IMPACT OF KUNTH (*Mikania micrantha*) INVASION ON THE HABITAT OF WILD WATER BUFFALO (*Bubalus arnee* Kerr, 1792) IN KOSHI TAPPU WILDLIFE RESERVE, NEPAL

Entry 01
M.Sc. Zoo Dept. Ecology
Signature
Date: 20 July 2018
(2075/4/4)

Niru Kumari Magar
T.U. Registration No: 5-1-14-282-2004
T.U. Examination Roll No: 31
Batch: 2070/2071

A thesis submitted in partial fulfillment of the requirements for the Degree of Master of Science in Zoology with special paper Ecology and Environment

Submitted to
Central Department of Zoology
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu

July, 2018

DECLARATION

I hereby declare that the work presented in this thesis **"IMPACT OF KUNTH (*Mikania micrantha*) INVASION ON THE HABITAT OF WILD WATER BUFFALO (*Bubalus arnee* Kerr, 1792) IN KOSHI TAPPU WILDLIFE RESERVE, NEPAL"** has been done by myself and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

Date: 19/7/2018

.....

Niru Kumari Magar

TRIBHUVAN UNIVERSITY
☎ 01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

Ref.No.:

RECOMMENDATION

This is to inform that the thesis entitled **"Impact of the Kunth (*Mikania micrantha*) Invasion on the Habitat of Wild Water Buffalo (*Bubalus arnee* Kerr, 1792) in Koshi Tappu Wildlife Reserve, Nepal"** has been carried out by Ms Niru Kumari Magar for the partial fulfillment of the requirements for the Degree of Master of Science in Zoology with special paper in Ecology and Environment. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted to any institutions for other degrees.

Date 20/7/2018

MKChalise

.....

Prof. Dr. Mukesh Kumar Chalise
Supervisor
Central Department of Zoology
Tribhuvan University
Kirtipur, Nepal

TRIBHUVAN UNIVERSITY
☎ 01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

Ref.No.:

Central Department of Zoology T.U., Kirtipur

LETTER OF APPROVAL

On the recommendation of supervisor Prof. Dr. Mukesh Kumar Chalise this thesis submitted by Ms Niru Kumari Magar entitled **"IMPACT OF KUNTH (*Mikania micrantha*) INVASION ON THE HABITAT OF WILD WATER BUFFALO (*Bubalus arnee* Kerr, 1792) IN KOSHI TAPPU WILDLIFE RESERVE, NEPAL"** is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Ecology and Environment.

Date: 20 July 2018

.....

Prof. Dr. Ranjana Gupta
Head of Department
Central Department of Zoology
Tribhuvan University,
Kirtipur, Kathmandu, Nepal

TRIBHUVAN UNIVERSITY
01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

Ref.No.:

Central Department of Zoology T.U., Kirtipur

CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Ms Niru Kumari Magar entitled **"IMPACT OF KUNTH (*Mikania micrantha*) INVASION ON THE HABITAT OF WILD WATER BUFFALO (*Bubalus arnee* Kerr, 1792) IN KOSHI TAPPU WILDLIFE RESERVE, NEPAL"** has been accepted for the partial fulfillment of the requirements for the Degree of Master of Science in Zoology specializing in Ecology and Environment.

EVALUATION COMMITTEE

MK Chalise

.....

Prof. Dr. Mukesh Kumar Chalise
Supervisor
Central Department of Zoology

.....

Prof. Dr. Tej Bahadur Thapa
Head of Department
Central Department of Zoology

.....

External Examiner

.....

Internal Examiner

Date of Examination: 26/8/2018

ACKNOWLEDGEMENTS

I would like to express my cordial thanks and sincere gratitude to my supervisor Prof. Dr. Mukesh Kumar Chalise, Central Department of Zoology, T.U. for his supervision, guidance and encouragement throughout my study. His constructive comments, help and practical suggestion inspired me to accomplish this work successfully.

I am grateful to Prof. Dr. Tej Bahadur Thapa, Head of Central Department of Zoology, T.U., for her kind support and the Central Department of Zoology for providing required research permissions and equipment. I am equally thankful to all teaching and non-teaching staff of the Department for their encouragement.

I am very thankful and grateful to Ms Sandhya Sharma, for her support and encouragement and also have helped in GIS. I am grateful to Mr. Arjun Karki for providing guidance in the field. My special thanks go to Ms. Sapana Khaiju for her assistance throughout the survey period. I am also thankful to Ms. Rasmi Kunwar, Mr. Nir Singh Rai and Mr. Purnaman Shrestha for their help and support.

I am grateful to NTNC for providing the fund for this research and for Idea Wild for providing the materials for this research.

Last but not the least, I am very much grateful to my family and my brothers who provided encouragement and inspiration during the difficult part of my study. I appreciate everyone who contributed towards completion of the work.

Niru Kumari Magar
nirumagar901@gmail.com

ABSTRACT

Wild Water Buffalo (*Bubalus arnee*) is an endangered and second largest bovine which has been listed in CITES Appendix-III, occurs in Koshi Tappu Wildlife Reserve. Study was conducted between March-April 2016, aiming to assess the status and distribution of *Mikania* and its impact on wild water buffalo habitat. Six sites were selected to investigate the invasion of *Mikania*, within community forest and in reserve site. Within those sites different types of quadrate were laid down randomly. According to forest size and type 64m*64m, 20m*20m laid for forest, 5m*5m and 1m*1m were laid for shrub and herb respectively. Among the different sites, Madhuvan reserve site has the highest *Mikania* coverage (39%) and highest presence of wild water buffalo (88.57%) was observed and lowest coverage (8%) in Prakashpur community forest where almost wild water buffalo avoided this site only (8%) was observed. 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 2013. For status of *Mikania* and wild water buffalo, map was prepared by using ArcGIS 10.2. An index of species reduction (ISR) was calculated to find out the impact of *Mikania* on different tree species. ISR indicated that *Dalbergia Sissoo* (0.077) was most impacted tree by *Mikania*. Questionnaire survey was conducted to know people perception about the *Mikania* on wild water buffalo habitat. About 42% people responded on highly invade in KTWR till now. Even though exhibited high invasion, (67%) people responded on not consuming of *Mikania* by wild water buffalo. For habitat preference scan sampling was performed, and it indicated wild water buffalo spent (81%) time on grassland and least (7%) time on forest habitat. Finding of this study showed even though habitat impacted by invasion, no direct influenced on wild water buffalo. Feeding ecology of wild water buffalo should be studied in detail is recommended.

Key words: ***Habitat, Impact, Mikania, Wild water buffalo***

TABLE OF CONTENTS

Title **Pages No.**

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

1. INTRODUCTION

1.1 Background

Invasive plants are exotic species that threaten native ecosystems, habitats or species (CBD 2008). They are considered either deliberate or accidental ecological con-sequences of economic processes (Holmes *et al.* 2009) and their global expansion and distribution is accelerated due to global trade and human mobility (Meyerson and Mooney 2007). Nepal has a list of over 166 species of naturalized alien plant species (Tiwari *et al.* 2005). Among them, several species have been spreading aggressively by colonizing several landscapes and ecosystems displacing the native species. One of them a vine from the family Compositae (Asteraceae), *Mikania micrantha*, Kunth, a fast growing climber, commonly called mile-a-minute weed (Holm *et al.* 1977) capable of producing large amount of biomass, and is highly invasive in humid tropical and subtropical regions of Asia and has Pacific Islands (Waterhouse 1994). It has been reported to grow 27 mm a day (www.issg.org) and has high sexual and vegetative reproductive capacity (Choudhary 1972; Swamy and Ramkrishnan 1987) which retards the growth of other species due to allelopathic effects (Ye and Zhou 2001). It is commonly known as American rope, Chinese creeper (Yadav 2010) and also known as Panilahara, Birelahara, Titelahara, Bakhrelahara, Pyangrilahara, Banludejhar, Bahramase, and Lahare banmara by the various local dialects in different parts and community of Nepal (Tiwari *et al.* 2005). The weed has been rapidly invading the different tropical ecosystems of Nepal (forest, cropland, grassland, and wetland) distributed along Mechi to Lumbini zones (Ilam/ Jhapa to Rupandehi districts) (Siwakoti 2007). It is the world's worst 100 invasive alien species (IAS) (Lowe *et al.* 2000) and the International Union for Conservation of Nature (IUCN) has recognized *Mikania* as a major invasive alien species of Nepal and categorized it as high risk posed Invasive Alien Species (Tiwari *et al.* 2005). The weed has been creating a serious threat in the protected areas i.e. Koshi Tappu Wildlife Reserve (KTWR), Parsa National Park (PNP) and Chitwan National Park (CNP) (Murphy *et al.* 2013) by suppressing the growth of native plants and preventing the regenerations of other plants due to its high dispersal ability and adaptability (Siwakoti 2007).

1.1.1. Global Distribution of *Mikania*

Native: It is native to North, Central and South America (www.cabi.org).

Alien: It is invasive to American Samoa, Australia, Bangladesh, Bhutan, British Indian Ocean Territory (BIOT), Cambodia, China, Christmas Island (Indian Ocean), Cook Islands, Fiji, French Polynesia, Guam, Hong Kong, India, Indonesia, Malaysia, Mauritius, Micronesia, Mirshall Islands, Nepal, New Caledonia, Niue, Northern Mariana Islands, Papua New Guinea, Philippines, Singapore, Solomon Islands, Sri Lanka, Taiwan, Thailand, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis and Futuna.

In most of the country, it is intentionally introduced rather than accidental. For example in Taiwan it is introduced as soil conservation, in India, Indonesia and Malaysia as ground cover etc. (www.cabi.org).

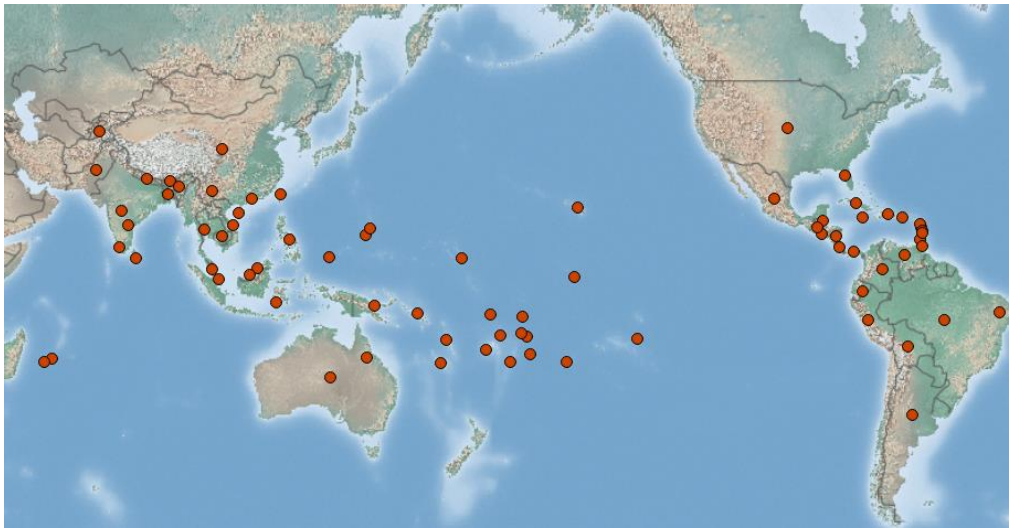


Figure 1. Global distribution of *Mikania*. Source: www.cabi.org

1.1.2. Distribution in Nepal

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). It had been believed that *Mikania* introduced to Nepal via north east India (Assam) through tea sapling or seeds and appears to be spreading rampantly westwards up to Dang including KTWR, CNP and PNP (Siwakoti 2007; Murphy *et al.* 2013).

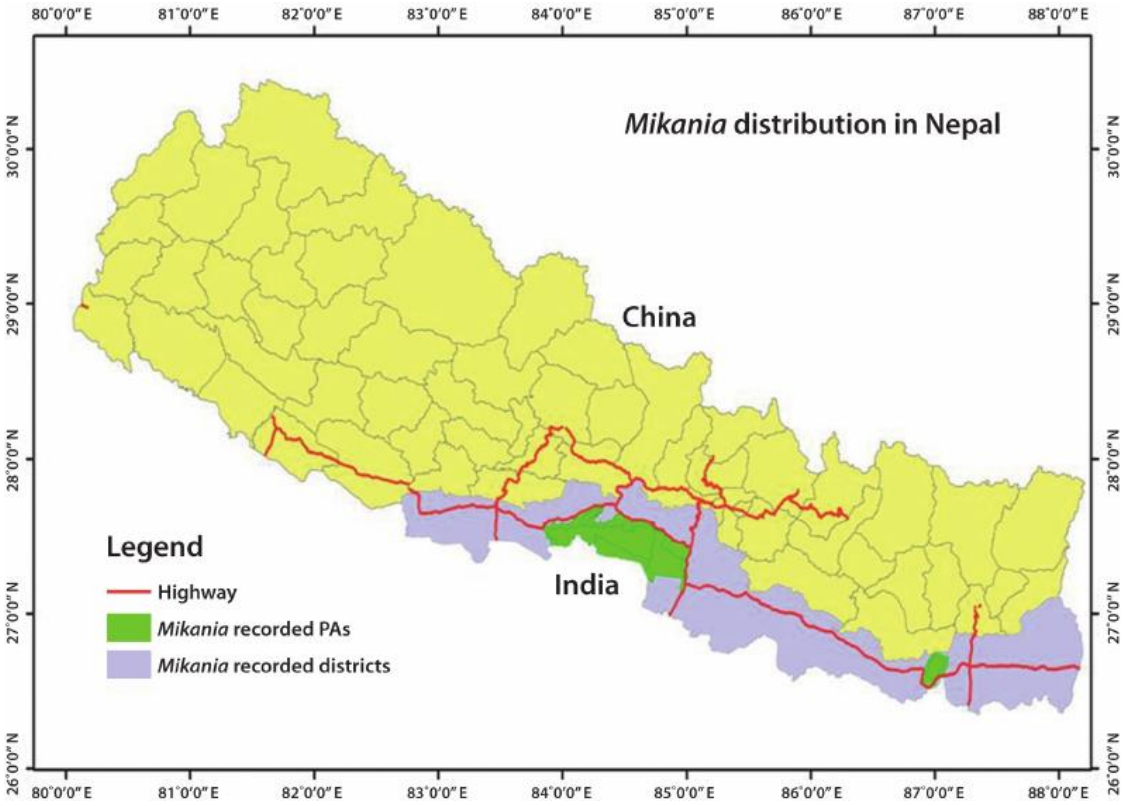


Figure 2. *Mikania* distribution in Nepal, Source: Rai *et al*. (2012)

1.1.3. Hosts

M. micrantha is a serious weed of agriculture, affecting over 20 species, including plantation tree such as *Citrus sp.*, *Theobroma cacao* (cocoa), *coffea sp.* (Coffee), *Camellia sinensis* (tea), *Tectong grandis* (teak), *Hevea brasiliensis* (rubber), *Elaeis guineensis* (African oil palm), *Cocos nucifera* (coconut), *Bambusa vulgaris* (common bamboo), *Musa sp.* (banana), *Manihot esculenta* (cassava), *Zingiber officinale* (ginger), *Carica papaya* (payaya), *Ananas comosus* (pineapple), *Litchi chinensis* (lychee), *Saccharu officinarum* (sugarcane), *Ipomoea batatas* (sweet potato), *Colocasia esculenta* (taro) and *Dioscorea* (yams), especially warm, moist locations or where soil fertility is high (Cock 1982; Waterhouse and Norris 1987; Holm *et al.* 1991; Abraham *et al.* 2002a; Macanawai *et al.* 2010; Day *et al.* 2012). It is transmitted through naturally (air, water), anthropogenically (accidentally or intentionally) and vector transmission (adhering to animals).

1.1.4. Habitat

It can grow in wide range of habitats usually found in damps, along streams, roadsides, waste lands, fence lines, edges of forest, among crops, lowlands with adequate temperature, rainfall, light (Adams *et al.* 1972; Waterhouse and Norris 1987; Holm *et al.* 1991; Day *et al.* 2012) and also in areas affected by slash and burn agriculture (Rawat 1997) and sand-filled areas (Lee *et al.* 1997).

1.2. Wild Water Buffalo (*Bubalus arnee*)

Bubalus arnee is an endangered (En) and second largest bovine listed in CITES Appendix-III and only found in KTWR. The habitats of *Bubalus arnee* are low-lying grassland surrounded with riverine forest but rarely woodlands also preferred (Lydekker *et al.* 1926; Prater 1971; Choudhary 1994). Typical structure of herds containing 15-20 individuals are common (Chalise 2008) as well as large herd of 35-58 have been observed and solitary males were also been spotted. A healthy wild buffalo weighs 800-1,200 kg and height of 2.4-3 m (IUCN 2011) with up to 2 m wide horn (Chalise 2008), presence of tuft of hair on forehead, hooves are comparatively larger and broader than any other bovid (Nowak 1999). It has average life span of 25 years in wild and 29 years in captivity (Nowak 1999). They are nocturnal though they spend mostly morning and evening hours lying in dense cover (Rai and Chalise 2014) and during midday, they wallow in freshwater or muddy water which help them to maintain their body temperature (Chalise 2008). They are probably grazers by preference, feeding mainly on grasses when available, but they also eat herbs, fruits, and bark as well as browsing trees and shrubs. *Cynodon dactylon, Themeda quadrivavlvis* and *Coix* sp. as grasses are known to be fed by wild water buffalo and also they have been observed feeding on the Sedge (*Cyperus corymbosus*) in India (Danial and Grubh 1966). Wild Buffalo also feeds on crops, including rice, sugar cane, and jute, sometimes causing considerable damage (Kushwaha 1986; Bauer 1987).

1.2.1. Distribution of Wild Water Buffalo

Wild buffaloes restricted in small areas of the world i.e. Nepal, India, Bhutan, Cambodia, Sri Lanka, Myanmar, and Thailand. Wild population in Sri Lanka are not clear whether wholly or partially domestic origin (Hedge 1995). Putative wild stock exists in western Thailand, east and central India, southern Bhutan and southeast Nepal in isolated reserves (Corbett and Hill 1992). Wild population restricted in Assam and Madhyapradesh of India, Royal Manas National Park of Bhutan, Koshi Tappu Wildlife Reserve of Nepal, Kuai Kha Khaeng Wildlife Sanctuary of Thailand (Scherf 2000).

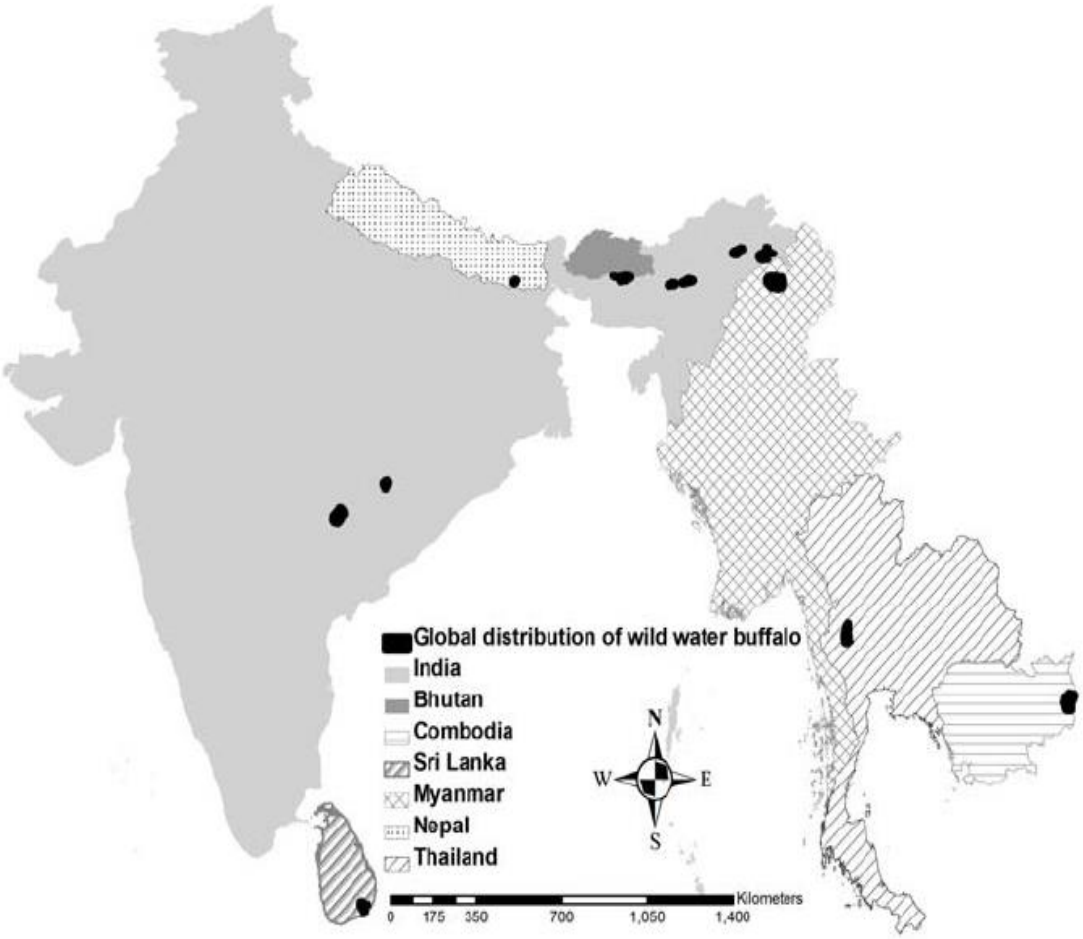


Figure 3. Global distribution of wild water buffalo, source: www.ijcs.ua

1.3. Objectives

General objective

- To assess the impact of *Mikania micrantha* infestation on the habitat of Wild Water Buffalo.

Specific objectives

- To identify the food plant of *Bubalus arnee* in KTWR.
- To study the status and distribution of *Mikania micrantha*.
- To assess the impact of *Mikania micrantha* on the habitat of *Bubalus arnee*.

1.4. Justification of the study

Invasive species are considered as one of the important drivers of ecosystem change and the second most serious threat to natural habitats after habitat fragmentation (Randall 1996; Millennium ecosystem assessment 2005). One of them is *Mikania*, which has been creating serious problem in protected areas by invading the core and buffer zone and threatening to biological diversity and ecosystem. The single plant can release as many as 40,000 visible seeds in every year and even the tiniest stem fragment is capable to grow a new plant in a moist area (Tiwari et al. 2005). Its nutrient uptake efficiency was higher after burning, it adapted to survival after fire (Swamy and Ram krishnan 1988) and appears to grow best where annual average temperature is usually higher than 210c and soil moisture is over 15% (Huang et al. 2000) as like the suitable habitat environment of water buffalo. The plant spread appallingly fast and becomes dense within 8-10 years (Tiwari et al. 2005) and damages or kills other plants by cutting out the light and smothering them. Due to invasion of the *Mikania* the grasses in the reserve area have been reduced so that wild animals (e.g. Wild water buffalo, wild boar etc.) damage the crops as well is not a good fodder, it reduces milk of cattle and cause abdominal disorder (Siwakoti 2007). *Mikania* has been proliferated rapidly in forest trees, grasslands and wetlands of KTWR which was more seriously invaded in eastern side (Siwakoti 2007) which lead into scarcity of food, could contribute to the conflict. Since the study conducted to mainly focus on wild water buffalo and its habitat impacted via *Mikania*, this study investigates the major impacted area and major impacted plant species and also explores the consumption of *Mikania* by wild buffalo and in allocating the effective conservation measures for the conservation of *Bubalus arnee* and its habitat.

1.5. Limitation of the study

- Research could not be taken at night time due to security reason.

2. LITERATURE REVIEW

2.1. *Mikania* invasion in Nepal

Mikania micrantha, a fast growing perennial creeper vine (www.issg.org) has been listed as one of the 100 worst invasive alien species (Lowe *et al.* 2001) and considered second serious weed in South Pacific (Water house and Norris 1987).

Mikania was first reported from Ilam in 1963 by Kitamura (Adhikari 2004). After that it is aggressively spreading towards west. Now it is recorded in 20 out of 75 districts of Nepal (Rai *et al.* 2012).

The weed has been notorious creating severe problems in the protected areas like CNP, KTWR and PNP (Murphy *et al.* 2013). It is considered as most problematic in terrestrial ecosystem in eastern and Central Nepal (Poudel *et al.* 2005).

In CNP, high invasion of *Mikania micrantha* has been observed in the northern part of core and buffer zone of the park (Sapkota 2007). Currently almost 44% of rhino habitat has been affected by *Mikania* and 15% have high infestation (50% coverage) (Murphy *et al.* 2013).

2.2. Invasion in Koshi Tappu Wildlife Reserve

Mikania micrantha is one of the well-established invasive alien weeds in the tropical part of eastern and central Nepal (Tiwari *et al.* 2005). The weed has been making serious problems in the forests, grasslands, croplands and wetlands of the KTWR as well as buffer zone (Siwakoti 2007).

2.3. Impact of *Mikania micrantha*

Mikania is the most notorious weed in the South and South-East Asia (Murphy *et al.* 2013; Barreto and Evans 1995) and its abundance reduces the availability of native species (Sapkota 2007). A single plant of *Mikania* can cover 20-25 sq. meter even though weed's top part dried up suckers of main stalk may serve for several years. Severe impact have been seen in *Acacia catechu*, *Dalbergia sissoo* and *Bombax ceiba* with ISR value 10.43%, 1.22% and 2.432% as well *Imperata cylindrica* in grassland were found smothered by 50-50 composition with weed. During hot summer, in absence of grass *Mikania* consumption by rhino has been observed (Ram 2008).

Its impact was higher in flood plains than other habitats which are also preferred habitat of mega herbivore (Pradhan 2007). High increment of weed caused deteriorating habitat quality, significant reduction on biomass production of food plant and other factors such as drying of water holes moreover hold potentiality to destroy prime habitats of threatened and important species could lead to decline in population (Subedi *et al*. 2013). If such intensification continues, it could adversely affect on carrying capacity of the rhinos and other herbivores which directly poses an increasing threat (Lamichhane *et al.* 2014). Heavy invasion occurred in wetland (40%) followed by riverine forest (27.03%) and tall grassland (20.17%), which has increased by 3.45% (Lamichhane *et al.* 2014) and about 52% of native species have been affected in CNP and its Buffer Zone (Shrestha 2011).

In KTWR, Heavy invasion of the *Mikania* weed was observed in the core area (50-80%) followed by buffer zone community forest (20-50%) and the cropland covered (about 10%). Core area was undisturbed areas so it has got opportunity to spread rapidly (Siwakoti 2007). Infestation of *Mikania* imprinted negative impacts on people livelihoods as the vines

was increasing rapidly in both Buffer Zone and the core area and displacing native regenerations which leading to destroying wildlife habitats and jungle hiking trails as a result wild animals have moved towards the core area for suitable habitat in CNP. As a result visitor number have been declined (DNPWC 2010; DNPWC 2011).
In Koshi Tappu User Groups cleaned the *Mikania* once or twice a year (September-October and April-May). For first time to clean *Mikania* in 4 ha of land, Saptakoshi Buffer Zone Community Forest spent about Nepalese rupees 1, 20,000.00 and has been cleaning twice a year by spending about Rs 60,000.00. The expenses were covered by the voluntarily support of the User Group members and some supports collected from the different conservation organizations working in the KTWR area. People used fresh *Mikania* vines to feed goat and cattle as fodder caused abdominal disorder and reduced production of milk (Siwakoti 2007).

2.4. Uses

In India, Malaysia, Taiwan used as cover crop, prevent soil erosion, soil improvement also been used as fodder for sheep and cattle in Nepal, India, Malaysia and Fiji (Wirjahardja 1976; Zhang *et al.* 2004; Siwakoti 2007; Puzari *et al.* 2010; Macanawai *et al.* 2012; Tripathi *et al.* 2012; PIER 2015). However, its consumption also shown to cause hepatotoxicity. It has been reported to increase the growth and yield of rice in Mizoram, India when used as green manure. However, it is not particularly suitable for mulching and composting due to its high water content and rapid rate of decomposition (Sankaran 2007).

Mikania have some property of antibacterial and antimicrobial has been used as medicinal herb in various countries. In its native range *Mikania* use in folk medicine to cure snake bite, in Assam (NE India), Kabi tribe use the leaf juice as antidote for insect and scorpion bites, in Fiji, Samoa and Papua New Guinea to treat cuts and nausea (Day *et al.* 2012; Macanawai *et al.* 2012), and in Ecuador, used as a rat poison (Holmes 1975). In Africa, leaves were used to making vegetable soup as well it can be used as topical ointment for eliminating discomfort of hornet, bee and ant sting (PIER 2015).

Poudal (2010) study showed the efficient use of forest weed in the form of densified briquette fuel will form potential source of alternative source of energy which will contribute to conserve biodiversity.

2.5. Control

2.5.1. Mechanical control

Manual methods (sickle weeding or uprooting) but more expensive than chemical option. (Sankaran 1999). Repetitive cutting (Kuo *et al.* 2002) above the ground biomass before flowering i.e. September in Nepal, two consecutive cutting in a 3-week interval (Rai *et al.* 2012).

2.5.2. Chemical control

Glyphosate + picloram (Ahmad-Faiz 1992), glyphosate and dicamba, paraquat + diuron (Teng and The 1990), 2,4-D amine, 2,4-D-sodium and ioxynil applied six weeks apart hexazinone + diuron at four weeks apart and 2,4-D-sodium followed six weeks later by glyphosate (Mangoensoekarjo 1978), triclopyr + picloram showed best result in India

(Sankaran 1999).

2.5.3. Biological control

Cuscuta reflexa smothered surface of *Mikania* formed haustorium on all the plant species where the stem touches (Sapkota 2007). An insect *Liothrips Mikaniae* considered most promising pathogen but failed, a rust fungus *Puccinai spegazzinii* infecting all aerial parts leading to killing whole plant, the butterfly *Actinote anteas* has controlled *Mikania* in lowland areas of Sumatra (www.cabi.org).

2.6. Habitat of Wild Water Buffalo

Wild water buffalo are terrestrial also heavily dependent on water and spend most of time on wallowing. They found in tropical, subtropical and wetlands preferred riverine forest, grassland, marshes and swamps which are mixture of tall grasses, rivers and streams and scatter or scrubby woodland and forest. Such habitat is perfect to provide of adequate water for drinking and wallowing, abundant food and dense cover (Dahmer 1978; Gurung and Singh 1996; Nowak 1999). They shows seasonal variations in habitat utilization (Dahmer 1978). Due to sunlight intensity factor, in winter they prefer open short grassland whereas forest and agricultural fields in monsoon (Eisenberg and Lockart 1972).

Since pure wild water buffalo had been vanished in Bangladesh, Laos, Vietnam, and Sri Lanka (Hedges *et al.* 2008; Choudhury 2010) they are restricted in few areas. In India, in late 1980s, fewer than 100 were left in Madhya Pradesh (Divekar and Bhusan 1988) and by 1992 only 50 were survived (Choudhury 1994). In Bhutan and Cambodia small number of population exist (Choudhury 2010; Tordoff *et al.* 2005) as well small herds of less than 40 individuals occur in Thailand (Chaiyarat 2004).

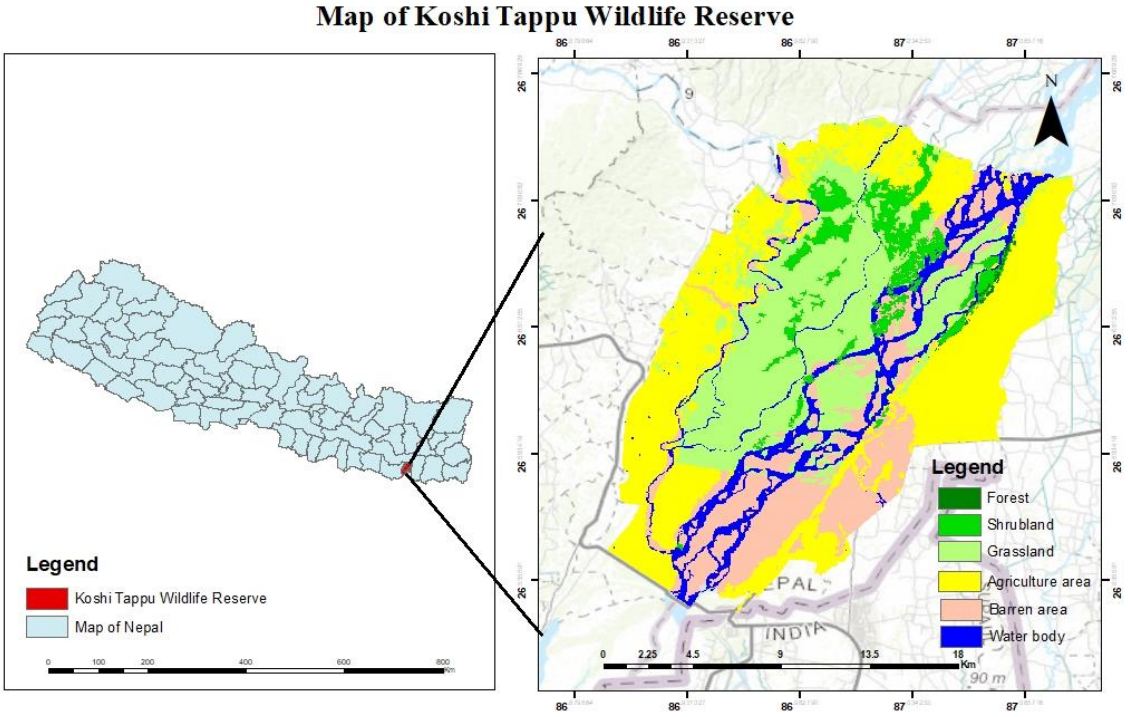
In Nepal, wild buffalo was found in both CNP and KTWR due to heavy poaching and heavy destruction Chitwan wild water buffalo had become extinct in 1970s (Seidensticker 1975) currently wild water buffalo population growing from 219 individuals in 2009 to 432 individuals in 2016 by 7% (Kathmandu post 2016) and some have been transferred in CNP as well (Kathmandu post 2016).

3. MATERIALS AND METHODS

3.1 Study area

3.1.1. Physical part

The study area exist at eastern terai cover the area of Sunsari, Saptari and Udaypur district which is located between 86°55'-87°05'E longitude and 26°34'-26°35'N latitude in the flood plain of the Sapta Koshi river. It is the only habitat for the last remaining population of wild water buffalo, and was also designated as a wetland of international importance by the Ramsar Convention in 1987 for its special role in maintaining genetic and ecological diversity of the region (Shah 1997; Karki 2008) and established as a protected area in 1976 under the IUCN category IV, spreads over an area of 175 km^2 (IUCN 1990; Karki 2008) with 173 km^2 as buffer zone and It ranges in altitude from 75 -81m (Shah 1997). It is mainly characterized extensive wetland habitats in the form of floodplains, oxbow lakes and swamp forest. The terrestrial vegetation consists of grassland savannah as well as small areas of degraded forest (DNPWC 2002).



3.1.2. Climate

It exhibits subtropical climate with summer monsoon starting at April to May and extreme thunderstorms and lightening at June to September as well high temperatures are common in the summer. Precipitation has been erratic and much shorter duration which lead to either excessive flood or more dryness. The greatest amount of precipitation occurs in July and Aug with average of 660mm of rainfall and minimum/driest month is January and December.

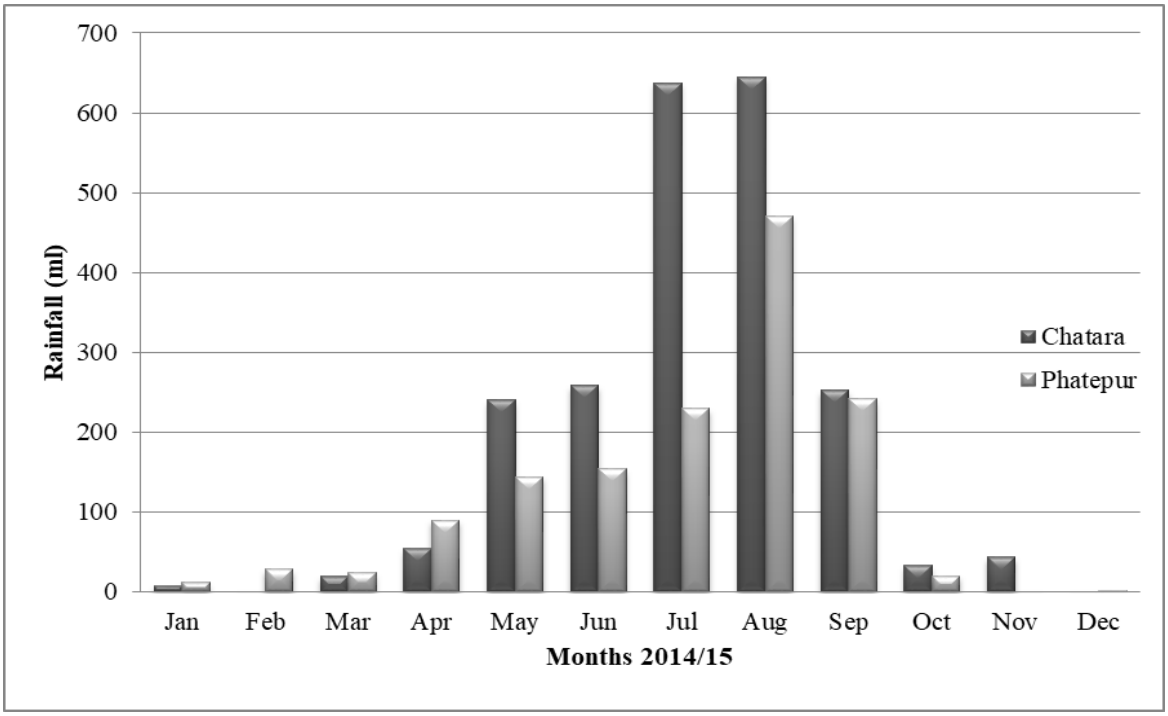


Figure 5. Monthly rainfall (mm) of Chatara and Phatepur

3.1.3. Flora

The reserve is mainly characterized by mixed deciduous riverine forest exhibit four types of habitat with forest cover 1% of land of reserve, rivers and streams cover 10%, marshes 5%, lakes and ponds 1% of reserve and grassland is dominant covering 56% of reserve and 5% of agricultural land (ICIMOD 2014). Reserve is rich in biodiversity with 670 species of vascular plants (Shah 1997; Bhandari 1998; Siwakoti 2006) 11 protected species (IUCN 1998; DNPWC 2009), aquatic species 78 (Shrestha 1996), species of ethno-botanical use 63 (Shrestha 1996; DNPWC 2009), Desmids 26 (Rai and Misra 2009). The vegetation includes mainly Khair (*Acacia catechu*), Sissoo (*Dalbergia sissoo*), Bayer (*Zizyphus* sp.), Simal (*Bombex ceiba*), Rhino apple (*Trewia nudiflora*), Khasreto (*Ficus hispida*), Jamun (*Syzugium cumini*), Khari (*Celtis australis*) etc. followed by herbs-tall Elephant grass (*Saccharum spontaneum*), *Imperata* sp., *Typha* sp., Dubo (*Cynodone dactylon*) , ferns sp. as well invasive species like water hyacinth (*Eichhornias crassipes*), Shrubby morning glory (*Ipomea carnea*), Chinese creeper (*Mikania micrantha*), Aligator weed (*Alternanthera philoxeroides*), *Lantana camera* etc.

3.1.4. Fauna

The reserve is highly rich in faunal diversity with 21 species of mammals (Chhetry and Pal

2010), 45 species of herpeto-fauna (DNPWC 2009), 77 species of butterflies and 494 species of birds (BCN 2011). Some species found in KTWR are Wild Water Buffalo (*Bubalus arnee*), Asiatic Elephant (*Elephus maximus*), Rhesus Macaque (*Macaca mulatta*), Spotted Deer (*Axis axis*), Hog Deer (*Hyelaphus porcinus*), Wild Boar (*Sus scrofa*), Golden Jackel (*Canis aureus*), Gangetic Dolphin (*Platanista gangetica*), Blue Bull (*Boselaphus tragocamelus*), as well reptiles like Gangetic gharial (*Gavialis gangeticus*), Marsh Crocodile (*Crocodylus palustris*), Rock python (*Python morulus*) etc. Present of Rich diversity of birds like Bengal Florican (*Houbaropsis bengalenseis*), Large Adjutant Stork (*Leptoptilos dubius*), Black Headed Cuckoo Shrike (*Coracina melanoptera*), Drongo (*Dicrurus* sp.), Cattle Egret (*Bubulcus ibis*), Dove (*Streptopelia* sp.), Common Myna (*Acridotheres tristis*) etc.

3.2. Methods of Data Collection

3.2.1. Reconnaissance survey

Preliminary survey was conducted from March 20 to 23, 2016 to identify the preference habitat of wild water buffalo and *Mikania* invasion area. After that research field work was carried out from March 25 to April 17, 2016. Study was conducted by discussion with park authorities, guides, key informants and local people. During the survey, solitary and herd of wild water buffalo were observed. Secondary data were collected through relevant literature, journals, books, reports, internet etc.

3.2.2. Block Division

Since wild water buffalo sometime spotted at community forest area as well their dung had been observed, study area Kusaha, Madhuban and Prakashpur were divided into six blocks, 3 inside the reserve side and 3 at the community forest area. Blocks which are within the reserve side named as Kusaha reserve, Madhuban reserve and Prakashpur reserve and blocks which are laid at the community side named as, Kusaha community, Madhuban community and Prakashpur community.

3.2.3. Vegetation analysis

At research site, near riverbank with small and tall grasses was categorize as grassland and, tall grasses with small woody shrub were named as shrub side. Whereas, in forest Sissoo forest, mixed Sisso-Khayer forest and small and patchy forest was observed. In each block for tree species according to forest size 20m×20m, 64m×64m, for shrubs 5m×5m and for herbs species 1m×1m quadrats were randomly allocated. Plant species were identified by local people and guide. Diameter at breast height (DBH) of tree species were recorded using measuring tape and only greater than 8cm of DBH were taken.

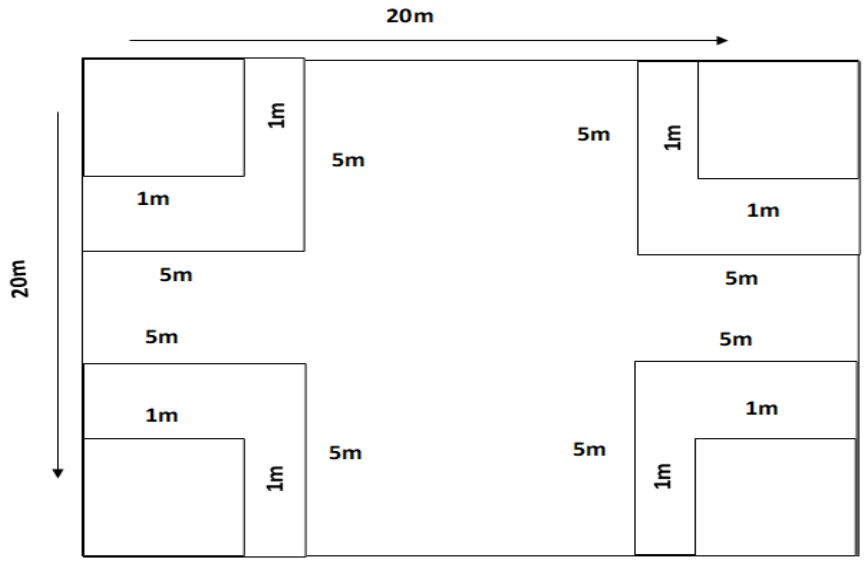


Figure 6. Layout of quadrats

3.2.4. Scan sampling

Preference of habitat and consumption of food was determined by scan sampling (Altmann 1974) method. The scan sampling was carried out for about 120 hours in which ten minutes of observation and one minute of interval was taken.

3.2.4.1. Focal sampling

As they were in herd, focal sampling was performed for the observation. For the purpose of preference, three shifts, morning 6:00am–10:00am, day 10:00am-2:00pm and evening 2:00pm-6:00pm were scheduled and observation were performed in alternative days.

Shift Day	Morning	Day	Evening
1st	Obs.	×	Obs.
2nd	×	Obs.	Obs.
3rd	Obs.	Obs.	×

Note: Obs. = observation takes place, × = observation didn't take place

3.3 Statistical analysis

3.3.1. Shannon-wiener Diversity index (H)

It conveys the species richness and species equitability. The higher the number, the higher is the species diversity. The Shannon Wiener index for diversity was calculated (Michael 1990) 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!)

3.3.2. Simpson's Index

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. 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= $\frac{\sum \mathbf{n(n-1)}}{\mathbf{N(N-1)}}$

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 to 1. With this index, zero represents infinite diversity and one, no diversity. i.e., higher the value of D, lower is diversity. This is neither intuitive nor logical, so to get over this problem, D is often subtracted from one to give the species diversity.

3.3.3. 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 which refers to the actual ground covered by the stems. It was calculated as following way.

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).

$$\text{Density of species} = \frac{\text{Total number of individuals of a species}}{Total\ area\ sampled}$$

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

iv) Frequency and Relative Frequency

Frequency of a species is the percentage of quadrats 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).

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

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

3.3.4. Prominence value

To calculate the prominence value, the percentage cover of each species is assumed, estimated in each quadrats 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

3.4. Impact analysis of *Mikania micrantha*

3.4.1. Index of Species Reduction

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

$$\text{ISR} = \frac{A \times B}{C}$$ (Pradhan 2007)

Where,

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

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

$$\text{C} = \frac{\text{Number of pole sized trees of species X}}{\text{Number pole size trees of all species}}$$

The diameter at breast height (DBH) of all the impacted trees were measured. Generally invaded tree up to 20 m height classified as dead trees. Similarly, coverage on tree and on ground also has been recorded.

3.5. Questionnaire survey

At buffer zone, one hundred people were sampled and interviewed by using semi structure question to find their perception about preference of habitat, consumption of food plant species and *Mikania* invasion.

3.6. GIS mapping of *Mikania* distribution and preference habitat of *Bubalus arnee*

For GIS mapping, field data, latitude/longitude of *Mikania* and arna were collected with the help of GPS. GIS mapping of *Mikania micrantha* distribution and wild water buffalo preference habitat of study area was done by using ArcGIS 10.2 and Google Earth 10.

3.7. Data analysis

All collected data were entered into Microsoft Excel 2013 and Notepad and imported into R software. For diversity, impact assessment, people perception about consumption of *Mikania* and habitat preference of wild water buffalo were analyzed using R-studio while scan sampling through Excel 2013.

4. RESULTS

Out of the six study blocks, three blocks were overlaid in the core area while three in the buffer zone of KTWR. Altogether 29 plots in which 20mx20m, 64mx64m was laid out with *Mikania* presence in 19 plots and wild water buffalo recorded from seven plots.

4.1. Diversity Indices

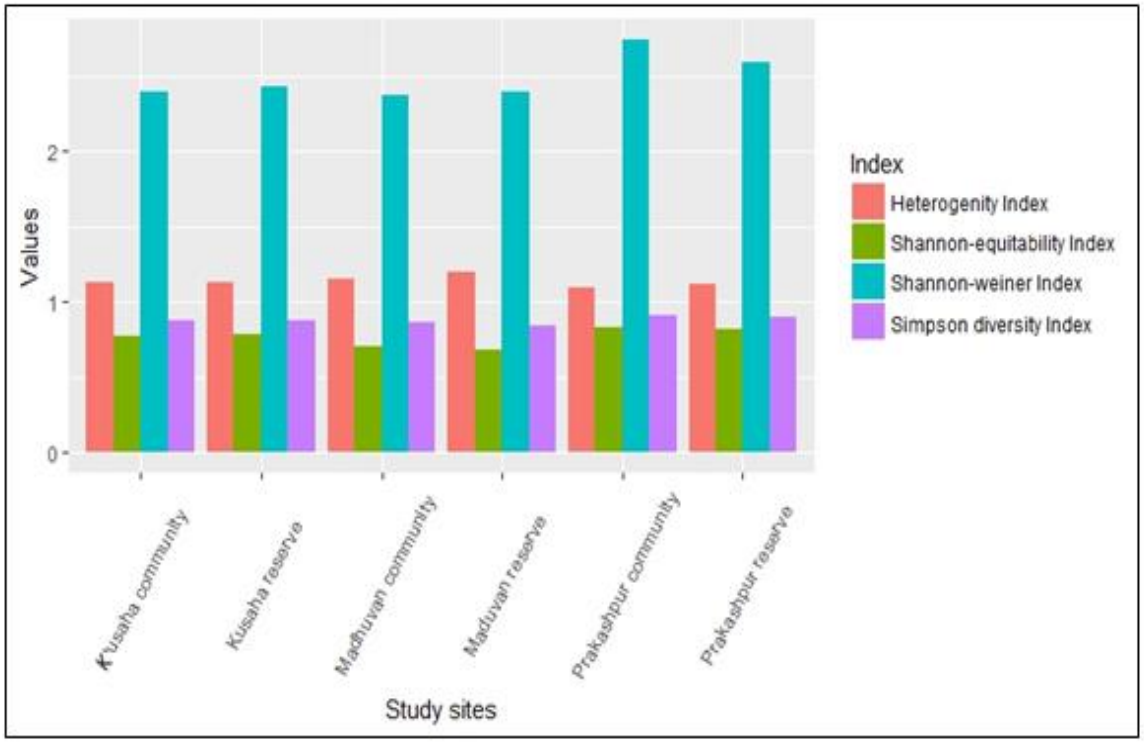


Figure 7. Diversity indices of plant species of different study sites

Among the six different study sites, the four different indices showed Shannon weiner Index (H' = 2.73), Simpson index (D = 0.915) and Shannon equitability index (SHEI = 0.82) and Simpson diversity index (D = 0.84) in Prakashpur community followed by Prakashpur reserve site. While indices showed low diversity at Madhuvan community and Madhuvan reserve site (Figure 7).

4.2. Important Value index (IVI)

Important value index (IVI) shows the most dominant species in the forest.

Table 1. Important Value Index of tree species

Common name	Scientific name	IVI
Sisso	*Dalbergia sissoo*	97.28
Rhino apple	*Trewia nudiflora*	53.98
Kadam	*Neolamarckia cadamba*	5.66
Bhogate	*Maesa macrophylla*	3.6
Simal	*Bombax ceiba*	31.38
Khasreto	*Ficus hispida*	3.32
Ipil-ipil	*Leucaena leucocephala*	1.35
Khirro	*Holorrhena antidysentrica*	8.33

Rato Tanki	*Bauhinia longifolia*	3.2
Khari	*Celtis australis*	14.69
Khair	*Senegalia catechu*	16.96
Sirish	*Albizia* sps.	9.94
Sugar apple	*Annona squamosa*	2.19
Dudhilo	*Ficus nemoralis*	5.77
Champa phul	*Plumeria* sps.	4.26

IVI result indicated *Dalbergia sissoo* (IVI = 97.28) was most dominant plant species in the study area followed by *Trewia nudiflora* (IVI = 53.98) while least species was of *Leucaena leucocephala* (IVI = 1.35) and *Annona squamosa* (IVI = 2.19) (Table1).

4.3. Prominence value (PV)

Table 2. Prominence value of *Mikania* and some plant species eaten by *B. arnee*

Scientific name	Common name	Total frequency	Mean percentage cover of species (M_X)	Frequency of occurrence of species ($\sqrt{f_x}$)	Prominence value of species (PV_X) = $M_X((\sqrt{f_x})$
Cynodone dactylon	Dubo	33	13.60	5.7	78.15
Imparata cylindrica	Siru	43	35.73	6.6	234.3
Saccharum spontaneum	kaans	29	567.11	1.86	771.27
Typha sp.	Pater	29	316.924	2.625	513.42
Mikania micrantha	Kunth	25	21.004	2.59	33.82
Dalbergia sissoo	Sissoo	28	0.13	5.3	0.7
Acacia catechu	Khayer	5	0.02	2.2	0.04
Bombax ceiba	Simal	7	0.01	2.6	0.001
Syzugium cumini	Jamun	7	0.04	2.6	0.11
Celtis australis	Khari	7	0.01	2.6	0.01

To know the abundance of plant species of grassland PV was calculated. Calculated PV elucidated the *S. spontneum* (PV = 771.27), was most abundant followed by *Typha* (PV = 513.42), *I. cylindrica* (PV = 234.3) *C. dactylon* (PV = 78.15) and *Mikania* (33.82) and least abundant were Khari (PV = 0.01) and *A. catechu* (PV = 0.04) (Table 3).

4.4. GIS Mapping of *Mikania* and *B. arnee* distribution in the study sites

GIS map displayed *Mikania* have invaded in all 6 blocks including wild buffalo presence habitat. Heavy invasion found in forest area than open grassland. Most of the wild buffalo were recorded in grassland near water body, which mean invasion impacted in habitat but wild buffalo avoided it (Figure 8).

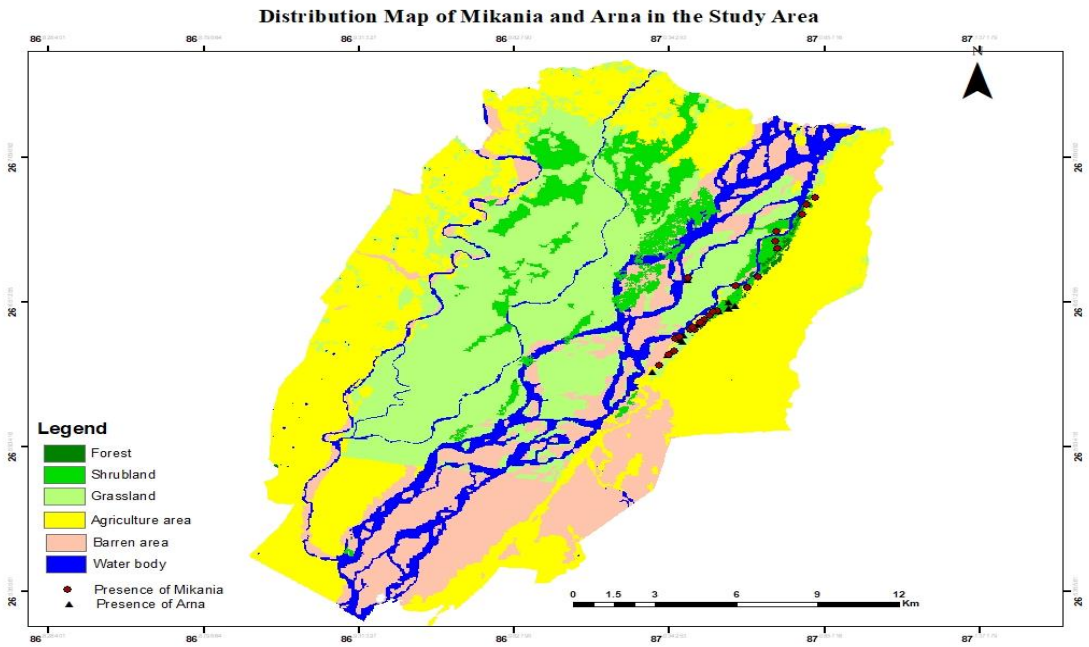


Figure 8. Presence of *Mikania* and *B. arnee*

4.5. Presence of *B. arnee* in relation to coverage of *Mikania*

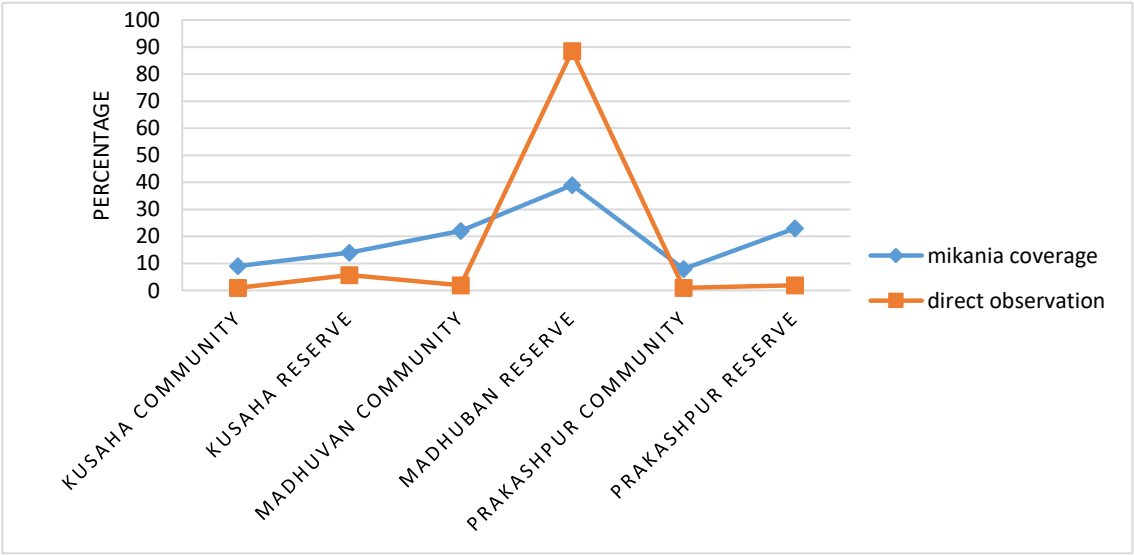


Figure 9. Relation of *Mikania* coverage and presence of *B. arnee* in different sites

Throughout the research 105 wild buffaloes were observed directly. Among the study sites, the population of wild buffalo (88.57%) and coverage of *Mikania* (39%) was highest observed in Madhuvan reserve while least in Kusaha community, wild buffalo (0.95%) and coverage (9%) and in Prakashpur community sites wild buffalo (0.95%) and coverage (8%) observed (Figure

9). Furthermore, linear regression indicated negative relation between presence of wild water buffalo and coverage of *Mikania* (t value = -1.807, $P < 0.05$).

4.6. Index of Species Reduction

Index of Species Reduction of major tree species due to impact of *Mikania micrantha* was calculated.

Table 3. ISR of major tree species of study area

S.No	Sp. Name	Killed species	Impacted species	Total number	Pole sized	Total number	ISR=(a*b)/c
1	Sisso	14	68	359	32	63	0.077
2	Rhino apple	0	13	106	4	63	0
3	Simal	0	4	14	0	63	0
4	Kadam	0	0	2	0	63	0
5	Bhogate	0	0	10	0	63	0
6	Khair	0	0	8	0	63	0
7	khasreto	0	2	4	0	63	0
8	Khari	0	1	11	0	63	0
9	Kadam	0	0	2	0	63	0
10	Ipil-ipil	0	1	1	0	63	0
11	Sugar apple	0	0	1	0	63	0
12	Sirish	0	0	8	0	63	0
13	Khirro	0	0	7	0	63	0
14	Champa phul	0	0	1	0	63	0
15	Dudhilo	0	0	1	0	63	0

The above table represented indices of species reduction (ISR) value of different species and indicated sissoo (ISR=0.077) was the highly impacted species in the site during the study period (Table 4).

4.7. Scan sampling

To observe the preference habitat of wild buffalo in scan sampling, focal sampling was performed. Scan sampling (Figure 10) showed wild buffaloes most of the time (81%) spent in near water body grassland area. Due to maximum time budgeted by wild buffalo on grassland area, *Mikania* was not consumed seemed through scan sampling.

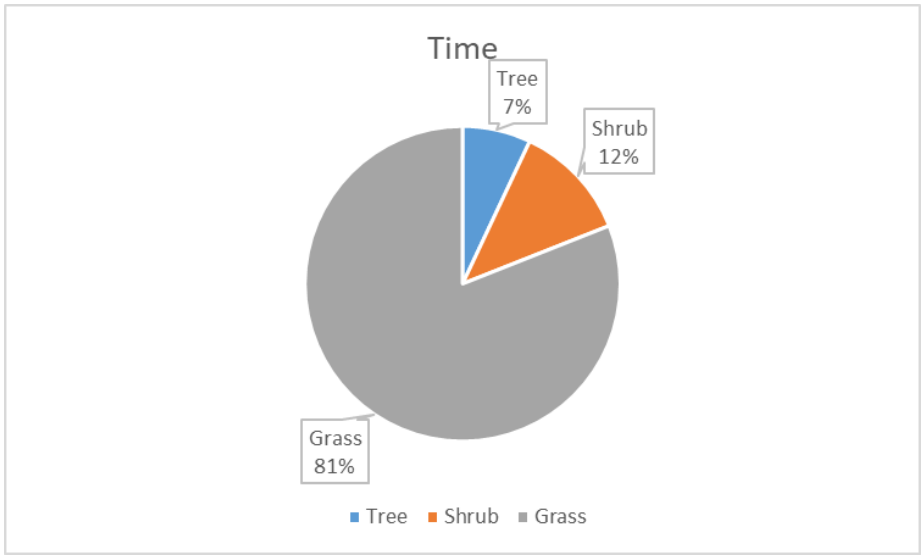


Figure 10. Time spend in habitat through scan sampling

4.8. People perception about consumption of food

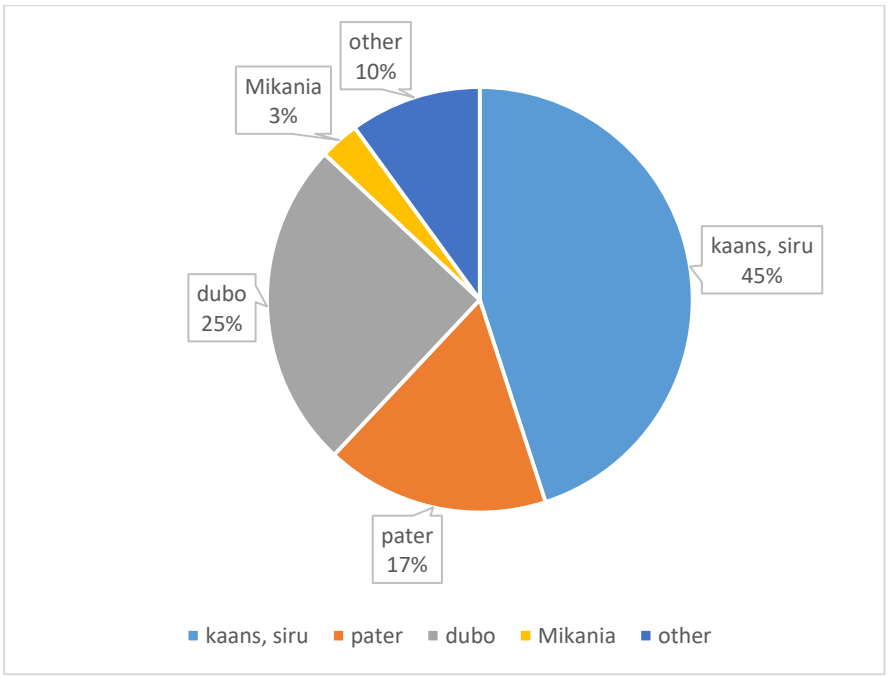


Figure 11. Consumption of food

According to respondent, most consumable food of arna is kaans and siru, 45% respond on it and followed by dubo.

4.9. People perception about rate of spreading of *Mikania*

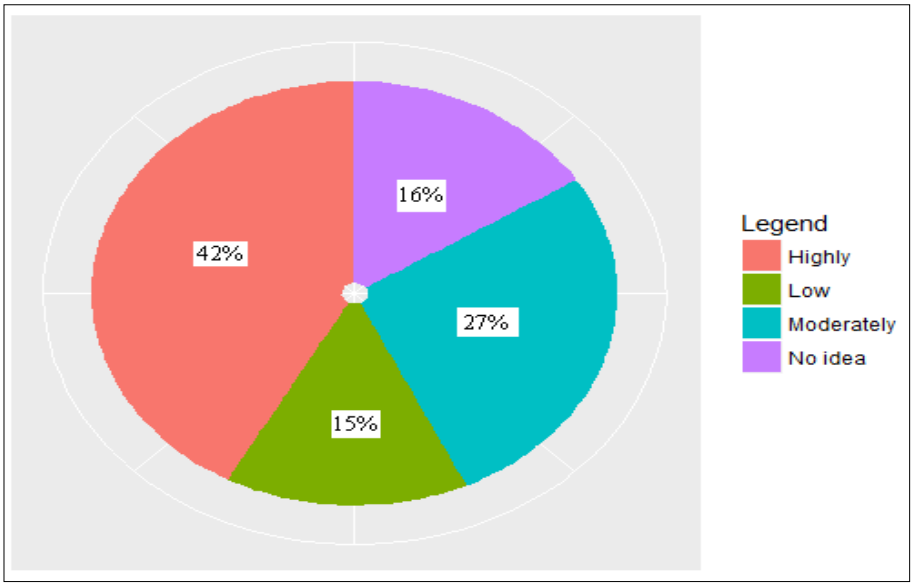


Figure 12. Rate of spreading of *Mikania*

Among interviewed person 84% of respondents were known about the *Mikania* while 16% were unknown. Among the known respondent about 42% believed that *Mikania* highly spreaded in KTWR till now and about 15% responds on low invasion (Figure 12).

4.10. Response of people about habitat preference

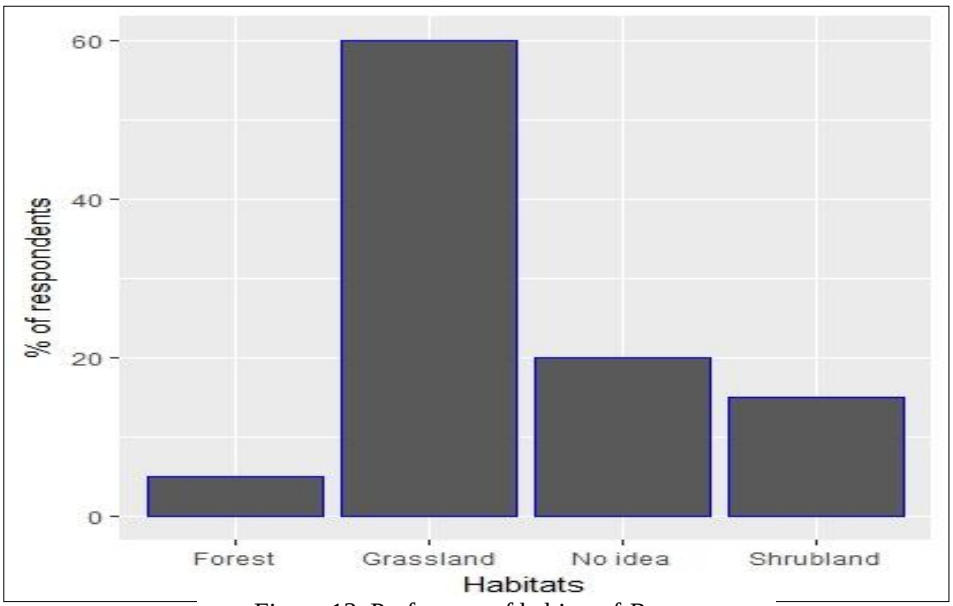


Figure 13. Preference of habitat of *B. arnee*

Among the respondents, (60%) mentioned that the most preferred habitat for wild buffalo was grassland followed by (15%) who believed shrub land to be preferred one. Where (20%) were unknown about the fact and about (5%) believed wild buffalo spend most of their time at forest (Figure 13).

4.11. People perception about consumption of *Mikania* by *B. arnee*

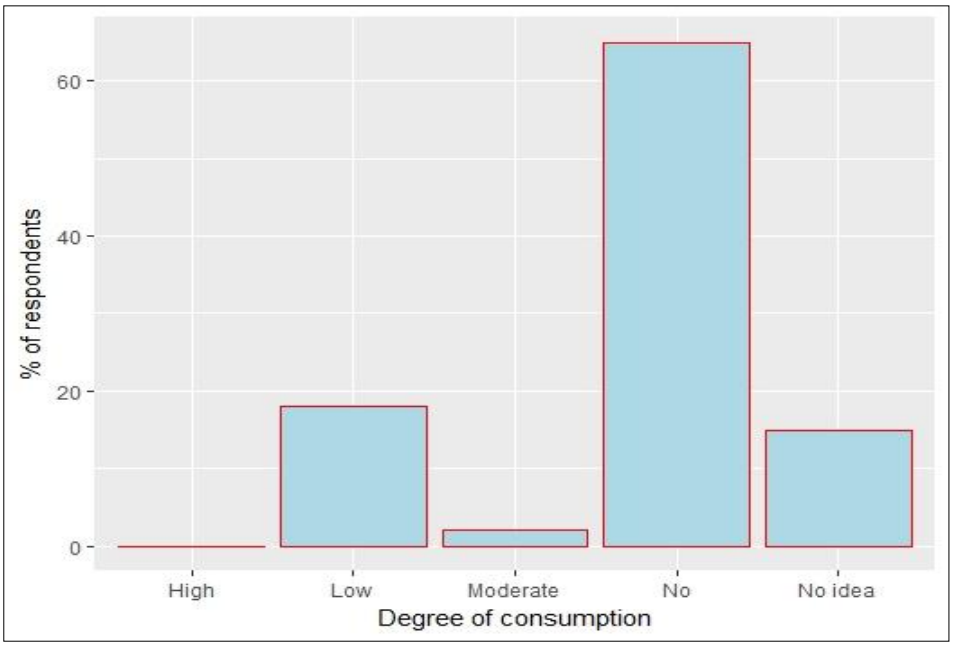


Figure 14. Consumption of *Mikania*

Regarding the degree of consumption of *Mikania* by *B. arnee*, about (18%) replied low feeding of *Mikania* while 67% replied no consumption of *Mikania* (Figure 14).

5. DISCUSSION

Research is conducted mainly to assess the impact done by *Mikania* in habitat of wild water buffalo. Study showed wild water buffalo mostly occupied in Madhuvan and Kusaha reserve site and these both sites have almost similar diversity.
Among the six different study sites, from the four different indices (Figure 7) indicated Prakashpur community and Prakashpur reserve sites were highly diversified while Madhuvan reserve site had low diversity and high Sissoo dominant in this site.

IVI indicated the most dominant species in the forest was *D. sissoo* (IVI = 97.28) followed by *T. nudiflora* (IVI = 53.98) while least species was of *L. leucocephala* (IVI = 1.35) and *A. squamosa* (IVI = 2.19).
Index of Species Reduction result showed Sissoo (ISR = 0.077) was mostly impacted plant species in my study. Shrestha *et al*. (2013) study in KTWRBZ showed Sissoo (*D. sissoo*), Khair (*A. catechu*), Bayer (*Z. marutiana*) were affected species and among them Sissoo was found to be mostly affected by *Mikania*. In my study, only Sissoo affected might be intervention of season, study conducted on summer/dry season when flower sprouting and plants start shading leaves, not much impacted on other species were observed.

Likewise among the food plant species PV showed *S. spontaneum* (PV = 771.27) was most abundant food plant species followed by *Typha* (PV = 513.42), *I. cylindrica* (PV = 234.3), *C. dactylon* (PV = 78.15) and *Mikania* (PV=33.82) and least abundant were Khari (PV = 0.01) and *Acacia catechu* (PV = 0.04). On the sandy ground *S. spontaneum* density 247 per square meter was recorded (Rai 2013). This indicates preferred food plant species have high abundance while *Mikania* found to be low PV may be due to hot/dry season, cutting for fodder by locals.

Similarly in Figure 9, highest coverage of *Mikania* have shown in Madhuban reserve site and Prakashpur reserve site and least at Prakashpur community site. Similarly, Shrestha *et al*. (2013) study showed 90% coverage on Sissoo forest and Siwakoti (2007) result portrayed heavy invasion in core area (50%-80%) followed by community forest (20%-50%) and heavy invasion occurred in eastern side (Sunsari district) than western side (Saptari and Udayapur district) of KTWR. Result indicated inside the reserve sites had high invasion may be uninterrupted to *Mikania* which led to high coverage. Also showed community forest have low coverage of *Mikania* due to huge amount of use as fodder. Ram (2008) study also revealed same result of respondents, domestic cattle consumed *Mikania* and people use to make fodder to feed cattles in KTWR.
Even though result plotted heavy invasion (39%) at Madhuban reserve site, (88.57%) wild buffalo preferred this habitat site and least in Prakashpur and Kusaha community sites where least coverage shown. Linear regression showed negative relation between *Mikania* coverage and wild water buffalo presence in different sites (t value = -1.807, $P < 0.05$), which mean if *Mikania* coverage is higher than wild water buffalo presence is lower. Likewise Chaudhary (2001) study also showed 41-50% wild buffalo preferred Madhuban-Kushaha site for suitable habitat with flood plain grassland, wood plain grassland, Khair-Sissoo forest rather than Prakashpur where area almost cover with sand and little with flood-plain grassland. Preference of Madhuvan site may be water wholes with abundant amount of food plant species. As well

as Prakashpur have many interference and disturbances than other sites might be the cause of lead wild buffalo preferred to Kushaha site.

Scan sampling indicated wild buffalo most of the time (81%) spent in near water grassland and least in tree side (7%). Same as according to people perception (60%) respondents responded on maximum time spent in grassland. At that season they spent (46%) of time in grazing on the sandy and hot ground with small sprouting of *S. spontanium* at river banks (Rai 2013). Abundance of food plant avaibility, near water bodies make wild buffalo preferred grassland area habitat.
According to respondent, *C. dactylon, I. cylindrica, S. spontaneum* were most consumable food plant species. Chaudhary (2001) also had similarly observed *C. dactylon, I. cylindrica, S. spontaneum* were most preferred while *Acacia catechu, B. ceiba, D. sissoo* were less preferred plant species as well as his faecal analysis revealed that high portion of diet of wild buffalo composed of herb (41.18%) in which *C. dactylon* (16.48%), *I. cylindrica* (12.45%), *S. spontaneum* (11.56%) and (17.67%) browsed in which *Acacia catechu* (2.67%), *Bombax ceiba* (0.44%), *D. sissoo* (4%).

Even though people shared their thought on high invasion of *Mikania* till now, GIS map (Figure 8) shown that wild buffalo less likely to avoid the *Mikania* invasion site and almost not consuming of *Mikania* and also at field observation, observed that.

4. CONCLUSIONS AND RECOMMENDATION

Among the six different study sites, altogether 95 plant species were recorded. Among them 30 species of tree, 20 species of shrub and 45 species of herb. Prakashpur site have high diversity with 13 species of tree and low at Kusaha reserve site with 6 species of tree recorded.

Based on IVI, eastern side of Koshi Tappu is highly dominant by Sissoo.
In grassland, preferred food plant species *S. spontaneum, Typha, I. cylindrica, C. dactylon* found to be most abundant plant species. While *Mikania* seemed to be have low abundance and it mostly impacted in Sissoo forest, which indicated food plant species was not affected by *Mikania* at that season.

Madhuvan reserve site have highest *Mikania* coverage followed by Kusaha reserve site which are most preferable habitat of wild buffalo by (88.57%) and (5.7%) respectively. On the basis of respondents, it is concluded that *Mikania* is highly invading in the habitat. Through scan sampling, it was clear that wild buffalo preferred near water grassland for grazing. Wild water buffalo sensitive towards the presence of *Mikania* and avoid the presence of *Mikania*. Hence even if *Mikania* is higher in Madhuvan where most of the time spent by wild buffalo, they grazed at riverside grassland. It concluded that even though habitat was affected by *Mikania*, wild buffalo was not directly influenced.

Based on research, some recommendations put forwarded as follows:

- Even though *Mikania* have many negative impacts, people should be promoted or practiced as *Mikania* as ethno-botanically due to it have many medicinal value.
- It could be promoted as briquette fuel, since it is potential source of alternative energy.
- Since this study was conducted at dry season, other season also should be studied while *Mikania* coverage and wild water buffalo presence vary according to season.
- Feeding ecology of wild water buffalo should be studied in detail.
- Impact of domestic livestock on habitat of wild water buffalo could be observed.

5. REFERENCES

Altman, J. 1974. Observational Study of Behavior: Sampling Methods. Behavior, **49**: 227-267.

Abraham, M., Abraham, C.T. and George, M. 2002. Competition of *Mikania* with common crops of Kerala. India Journal of Weed Science, **34**: 96-99.

Adams, C.G. and Proctor, R.R. 1972. Flowering plants of Jamaica. University of the West Indies. Mona, Jamaica.

Adhikari, B. 2004. Presentation on the *Mikania* problem in Nepal. *Mikania micrantha* weed invasion in Nepal. First National Stakeholders' Workshop. 25 November 2004.

Ahmad-Faiz, M.A. 1992. Comparison of three weeding methods in rubber cultivation. Planters' Bulletin Rubber Research Institute of Malaysia. 212-213: 99-101.

Aryal, A., Shrestha, T.K., Ram, A., Frey, W., Groves, C., Hemmer, H. *et al.* 2011. Call to Conserve the Wild Water Buffalo (*Bubalus Arnee*) in Nepal. International Jounal of Conservation Science, **2**: 161-168.

Baral, H.S. and Inskipp, C. 2005. Important bird areas in Nepal: Key sites of conservation. Bird Conservation Nepal, Kathamndu, Nepal and Birdlife International, Cambridge, UK.

Barreto, R.W. and Evans, H.C. 1995. The Mycobiota of the Weed *Mikania micrantha* in Southern Brazil with Particular Reference to Fungal Pathogens for Biological Control. Mycological Research, **99**(3): 343–352.

Bauer, J.J. 1987. Recommendations for species and habitat management Kosi Tappu Wildlife Reserve after sever monsoonal flooding in 1987. Unpublished FAO report number DNPWC/FAO NEP: 85/011.

BCN 2011. Bird check list of the Koshi Tappu Wildlife Reserve. Kathmandu, Nepal: Bird Conservation Nepal.

Bhandari, B. 1998. An Inventory of Nepal's Tarai Wetlands. Final Report submitted to IUCN Nepal, Kathmandu.

Chalise, M.K. 2000. Biodiversity of wild food plants in relation to the monkeys feeding ecology. In the Proc. of Eighth International Workshop of BIO-REFOR, Japan, under Biotech. Applications for Reforestation and Bio-diversity Conservation, pp. 289-294.

Chalise, M.K. 2008. Nepalka Samrakshit Banyajantu, (Nepal's Protected Wildlife) in Nepali. Shajha Prakashan, Lalitpur Kathmandu Nepal, pp. 116.

Chaiyarat, R., Lauhachinda, V., Kutintara, U., Bhumpakphan, N. and Pravurasiddhi, T. 2004.

Population of Wild Water Buffalo (*Bubalus bubalis*) in Huai Kha Khaeng Wildlife Sanctury, Thailand. Natural History Bulletin Siam Society, **52**(2): 151-162.

Chaudhary, L.N. 2001. Status, Distribution and Feeding Habit of Wild buffalo (Bubalus bubalis arnee) of Koshi Tappu Wildlife Reserve. Msc. Thesis. Central Department of Zoology, Tribhuwan University, Kathmandu, Nepal.

Chhetry, D.T. and Pal, J. 2010. Diversity of Mammals in and around Koshi Tappu Wildlife Reserve. Our nature, **8**: 254-257.

Choudhary, A.K. 1972. Controversial *Mikania* (climber): A threat to the forests and agriculture. Indian Foresters, **98**: 178-186.

Choudhary, A. 1994. Steep decline of wild buffalo in North east India adjoining indo- Nepal boarder area. Oryx, **28**(1): 70–73.

Choudhury, A. 2010. The vanishing herds: the wild water buffalo. Gibbon Books, Rhino Foundation, CEPF and COA, Taiwan, Guwahati, India.

Choudhury, A. 1994. The decline of the wild water buffalo in northeast India. Oryx, **28**(1): 70-73.

Cock, M.J.W. 1982. Potential biological agents for *Mikania micrantha* H. from the Neotropical region. Tropical Pest Management**, 28**: 242-254.

CBD. 2008. Alien species that threaten ecosystems, habitats or species. Convention on Biological Diversity, United Nations.

Corbet, G.B., Hill, J.E. 1992. The mammals of Himalayan Region. Natural History Museum Publlication, Oxford University press. Oxford, UK.

Curtis, J.T. and McIntosh, R.P. 1951. An Upland continuum in the Praine Forest Border region of Wisconsin, pp. **32**: 476-496.

Dahmer, T.D. 1978. Status and distribution of the Wild Asian Buffalo (*Bubalus bubalis*) in Nepal. Unpublished M.S. Thesis, University of Montana, Missoula, USA. pp. 71.

Daniel, J.C. and Grubh, B.R. 1966. The Indian wild buffalo *Bubalus bubalis* (Linn.) in peninsular India: a preliminary survey. Jour of the Bombay Nat. His. Soc. **63**: 32-53.

Day, M.D., Kawi, A., Kurika, K., Dewhurst, C.F., Waisale, S., Saul-Maora, J. *et al*. 2012. *Mikania*micrantha Kunth (Asteraceae) (mile-a-minute): its distribution and physical and socioeconomic impacts in Papua New Guinea. Pacific Science, **66**(2): 213-223.

Divekar, H.K. and Bhusan, B. 1988. Status of Wild Asiatic Buffalo (*Bubalus bubalis*) in the Raipur and Bastar Districts of Madhya Pradesh. Technical Report of the Bombay Natural History Society of the Salim Ali Nature Conservation Fund.

DNPWC. 2002. Koshi Tappu Wildlife Reserve (a Rasmar site) Management Plan: 2002-2007, Department of National Parks and Wildlife Conservation, Kathmandu.

DNPWC. 2009. Koshi Tappu Wildlife Reserve and Buffer Zone Management Plan 2009–2013. Kathmandu, Nepal: Government of Nepal, Department of National Parks and Wildlife Conservation

DNPWC. 2010. Annual report Shrawan 2066-Ashad 2067 (July 2009-June 2010), in, Kathmandu: Department of National Park and Wildlife Conservation (DNPWC).

DNPWC. 2011. Annual report Shrawan 2067-Ashad 2068 (July 2010-June 2011), in, Kathmandu: Department of National Parks and Wildlife Conservation (DNPWC).

Eisenberg, J.F. and Lockart, M. 1972. An Ecological Reconnaissance of Wilpattu National Park, Ceylon. Journal of Wildlife Management, **35**(5): 644-647.

GoN. 2005. Annual Report 2004-2005. Kathmandu: GoN Ministry of Forest and Soil Conservation, and Department of National Parks and Wildlife Conservation, Kathmandu, Nepal.

Gurung, K. and Singh, R. 1996. Field Guide to the Mammals of the Indian Subcontinent. London: Academic Press Limited.

Hedges, S., Baral, H.S., Timmins, R.J., Duckworth, J.W. 2008. "*Bubalus arnee*". The IUCN Red List of Threatened Species. IUCN, 15 January 2018.

Hedges, S. 1995. Asian Wild water buffalo: Draft Report and Conservation Action Plan (parts I & II). Unpublished Report, IUCN, Switzerland.

Holm, T.G., Pancho, J.V., Herberger, J.P. and Plucknett, D.L. 1991. A Geographic Atlas of World Weeds. Malabar, Florida, USA: Krieger Publishing Company.

Holm, L.G., Plucknett, D.L., Pancho, J.V. and Herberger, J.P. 1977. The World Worst Weed-Distribution and Biology, University press of Hawaii, Honolulu, USA.

Holmes, T.P., Aukema, J.E., Holle, B.V., Liehold, A. and Sills, E. 2009. Economic impacts of invasive species in Forests, past, present and future, Annals of the New York Academy of Science, pp. 162: 18-38.

Holmes, W. 1975. A revision of Mikania scandens and relatives (Compositae). Ph.D. Thesis. Mississippi State, MS. Mississippi State University, USA.

Huang, Z.L., Cao, H.L., Liang, X.D., Ye, W.H., Feng, H.L. and Cai, C.X. 2000. The growth and damaging effect of *Mikania micrantha* indifferent habitats. Journal of Tropical and Subtropical Botany, pp. **8**: 131–138.

ICIMOD. 2014. An integrated Assessment of Effects of Natural and Human Disturbances on a Wetland Ecosystem "A Retrospective of from Koshi Tappu Wildlife Reserve, Nepal" International Centre of Integrated Mountain Development, Nepal.

IUCN. 1990. Directory of wetlands of international importance. Ramsar Convention Bureau, Gland: IUCN.

IUCN. 1998. An Interpretation and Education System of Koshi Tappu Wildlife Reserve and its Buffer Zones. Kathmandu: IUCN, Nepal.

IUCN. 2011. The status of mammals of Nepal. The National red list series. <http://www.icunredlist.org> accessed on 13 January 2013.

Karki, J.B. 2008. Koshi Tappu Ramsar Site: Updates on Ramsar Information Sheet on Wetlands. The Initiation, **1**(2): 10-16.

Kathmandupost 2016. "Arna population up in Koshi Tappu Reserve". www.kanthmandupost.ekantipur.com.

Kathmandupost 2016. "KTWR to shift 30 'Arna' to Chitwan". www.kathmadupost.ekantipur.com.

Kushwaha, H.P. 1986. Comparison of census data for wild buffalo and domestic livestock (buffalo and cow) in Koshi Tappu Wildlife Reserve. Unpublished project report, Institute of Forestry, Thribhuwan University, Nepal.

Kuo, L.K., Chen, T.Y. and Lin, C.C. 2002. Using a consecutive-cutting method and allelopathy to control the invasive vine, *Mikania micrantha* H.B.K. Taiwan. Journal of Forest Science, **17**: 171–181.

Lamichhane, B.R., Subedi, N., Chapagain, N., Dhakal, M., Pokharel, C.P., Murphy, S.T. and Amin, R. 2014. Status of *Mikania micrantha* Invasion in the Rhino Habitat of Chitwan National Park, Nepal. In: Lamichhane, B.R., Subedi, N., Chapagain, N., Dhakal, M., Pokharel, C.P., Murphy, S.T. and Amin, R. eds. Proceeding of International Conference on Invasive Alien Species Management, 25-27 March 2014, Sauraha, Chitwan, Nepal. 52-60 pp.

Lee, S.K., Goh, K.C. and Yee, S.O. 1997. Natural regeneration of vegetation as an alternative for greening sand-filled reclaimed land in Singapore. Land Degradation & Development, **8**(1): 59-70.

Lowe S., Browne, M., Boudjelas, S. and Poorter, De.M. 2000. 100 of the World's Worst Invasive Alien Species. A selection from the Global Invasive Species Database.

Lydekker, R. and Dollman, J.G. 1926. The game animals of Africa. Second edition London, Rowland ward, pp. 1-483.

Macanawai, A.R., Day, M.D., Tumaneng-Diete, T. and Adkins, S.W. 2012. Vegetative growth and development of *Mikania micrantha* in taro and cassava production in Viti Levu, Fiji. Pakistan Journal of Weed Science Research, **18**: 377-384.

Macanawai, A.R., Day, M.D., Tumaneng-Diete, T. and Adkins, S.W. 2010. Frequency and density of *Mikania* micrantha and other weeds in taro and banana systems in eastern Viti Levu, Fiji. In: Zydenbos, S.M. eds. 17th Australasian weeds conference. New frontiers in New Zealand: together we can beat the weeds. Christchurch, New Zealand, 26-30 September 2010. Hastings, New Zealand: New Zealand Plant Protection Society, 116-119.

Mangoensoekarjo, S. 1978. Mile-a-minute (*Mikania micrantha* H.B.K.) control in immature oil palm. Proceedings, Plant Protection Conference, Malaysia, pp. 381-387.

Meyerson, L.A. and Mooney, H.A. 2007. Invasive alien species in an era of globalization. Frontiers in Ecology and the Environment **5**(4): 199-208.

Millennium Ecosystem Assessment 2005. Ecosystem and human well-beings. Washington, DC: Island Press. pp.137.

Murphy, S.T., Subedi, N., Jnawali, S.R., Lamichhane, B.R., Upadhyay, G.P., Cock, R. and Amin, R. 2013. Invasive *Mikania* in Chitwan National Park, Nepal: The Threat to the Indian rhinoceros and factor driving the invasion. Oryx, pp. **47**(3): 361-368.

Nowak, R.M. 1999. Walker's Mammals of the World. Volume 1. The Johns Hopkins University Press, Baltimore, USA and London, U.K. Quantitative Data. Oxford University Press, Oxford.

PIER 2015. Pacific Islands Ecosystems at Risk. Honolulu, USA: HEAR, University of Hawaii. http://www.hear.org/pier/index.html

Poudel, M.S. 2010. Potential *Mikania micrantha*, An Invasive Alien Species of Chitwan National Park, As a Raw Material in Briquetting. M.Sc. Thesis, College of Applied Sciences-Nepal, Tribhuvan University.

Poudel, A., Baral, H.S., Ellison, C. A., Subedi, K., Thomas, S. and Murphy, S. 2005. *Mikania micrantha* weed invasion in Nepal. A summary report of the first national workshop for stakeholders, held on 25 November, in Kathmandu, Nepal.

Pradhan, N.M.B. 2007. An ecological study of re-colonizing population of Asian elephants (*Elephus maximus*) in lowland Nepal. Phd. Thesis Norwegian University of Life Sciences, Department of Ecology and Natural Resource Management, Norway.

Prater, S.H. 1993. The book of Indian animals (reprints). Bombay Natural History Society and Oxford University press, India.

Puzari, K.C., Bhuvan, R.P., Dutta, P. and Nath, H.K.D. 2010. Distribution of *Mikania* and its economic impact on tea ecosystem of Assam. Indian Journal of Forestry, pp. **33**(1): 71-76.

Rai, N.S. and Chalise, M.K. 2014. Diurnal Activities of Wild Water Buffalo (*Bubalus arnee*) in KTWR, Eastern Nepal (A case study of Kusaha). Central Department of Zoology, Tribhuwan University. DNPWC, pp. 103-112.

Rai, N.S. 2013. Activities Pattern of Wild Buffalo (*Bubalus arnee* Kerr, 1792) in Koshi Tappu Wildlife Reserve, Nepal (A case study of Kusaha area). Msc. Thesis. Central Department of Zoology, Tribhuwan University, Nepal.

Rai, R.K., Sandilya, M. and Subedi, R. 2012. Controlling *Mikania micrantha* HBK: How effective manual cutting is? Journal of Ecology and Field Biology, pp. **35**(3): 235–242.

Rai, S.K. and Misra, P.K. 2009. On some desmids from Koshi Tappu Wildlife Reserve, Nepal. Ecoprint: An International Journal of Ecology, **15**: 47-58.

Ram, A.K. 2008. Impact of *Mikania micrantha* on Rhinoceros habitat in Chitwan National Park, Chitwan, Nepal. Msc. Thesis. Institute of Forestry, T.U., Pokhara, Nepal.

Randall, J.M. 1996. Weed control for the preservation of biological diversity. Weed Technology, **10**: 370–383.

Rawat, G.P. 1997. Conservation status of forests and wildlife in the Eastern Ghats, India. Environmental Conservation, pp. **24**: 307-315.

Sah, J.P. 1997. Koshi Tappu Wetlands: Nepal Ramsar Site, Bangkok. IUCN.

.

Sapkota, I. and Oden, P. C. 2008. Household characteristics and dependency on community forests in Terai of Nepal. International Journal of Social Forestry, **52**: 253–282.

Sapkota, L. 2007. Ecology and management issues of *Mikania micrantha* in Chitwan national park, Nepal, Banko Janakari, pp. **17**(2): 27–39.

Sankaran, K.V. 1999. *Mikania* management calls for biocontrol. Biocontrol News and Informartion, pp. **22**(3).

Scherf, B.D. 2000. World Watch List for Domestic Animal Diversity - 3rd Edition. Food and Agriculture Organization of the United Nations, Rome, Italy, 746 pp.

Seidensticker, L. 1975. Ungulate populations in Chitwan valley, Nepal. Office of Zoological Research, National Zoological Park, Smithsonian Institute, Washington D.C. USA.

Shrestha, T.K., Tamang, B. and Khadgi, A. 2013. A Study on control of *Mikania micarantha* in Lowland of Protected Areas in Nepal.

Shrestha, P. 1996. 'Diversity of Aquatic Macrophytes in the Koshi Tappu Wildlife Reserve and Surrounding Areas, Eastern Nepal'. In: Jha, P.K., Ghimire, G.P.S., Karmacharya, S.B., Baral, S.R., Lacaul, P. eds. Environment and Biodiversity: In the Context of South Asia, Kathmandu. Ecological Society (ECOS), pp 92-99.

Shrestha, R. 2011. Impact of *Mikania micrantha* H.B.K., An Invasive Alien Species on Native Flora of Chitwan National park And Its Buffer Zone, Nepal. Msc. Thesis, College of Applied Sciences, Tribhuwan University, Nepal.

Siwakoti,M. 2007. *Mikania* weed: A challenge for conservationists, Our Nature, **5**: 70-74.
Subedi, N., Jnawali, S.R., Dhakal, M., Pradhan N.M.B., Lamichhane, B.R., Malla, S., Amin, R. and Jhala, Y. 2013. Population status, structure and distribution of the Greater one-horned rhinoceros *Rhinoceros unicorni*s in Nepal. Oryx **47**(3): 352–360.

Swamy, P. S. and Ramakrishnan, P. S. 1988. Effect of Fire on Growth and Allocation Strategies of *Mikania micrantha* under Early Successional Enviroment. Journal Applied Ecology, **25**(2): 653-658.

Swamy, P.S. and Ramakrishnan, P.S. 1987. Weed potential of *Mikania micrantha* H.B.K. and its control in fallows after shifting agriculture (jhum) in north-east India. Agriculture Ecosystem Environment, **18**(3): 195-204.

Tordoff, A.W., Timmins, R.J., Maxwell, A., Keavuth, H., Vuthy, L. and Hourt, K.E. 2005. Biological assessment of the Lower Mekong Dry Forest Ecoregion. In: Tordoff, A.W., Timmins, R.J., Maxwell, A., Keavuth, H., Vuthy, L., Hourt, K.E. eds. WWF Greater Mekong Programme, Phnom Penth, Cambodia.

Tiwari, S., Adhikari, B., Siwakoti, M., and Subedi, K. 2005. An Inventory and Assessment of Invasive Alien Plant species of Nepal, IUCN, Kathmandu, Nepal.

Tripathi, R.S., Khan, M.L. and Yadav, A.S. 2012. Biology of *Mikania micrantha* H: a review. In: Bhatt, J.R., Singh, J.S., Singh, S.P., Tripathi, R.S., Kohli, R.K. eds. Invasive alien plants: an ecological appraisal for the Indian subcontinent. Wallingford, UK: CABI, 99-107.

Waterhouse, D.F. 1994. Biological Control of Weeds: Southeast Asian Prospects. Australien Centre for International Agricultural Research, Canberra, Australia.

Waterhouse, D.F. and Norris, K.R. 1987. Biological control: Pacific prospects, vii+454pp.

Wirjahardja, S. 1976. Autecological study of *Mikania* spp. In: Proceedings of 5th Asian-Pacific Weed Science Society Conference, Tokyo, Japan, pp. 70-73.

Yadav, N.P. 2003. How *Mikania micrantha* (Lahare banmara) destroy the forest and agricultural crops in residential area of Nepal? Forestry Nepal http://www.forestrynepal org/print/4534. 5 January 2011.

Zhang, L.Y., Ye, W.H., Cao, H.L. and Feng, H.L. 2004. *Mikania micrantha* H.B.K. in China-an overview. Weed Research, pp. **44**:42-49.

www.issg.org/database/welcome/content.asp.

https://www.cabi.org/

ANNEXES

Annex-1. Field Survey Form
Date of Survey:
GPS Point:
Location:
Quadrate No:
Quadrate size:

Site Information:

Habitat type: Grassland, shrubland and forest.

Mikania micrantha:
- Canopy Cover: 0 - 25%, 25% - 50%, 50% - 75%, 75% - 100%
- Ground Cover: 0 - 25%, 25% - 50%, 50% - 75%, 75% - 100%
- Frequency:

Plant species:
- Name of Species:
- Frequency:
- DBH:
- Height:

Wild water buffalo:
- Presence:
- Absence:
- No. of wild water buffalo:

Annex-2. Questionnaire Survey

Impact of *Mikania* on habitat of wild water buffalo

Name of Respondent: Date:
Village: Occupation:
GPS: Sex: Age:
1. Do you know the species *Mikania*? a. Yes b. No
2. Do you know that it is an invasive species? a. Yes b. No
3. How much *Mikania* spreaded in the reserve? a. Low b. Moderately c. Highly
4. How much this species invaded/spreaded over 10 years?
a. Not much b. Moderately c. Highly
5. Do you know wild water buffalo? a. Yes b. No
6. What kind of habitat does it prefer/use more?
a. Near wetland b. Grassland c. Forest
7. Does it encountered in *Mikania* invaded site? a. Yes b. No
8. If yes, how much *Mikania* invaded at that area?
a. Low b. Moderate c. High
9. In which month wild water buffalo have been encountered at invaded site?
……
10. Have you seen wild water buffalo eating/grazing *Mikania*? a. Yes b. No
11. If yes, how much does it consume?
a. Low b. Moderate c. High
12. At which time? a. Morning b. Day c. Evening
13. In which month? ……
14. Do you think *Mikania* is the main source of food for wild water buffalo? a. Yes b. No
15. If no, which species does it consume? …….
16. Do you think *Mikania* lowring the food plant species? a. Yes b. No
17. Do you use *Mikania* as fodder for cattles? a. Yes b. No
18. If yes, how do you feed *Mikania* to cattles?
a. In low quantity b. Mix with fodder c. only *Mikania*
19. Does *Mikania* shows any effect on cattles? a. Yes b. No
20. If yes, please specify ……..
21. Do you use any prevention measures to minimize the effect of *Mikania*?
a. Yes b. No
22. If yes, please specify …….

Picture 1. Male herd grazing at grass area

Picture 2. Dung of *B. arnee*

Picture 3. Licked place by *B. arnee*

Picture 4. Taking quadrat at grazing habitat

Picture 5. Pugmark of wild water buffalo

Picture 6. Observing impacted Sissoo species

Picture 7. Taking quadrat at shrubland

Picture 8. Mixed herd at shrubland

Picture 9. Taking questionnaire survey

Picture 10. Parasite plant *Cuscutta reflexa* on *Mikania*

Picture 11. Local people cutting *Mikania* with fodder

Picture 12. Cattle feeding *Mikania* with fodder