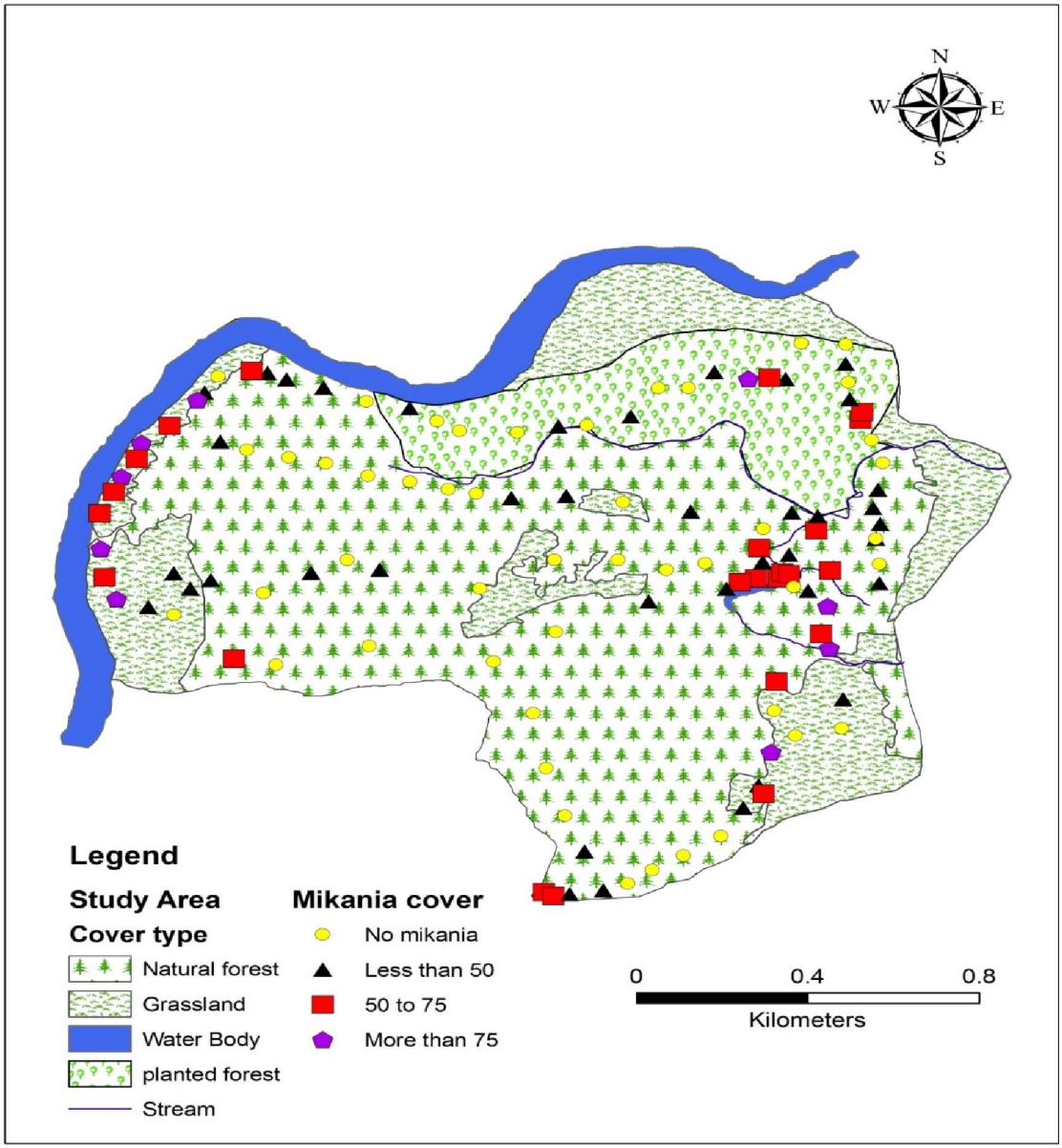

Figure 7: GIS mapping of Distribution and invasion of *Mikania micrantha* in BBCF

4.7 Assessment of Impact of *Mikania micrantha* on Habitat of *Rhinoceros unicornis*

The impact of *Mikania micrantha* on habitat of rhino highly depends of the type of the habitat, moisture condition, stage of succession and degree of disturbances. It was seen that the invasion of *Mikania micrantha* is generally higher in moist and damp areas, which are the most preferred-feeding habitat of Rhinoceros. It was also found that disturbed areas were more invaded by *Mikania micrantha* than undisturbed or less disturbed areas. The banks of the river are in early successional stage so percentage of invasion of

Mikania micrantha was found to be high over there, where major food species of rhino, *Imperata cylindrica, Saccharum species* and *Phragmites karka* were smothered by *Mikania i*nvasion.

4.7.1 Impact Analysis by comparing the *Mikania* Invasion with *Rhinoceros* habitat

The invasion of *Mikania micrantha* was generally found to be high in those area, which were preferred by *Rhinoceros unicornis*, and its food species were recorded. Its means the area or habitat preferred by *Rhinoceros unicorni*s were badly impacted by the invasion of *Mikania micrantha. Mikania micrantha* impact on *Rhinoceros unicornis* habitat was also analyzed by comparing the *Mikania micrantha* invasion and *Rhinoceros unicornis* habitat in figure 8. It is clear from the above figure that most of the rhinos preferred habitat is invaded by *Mikania micrantha*. Out of the eight-recorded rhinos, three were allocated in grassland one in Planted forest and rest four were allocated in natural forest. More rhinos were recorded near the water body and invaded area. From this, it is clear that rhino's preferred habitat is invaded by *Mikania micrantha*.

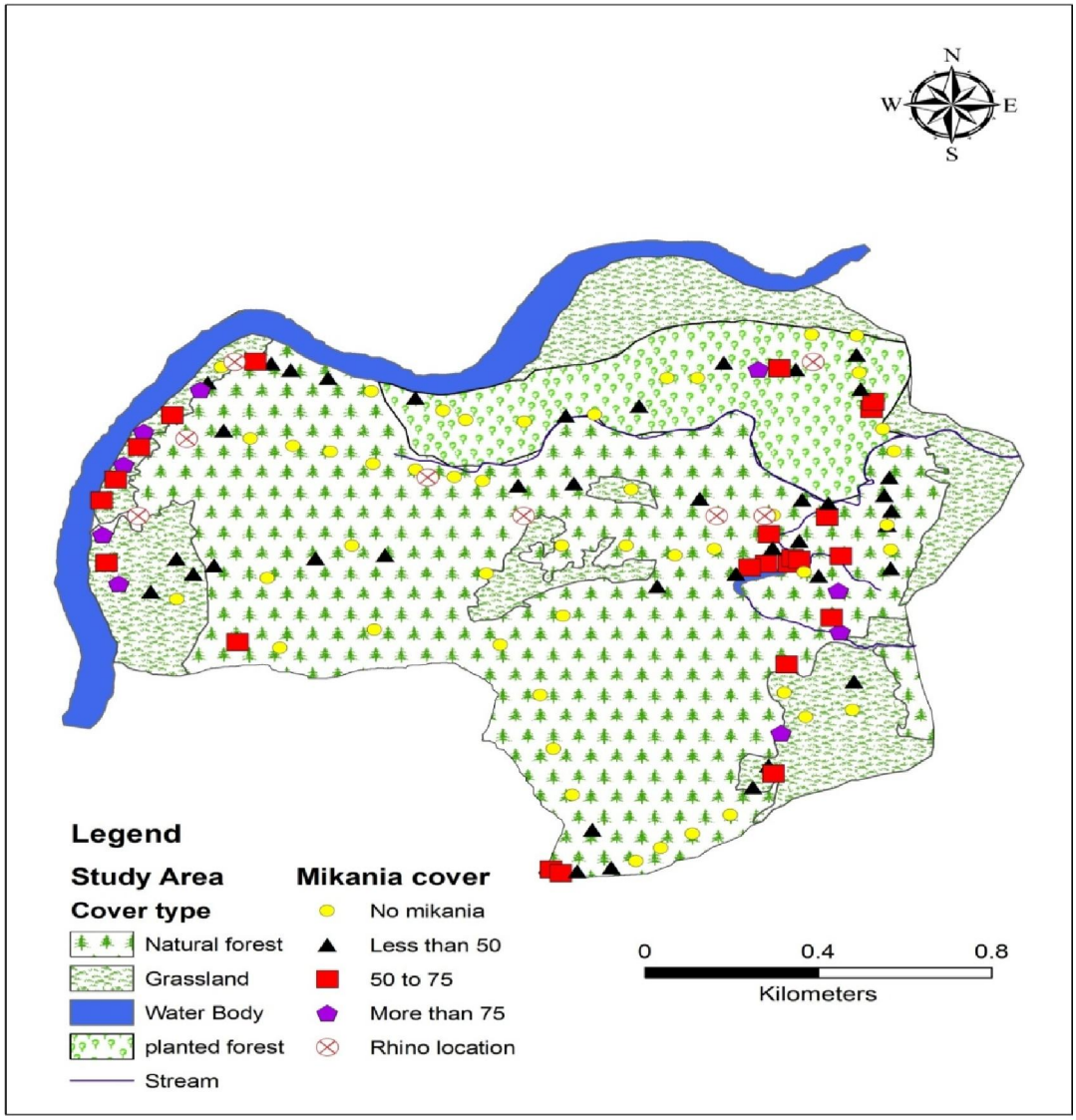

Figure 8: Map of study area showing allocation of rhinos in BBCF

4.7.2 Impact Classification on Major Tree Species

Among 378 recorded trees 5.820% tree were killed, 7.672% fully covered, 17.196% partially covered, 14.286% tree were covered in ground level by *Mikania micrantha* and rest of 55.026% were not impacted as shown in table 6.

Table 6: Impact classification of *Mikania micrantha* on trees

Impact classification	Number	Percentage **(%)**
Killed	22	5.820
Fully covered	29	7.672
Partially covered	65	17.196
Ground covered	54	14.286
Not impacted	208	55.026
Total	378	100.000

4.7.3 Index of Species Reduction (ISR)

Index of Species Reduction of major tree species due to impact of *Mikania micrantha* was calculated as done by (Pradhan 2007). Which demonstrates that on the foundation of ISR *Myrsine chisia* and *Litsea monopetala* were found to be most reduced among major tree species (ISR=11.50) followed by *Mallotus philipensis* (7.67), *Dysoxylum binecteriferum* (5.75), *Milusa veluta* (2.19) *Acacia catechu* (1.28), *Dalbergia sissoo* (0.90) and so on.

Table7: ISR of major tree species in BBCF

SN	Local name	Scientific name	A	B	C	ISR
1	Sisso	*Dalbergia sissoo*	0.45	0.04	0.02	0.90
2	Vellor	*Trewia nudiflora*	0.68	0.08	0.20	0.29
3	Dhadrung	*Ehertia elliptica*	0.34	0.20	0.20	0.35
6	Padke	*Albizia*	0.43	0.06	0.17	0.15
8	khayer	*Acacia catechu*	0.67	0.25	0.13	1.28
9	Sindure	*Mallotus philipensis*	0.17	1.00	0.02	7.67
10	Bilaune	*Myrsine chisia*	0.25	1.00	0.02	11.50
12	Kali Kath	*Milusa veluta*	0.14	1.00	0.07	2.19
13	Asare	*Murraya koenigii*	1.00	0.50	0.02	23.00
14	Simal	*Bombax ceiba*	0.38	0.10	0.07	0.59
15	Dhamina(binect	*Dysoxylum binecteriferum*	0.13	1.00	0.02	5.75
27	kutmiro	*Litsea monopetala*	0.50	0.50	0.02	11.50

4.8 Spearman's rho Correlation

As shown in table 8, species richness is highly negatively correlated with coverage of *Mikania micrantha* at 0.01 levels. The result indicates that if the coverage of *Mikania micrantha* is higher, species richness i.e. number of species gets lower.

Table 8: Spearman's rho correlation between *Mikania micrantha* coverage and Species richness

			*Mikani*a cover	Species richness
Spearman's rho	*Mikania* cover	Correlation Coefficient	1.000	-.764**
		Sig. (2-tailed)	.	.000
		N	43	43
	Species richness	Correlation Coefficient	-.764**	1.000
		Sig. (2-tailed)	.000	.
		N	43	43
**. Correlation is significant at the 0.01 level (2-tailed).				

From the table 9, *Mikania micrantha* is highly negatively correlated with number of food species at 0.01 levels. This result indicates that if the coverage of *Mikania micrantha* increases in the plot, the number of food species decreases. It is also clear that the abundance of food species of rhino were more sensitive towards *Mikania micrantha* coverage than species richness.

Table9: Spearman's rho correlation between *Mikania micrantha* coverage and number of food species

			Mikania cover	No. of food species
Spearman's rho	*Mikania* cover	Correlation Coefficient	1.000	-.815**
		Sig. (2-tailed)	.	.000
		N	43	43
	No. of food species	Correlation Coefficient	-.815**	1.000
		Sig. (2-tailed)	.000	.
		N	43	43
**. Correlation is significant at the 0.01 level (2-tailed).				

5. DISCUSSION

The main goal of this study was the assessment of impact of *Mikania micrantha* on habitat of *Rhinoceros* in Baghmara Buffer Zone Community Forest. Baghmara Buffer Zone Community Forest was found to be an important habitat for conservation of Greater One-horned Rhinoceros in spite of its relatively smaller area. Within this small area, there is a great potentiality to harbour significant number of rhinos. It contains three different types of riverine habitats namely *Albizia-Trewia* forest (natural forest) *Dalbergia-Trewia* forest (planted forest) and grassland dominated by *Imperata* and *Saccharum* species.

Among these three habitats, natural forest was more diversified than other two habitats, which may be due to higher maturity of natural forest than other two habitats. The lower diversity of grassland may be the frequent flooding because the grasslands were found to be located near the riverbank.

Based on IVI, the result showed that that leading dominant tree species of the natural forest were *Albizia julirissin* (84.73) followed by *Trewia nudiflora* (58.14) and *Bombax ceiba* (44.76) and in planted forest the leading dominant tree species were *Dalbergia sissoo* (109.97) followed by *Trewia nudiflora* (80.56) and *Tectona grandis* (28.030). According to previous study done by (Ram 2008) in BBCF *Albizia julirissin* (IVI=26.91) was found most dominant followed *Trewia nudiflora* (IVI=23.10) and *Dalbergia sissoo*(IVI=21.91).

Mikania micrantha, an invasive alien plant species of riverine forest of Chitwan National Park and its buffer zone area was most abundant species in natural forest and planted forest and the PV were 276.132 and 292.578 respectively. In case of grassland *Imperata cylindrica* was found to be most abundant grass species (PV=276.684) followed by *Saccharum spontaneum* (PV=139.550) and *Mikania micrantha* (PV=49.338). *Imperata cylindrica* and *Saccharum spontaneum* are potential food species of rhino so grassland was found to be preferential habitat of this mega herbivore. The low PV of *Mikania micrantha* in grassland may be due to the pulling by tractor as a local practice of control in grassland in order to maintenance of grassland for grass cutting. This practice not only has been providing an area for cutting grass to local people but also a good feeding habitat for rhinos and other ungulates in BBCF.

Based on (Jnawali1995) and (Kandel 2008) total 41 food species of Rhinoceros were record in Baghmara Buffer zone Community Forest. Where (Laurie 1978) reported parts

of 183 species of plants from 57, different botanical families were found to have been eaten by rhinos in CN. Jnawali (1995) reported 28 species based on fecal analysis with Shannon-Weiner diet diversity in Sauraha area. Similarly, Kandel (2008) had reported a higher diet richness of 42 species in the same area. Jnawali (1995) reported *Mikania micrantha* as stress food when the potential food species are scarcely available.

Among three-recorded habitat types, the density and relative density of *Mikania micrantha* was recorded high in planted forest, which was followed by natural forest and grassland and same trend was found in case of frequency and relative frequency. According to Ram (2008), frequency and relative frequency of *Mikania micrantha* in BBCF were 51.62 and 2.63 respectively but in this study frequency and relative frequency of *Mikania micrantha* in planted forest were 66.67 and 6.53, natural forest were 65 and 6.33 and in grassland were 36.36 and 3.65. Like other invasive plant species the distribution pattern of *Mikania micrantha* was found to be contagious or clumped in BBCF. This pattern of distribution may be due to its invasive characters and suitable habitat for its proliferation.

Ram (2008) reported 50% coverage of *Mikania micrantha* in BBCF but in this study, the percentage of coverage of *Mikania micrantha* in planted forest, natural forest and grassland were found to be 35.83%, 34.25% and 8.18% respectively. The lower coverage of *Mikania micrantha* in BBCF in this study than the study done by (Ram 2008) may be due to season, when the study were carried out, local practice of control of *Mikania micrantha* and other reasons.

An earlier study by (Sapkota 2007) had demonstrated the negative impact that *Mikania micrantha* has on plant species. For example, in highly invaded grassland many *I. cylindrica* and *S. spontaneum* plants were found dead and no new culms were observed sprouting from the rootstocks, and in highly invaded riverine/subtropical hardwood forests saplings of *B. ceiba, D. sissoo* and *Acacia catechu* had died and no regeneration was observed in Chitwan National Park. A same type of condition was found in this study in BBCF.

In an earlier study by Murphy (2013) *Mikania micrantha* was found across 44% of habitats sampled and almost 15% of these have a high infestation (> 50 percentage coverage). Highest densities were recorded from riverine forest, tall grass and wetland

habitats and this was where the highest numbers of rhinos were recorded in the habitats surveyed during the study. A same type of result was also found in this study in BBCF.

In this study, 378 recorded trees among them 5.820% tree were killed, 7.672% fully covered, 17.196% partially covered, 14.286% tree were covered in ground level by *Mikania micrantha* and rest of 55.026% were not impacted

Index of Species Reduction of major tree species due to impact of *Mikania micrantha* was calculated as done by (Pradhan 2007) showed that ISR of *Myrsine chisia* and *Litsea monopetala* were found to be most among major tree species followed by *Mallotus philipensis, Dysoxylum binecteriferum*, *Milusa veluta Acacia catechu*, *Dalbergia sissoo* and so on.

Spearman's rho correlation between *Mikania micrantha* coverage and species richness showed that species richness is highly negatively correlated with coverage of *Mikania micrantha* at 0.01 levels (r = -0.764 at0.01 levels of significance). The result indicates that if the coverage of *Mikania micrantha* is higher, species richness is lower i.e. number of species gets lower. Like this, species richness of food species of rhino were highly negatively correlated with coverage of *Mikania micrantha* at 0.01 levels (r = -0.815 at 0.01 levels of significance). A same type of outcome was recorded in the study done by (Sharma 2009) in her study conducted in Jankauli Buffer Zone Community Forest and Kumroj Buffer Zone Community Forest. She found Spearman's rho correlation between species richness & *Mikania micrantha* in Kumroj CF and Jankauli CF, r = -0.463 and – o.512 at 0.01 level of significance (2 tails). It was also clear that from this statistical test the impact of *Mikania micrantha* is higher in food species of rhino than over all species richness.

6. CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Altogether three types of habitat of rhino were recorded in BBCF; these are natural forest (*Albizia-Trewia* forest), planted forest (*Dalbergia-Trewia*) and grassland. In grassland, 1099 individual of plants were recorded under 50 species, in natural forest 2600 individual of plants were recorded under 53 species, and in planted forest 4252 individual of plants were recorded under 88 species

The floral diversity is the highest in the natural forest and which is followed planted forest and grassland.

Based on the IVI, the natural forest of BBCF was classified as *Albizia-Trewia* forest and planted forest as *Dalbergia-Trewia* forest.

Total 41 food species of rhino were record in BBCF.

Mikania micrantha is most abundant species in natural forest and planted forest. In case of grassland, *Imperata cylindrica* was found to be the most abundant grass species followed by *Saccharum spontaneum* and *Mikania micrantha.*

The status of *Mikania micrantha* was highest in both natural forest and planted forest but quite lower in grassland and it was highest in planted forest among three habitats. In all three habitats, it was found that the environmental factors were suitable for *Mikania micrantha* proliferations that support contagious distribution of over there.

In this study, the percentage of coverage of *Mikania micrantha* was found to be highest in planted forest. In natural forest, planted forest and grassland the percentage of coverage were found to be 34.25%, 35.83% and 8.18% respectively.

The invasion of *Mikania micrantha* is relatively higher in damp area; more disturb area like edge of forest, bank side of river, around the artificial water wholes and oxbow lake area and edge of forest and grassland. Major food species of *Rhinoceros unicornis*, *Imperata cylindrica, Saccharum species* and *Phragmites karka* were smothered by *Mikania i*nvasion. *Myrsine chisia* and *Litsea monopetala* were found to be more severely impacted species among major tree species followed by *Mallotus philipensis, Dysoxylum binecteriferum*, *Milusa veluta, Acacia catechu, Dalbergia sissoo* and so on.

The preferential habitat of rhino, where higher number of rhino was recorded were severely invaded by *Mikania micrantha.*

Species richness and the number of food species of rhino were significantly reduced by the presence of *Mikania micrantha*. Food species of rhino were found to be more sensitive towards presence of *Mikania micrantha* than the overall species richness. Thus, impact of *Mikania micrantha* on habitat of *Rhinoceros* in Baghmara Buffer Zone Community Forest was found to be negative.

6.2 Recommendations

- There is a need for mechanisms to enable stakeholders in biodiversity, forestry, agriculture and environmental agencies to work together in solving the problem of IAs at national level.
- Grassland management program should be launched.
- There should be involvement of local users for mechanical interventions in Buffer Community Forests.
- There is a need to form IAS Experts group from different relevant fields for the technical inputs.
- An effective policy framework is necessary to regulate, manage and control the introduction of alien species as well as existing laws, policies and regulations should be reviewed to address the weed and other issues.
- Intensive research need to be promoted so a regular assessment and monitoring of the invasive weed *Mikania micarantha* is necessary to understand its root cause and its impact.
- International networking is important for the control and management of IAS.

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8. ANNEXES

I. PV of shrubs and herbs in natural forest

SN	SCIENTIFIC NAME	Mx	√Fx	PVx
1	*Mikania micrantha*	34.250	8.062	276.132
2	*Clerodendron viscusum*	3.375	7.583	25.592
3	*Lantana camara*	1.375	3.536	4.861
4	*Adhatoda vesica*	0.250	2.236	0.559
5	*Cllicapra microphylla*	4.500	7.746	34.857
6	*Colebrookia oppositifolia*	2.875	6.892	19.815
7	Unkown1	1.000	4.472	4.472
8	*Urtica dioica*	4.125	7.583	31.279
9	*ziziphus mauritiana*	1.250	4.472	5.590
10	*Rubus ellipticus*	0.250	2.236	0.559
11	*Chromolaena odorata*	1.125	2.739	3.081
12	*Hyptis suaveolens*	1.000	4.472	4.472
13	*Solanum aculeatissium*	0.125	1.581	0.198
14	Unknown2	0.125	1.581	0.198
15	*Ardisia solanacea*	0.500	2.236	1.118
16	*Sida acuta*	0.250	2.236	0.559
17	*Callicarpa arborea*	0.250	2.236	0.559
18	*Bridelia retusa*	0.500	3.162	1.581
19	*Coffea bengalensis*	0.750	3.162	2.372
20	*Pocus bengalensis*	0.500	3.162	1.581
21	*Pterish vittata*	1.250	3.873	4.841
22	*Brassica campestris*	0.125	1.581	0.198
23	*Curcuma species*	0.500	3.162	1.581
24	*Alpinia*	0.250	2.236	0.559
25	*Cynodon dactylon*	5.500	6.708	36.895
26	*Eragrostistis uniolodes*	2.250	5.916	13.311
27	Unknown3	0.750	3.873	2.905
28	*Mimosa pudica*	0.250	2.236	0.559
29	*Hermertheria comparusa*	3.375	6.519	22.002
30	*Colocasia esculenta*	0.500	2.236	1.118
31	*Elusine indica*	2.875	5.701	16.390
32	*Ageratum conyzoides*	5.000	7.416	37.081

33	*Themeda*	0.500	2.236	1.118
34	*Diplazium esculentum*	3.000	7.746	23.238
35	*Tectaria macrodonta*	0.875	4.183	3.660
36	*Setaria species*	1.125	4.183	4.706
37	*Lepisorus bicolar*	1.500	5.477	8.216
38	*Oxalis latifolia*	0.875	4.472	3.913
39	*Piper longum*	0.250	2.236	0.559
40	*Imperata cylindrica*	4.375	5.244	22.943
41	*Jinospora sinensis*	0.125	1.581	0.198
42	*Boymera platifera*	0.500	3.162	1.581
43	*Parthenium*	0.250	2.236	0.559
44	*Cyperus species*	0.875	4.183	3.660
45	*Gigitaria species*	0.125	1.581	0.198
46	*Euphorbia hirta*	0.250	2.236	0.559
47	*Narenga porphyrocoma*	0.500	3.162	1.581
48	*Dioscorea deltoids*	0.375	2.739	1.027
49	*Canotis cristata*	0.125	1.581	0.198
50	*Parthenocissus semicordata*	0.250	2.236	0.559
51	*Saccharum spontaneum*	1.375	3.536	4.861
52	*Desmostachium bipinata*	0.500	3.162	1.581
53	*Nicotiana species*	0.500	3.162	1.581
54	*Cirsium walichii*	0.500	3.162	1.581
55	*Cymbopogon sp.*	1.000	3.162	3.162
56	*Vitex cerdivus*	0.500	3.162	0.198
57	*Scoparia dulis*	0.125	1.581	1.581
58	*Vetiveria zizanoids*	0.125	1.581	0.198
59	*Parthenocissus semicordata*	0.125	1.581	0.198
60	*Flemingia strobilifera*	0.250	2.236	0.559
61	*Chrysopogon aciculatus*	0.250	2.236	0.559
62	*Separis verticulata*	0.13	1.58	0.20

II. PV of herbs and shrubs in Planted Forest

SN	SCIENTFIC NAME	Mx	√Fx	PVx
1	*Mikania micrantha*	35.833	8.165	292.578
2	*Callicapra microphylla*	10.208	8.416	85.916
3	*Urtica dioica*	11.042	8.416	92.929
4	*Solanum aculeatissium*	2.500	5.774	14.434
5	*Parthenium*	1.250	4.082	5.103
6	*Persicaria hydropipper*	0.625	2.041	1.276
7	*Colebrookia oppositifolia*	1.458	3.536	5.156
8	*Chromolaena odorata*	0.833	2.887	2.406
9	*Clerodendron viscusum*	2.708	3.536	9.575
10	*Ardisia solanacea*	1.042	2.041	2.126
11	*Ageratum conyzoides*	6.250	7.638	47.735
12	*Eragrostistis uniolodes*	9.167	8.165	74.846
13	*Parthenocissus semicordata*	4.583	7.638	35.006
14	*Diplazium esculentum*	4.583	7.638	35.006
15	Nnknown1	0.833	4.082	3.402
16	*Colocasia esculenta*	0.833	4.082	3.402
17	*Cymbopogon sp.*	1.875	6.124	11.482
18	*Boymera platifera*	1.667	5.000	8.333
19	*Chrysopogon aciculatus*	2.917	5.774	16.839
20	Unknown2	1.042	3.536	3.683
21	*Achyranthus aspera*	1.250	5.000	6.250
22	*Nicotiana species*	0.833	4.082	3.402
23	*Elusine indica*	2.083	5.774	12.028
24	*Cynodon dactylon*	1.667	5.774	9.623
25	*Pterish vittata*	1.042	4.564	4.755
26	*Tectaria macrodonta*	1.250	5.000	6.250
27	*Lipisorus bicolor*	1.250	5.000	6.250
28	*Flemingia strobilifera*	1.250	5.000	6.250
29	*Cyperus species*	0.833	4.082	3.402
30	*Vetiveria zizanoids*	0.417	2.887	1.203
31	*Cirsium walichii*	0.417	2.887	1.203

32	*Dioscorea deltoids*	0.417	2.887	1.203
33	*Centella asiatica*	0.417	2.887	1.203
34	*Parthenium*	0.417	2.887	1.203
35	*Piper longum*	0.625	3.536	2.210
36	Unknown3	0.417	2.887	1.203
37	*Imperata cylindrica*	1.458	3.536	5.156
38	*Hermertheria comparusa*	1.458	3.536	5.156
39	*Equisetum debile*	0.208	3.536	0.737
40	*Separis verticulata*	0.417	2.887	1.203
41	*Saccharum spontaneum*	0.417	2.887	1.203

III. PV of herbs and shrubs in grassland

SN	SCIENTIFIC NAME	Mx	√Fx	PVx
1	*Mikania micrantha*	8.182	6.030	49.338
2	*Cllicapra microphylla*	4.318	6.396	27.619
3	*Chromolaena odorata*	2.727	5.222	14.243
4	*Urtica dioica*	0.682	3.693	2.518
5	Unknown1	2.273	3.015	6.853
6	*Hyptis suaveolens*	0.227	2.132	0.485
7	*Artemisia vulgaris*	0.455	3.015	1.371
8	*Colebrookia oppositifolia*	0.455	3.015	1.371
9	*Lantana camara*	0.455	3.015	1.371
10	*Clerodendron viscusum*	1.364	3.015	4.112
11	*Cirsium walichii*	5.000	7.385	36.927
12	*Cynodon dactylon*	5.227	7.071	36.962
13	*Desmostachium bipinata*	0.909	4.264	3.876
14	*Dgitaris species*	0.227	2.132	0.485
15	*Parthenocissus semicordata*	1.364	3.015	4.112
16	*Imperata cylindrica*	29.773	9.293	276.684
17	*Ageratum conyzoides*	2.727	6.030	16.446
18	*Tectaria macrodonta*	0.227	2.132	0.485
19	*Setaria species*	0.682	3.693	2.518
20	*Oxalis latifolia*	1.136	4.767	5.417
21	*Saccharum spontaneum*	16.364	8.528	139.550
22	*Lipisorus bicolor*	0.909	4.264	3.876
23	*Saccharum arundinaceum*	1.364	5.222	7.121
24	Unknown4	0.455	3.015	1.371
25	*Cyperus species*	1.818	6.030	10.964
26	*Narenga porphyrocoma*	1.818	5.222	9.495
27	*Saccharum bengalensis*	3.182	6.030	19.187

28	*Vetiveria zizanoids*	0.682	3.693	2.518
29	*Diplazium esculentum*	0.909	4.264	3.876
30	*Hermertheria comparusa*	5.000	5.222	26.112
31	*Desmodium species*	0.455	3.015	1.371
32	*Themeda villosa*	1.818	4.264	7.753
33	*Centella asiatica*	0.682	3.693	2.518
34	*Rernwardtia trigyan*	0.227	2.132	0.485
35	*Rungia parviflora*	1.364	3.015	4.112
36	*Phragmites karka*	5.455	6.742	36.775
37	*Mimosa pudica*	1.136	4.767	5.417
38	*Equisetum debile*	1.136	4.767	5.417
39	*Themeda species*	1.136	3.693	4.196
40	*Achyranthus aspera*	0.455	3.015	1.371
41	*Scoparia dulis*	0.227	2.132	0.485
42	*Cymbopogon sp.*	0.455	3.015	1.371
43	*Canotis cristata*	0.455	3.015	1.371
44	*Barleria cristata*	0.909	4.264	3.876
45	*Flemingia strobilifera*	0.455	3.015	1.371
46	*Eragrostistis uniolodes*	2.045	4.767	9.751

Photo plates

A mother rhino with her calf in oxbow lake of BBCF

Researcher measuring the bdh of *Trewia* tree, fully covered by *Mikania micrantha*

Regeneration *Mikania micrantha* from dung of rhino