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Author Affiliation:
[1]Kathmandu Forestry College, Nepal
[2]School of environment science and management, Nepal (email: ram.mandal@gmail.com),
[3]Institute of forestry Hetauda, Nepal

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Effect of invasive species on deer habitat using spatial analysis - A Study from Buffer zone community forests Chitwan, Nepal

Anusha Dhakal[1], **Ram Asheshwar Mandal**[2], **Yogendra Yadav**[3]

ABSTRACT

Limited researches have been conducted regarding this issue to show the effects of invasive species on deer habitat. This research was objectively conducted to assess the impact of invasive species in grass species foraged by deer using spatial technique between 2010 to 2020. Five buffer zone community forests namely Belsahar, Baatuli Pokhari, Dakshankali, Navajyoti, Bandevi were directly observed and an inventory of grass foraged by deer and invasive species was carried out. Total 269 nested quadrants were established to collect data, they were analyzed using Importance Value Index. The Land Use Land Cover change was detected between 2010 and 2020 in three classes i.e. Water bodies, grassland, forest land. Around 13.70% area was covered by *Mikania micrantha*, 31.72% was covered by *Lantana camara*, 3.05% was covered by *Ageratine adenophora*, 0.28% was covered by *Ageratum conyzoides*, 5.94% was covered by *Ageratum houstonianum*, 3.80% was covered by *Oxalis latifolia*, 1.65% was covered by Parthenium *hysterophorus*. The highest importance value index was of *Lantana camara* (74.78) while the lowest IVI was of *Cynodon dactylon*(Dudo) with 5.17. A totaten thematic maps were produced to show change in grassland. The grassland was decreased between 2010 and 2020 in the overall study area. The grassland was about 498.62 ha (65.18%) in 2010 which was about 305.24 ha (39.85%) in 2020. This was about 193.88 ha (-25.33%) less in 2020 than in 2010. The total area assessed during the study was 778.6ha and most of the water area was invaded by *Mikania* and grassland by *Lantana*. The study will be useful for the scientific community and policymaker to manage the invasive species in the buffer zone.

Keywords: Invasive species, importance value index, thematic class

1. INTRODUCTION

The invasive species is defined as the flora and fauna which are inadvertently or deliberately introduced by humans outside of their normal geographic range into a region where they are not originally found (Shaheen et al., 2019). This species has high capacity to grow and form monoculture and spread easily to compete with the native species (Mack et al., 2000). The infestation of invasive species is considered as the second highest threat to biological diversity

(Randall, 1996, Reddy, 2008, Baidar et al., 2017). Many important species are affected due to invasive species (Gurevitch and Padilla, 2004, Gaertner et al. 2009). The habitat of many species have been lost due to invasive and finally there is loss of ecosystem as well. Globally, over 42% species are endangered because of invasive species (Pimental et al., 2005). It is one of the most problematic terrestrial invasive species in tropical areas of Nepal (Poudel et al., 2005). The report showed that, there are over 200 invasive species in India, 46 invasive species recorded in Bhutan, about 500 invasive species reported in Pakistan while this record is about 219 plants specie in Nepal (Shrestha, 2016).

The invasive species are highly infesting in Nepal and cause big threat to habitat of herbivore like deer (Paini et al., 2016). Nepal is very suitable for many invasive species because of varying wide geographical range and heterogenic climatic conditions (Shrestha, 2016). *Mikania micrantha* is one of the major invasive plant species in tropical moist forest regions in Asia including Nepal (Baidar et al., 2017). This invasive species is spreading an alarming rate in Chitwan National Park (CNP) and damaging grass diversity. *Mikania micrantha* is a native of Central and South America ("Global Invasive Species Database," 2014. This species was first time reported in Ilam district in 1963 (Tiwari et al, 2005). This species has seriously invaded Koshi Tappu Wildlife Reserve, Chitwan National Park, and most of the Terai region. *Mikania micrantha* is called as mile-a-minute or American rope (Paudel, 2011), it is multi-branched. The extent of invasion and its impact on biodiversity is increasing every year. The report showed that about 20% area of Chitwan National Park is invaded because of invasive species (Khadka, 2017). *Lantana camara* is a more popular toxic weed rather in most of the countries. Generally, this species is infesting to pastures, grazing lands, and cropland. *Lantana camara* is also known as Spanish Flag or West Indian. This plant has beautiful flower in the verbena, native to American tropic.

Remote sensing tool is a useful tool to detect the change in vegetation and other land use land cover. The remote sensing also helps to assess the disturbance in the forest whether it is because of invasive species. The spatial analysis technique is worldwide applied to detect the affected areas in the forest caused by invasive species. However, there are very limited study regarding this at Barandabhar Corridor Forest in Chitwan National Park. The problem of invasive species is being very serious in the national park and it affects habit of deer. Every year, area of invasive species is expanding and replacing the grass species. Losing the grass land and species means declining of food of deer (Mack et al., 2000, Huang & Asner, 2009). Therefore this study was conducted to assess the effect of Invasive Alien Plant Species (IAPS) on deer habitat in Barandabhar Corridor in Chitwan National Park. The study regarding effect of invasive species on deer's habitat using spatial analysis has limited done. Thus, this study was carried to out analyse the effect on invasive species on deer's habitat.

2. MATERIALS AND METHODS

Study site: Total 6 Buffer zone community forests in Chitwan national park, Nepal were selected as study area. Buffer zone community forests are covered by forest land, grassland including invasive species, wetland, and the encroachment area. Altogether 269 plots were laid randomly on forest land, grassland, and wetland area. The latitude and longitude of the plots were recorded using Gramin GPS. Next, plots were established in the forest particularly 5m×5m in affected areas in order to record the coverage and abundance.

Spatial Data Acquisition: The images Landsat 8 OLI/TIRS of 2020 and Landsat 7 ETM of 2010 were downloaded USGS (https://www.usgs.gov) website. The path and row of images of Nepal were 142 and 40 respectively which were used to acquire the images (Table 1).

Table 1: Name and character of the image

WRS (Path/Row)	Scene ID	Sensor	Band utilized	Bandwidth	Resolution	No. of Bands	Acquired Date
Path:142 Row:41	LE71420412010089SGS00	Enhanced Thematic Mapper Plus	Band 1– Blue Band Band 2– Green Band 3– Red Band 4- (NIR)	0.45-0.52 0.52-0.60 0.63-0.69 0.77-0.90	30 30 30 30	8	2010/03/30
Path:142 Row:41	LC8141041202 0086LGN00	Operational Land Imager and Thermal Infrared Sensor	Band 2-Blue Band3- Green Band 4-Red Band 5-(NIR)	0.452-0.512 0.533-0.590 0.636-0.673 0.851-0.879	30 30 30 30	11	2020/03/26

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Training samples: Field data showing the GPS coordinates of different feature were collected to use as training samples for thematic classification.

Landsat Image Processing: The first step of image processing is images stacking. Next to this was clipping of the area of interest. Then, the false color composite was prepared based on the color composition of bands. The false color composite is 5, 4, 3 (for Landsat OLI_TIRS image), and 4, 3, 2 (for Landsat ETM+ image). Then, signature file was created in order to classify the image. The image was classified into three thematic classes particularly into forest, water bodies and grass land (Table 2).

Table 2: Definition of different LULC class

S.N	Classes	Definitions
1	Forest	Lands dominated by woody vegetation with a percent cover 50% and height exceeding 2 meters.
2	Water bodies	land or areas (such as marshes or swamps) that are covered often intermittently with shallow water or have soil saturated with moisture
3	Grassland	A large open area of country covered with grass, especially one used for grazing.

Finally, the accuracy assessment was performed to check the precision of classified map. Besides the ecological value index was assessed using following formulae (Zobel et al. 1987).

$$\text{Relative density} = \frac{\text{Number of individual of the species}}{\text{Number of individual of all the species}} \times 100$$

$$\text{Relative frequency} = \frac{\text{Number of occurrence of the species}}{\text{Number of occurrence of all the species}} \times 100$$

$$\text{Relative dominance} = \frac{\text{Total basal area of the species}}{\text{Total basal area of all the species}} \times 100$$

IVI = Relative Frequency + Relative Density + Relative Abundance

The Importance Value Index provides a picture of the relative contribution of a species to the entire community.

3. RESULTS

Status of grass and invasive species

Field study revealed that the mostly found species is *Mikania micrantha* (11.24%), followed by *Lantana camara* (9.18%), *Cynodon dactylon* (9.18%), *Oxalis latifolia* (9.16%) *Ageratine adenophora* (7.61%), *Imperata cylindrical* (6.34%), *Pogostemon benghalensis* (5.12%), *Arundo* donax (4.21%), *Ageratum houstonianum* (3.73%), P*arthenium hysterophorus* (3.73%), *Bauhinia vahlii* (3.61%), Ageratum *conyzoides* (3.31), *Centella asiatica* (3.31%), *Saccharum spontaneum* (3.17%), Fern(3.16%), *Myrsine semiserrata* (3.13%), *Asparagus Racemosus* (3.01%), *Flemingia macrophylla* (2.82%), *Desmodium gangeticum*(2.56 %), *Phoenix humilis* (2.33%) (Table 3).

Table 3: Status of invasive and grass species

SN	Scientific name	Local name	N/ha	Percentage	Remark
1.	*Imperata cylindrica*	Siru	105375	6.34	Grass species
2.	*Phoenix humilis*	Thakal	38787.87	2.33	Grass species
3.	*Desmodium gangeticum*	Ghantu	42500	2.56	Grass species
4.	*Flemingia macrophylla*	Bhatmaase	46944.44	2.82	Grass species
5.	*Fern*	Fern	52500	3.16	Grass species
6.	*Pogostemon benghalensis*	Rudhilo	85000	5.12	Grass species
7.	*Cynodon dactylon*	Dubo	152439.02	9.18	Grass species
8.	*Bauhinia vahlii*	Bhorla	60000	3.61	Grass species

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8	*Myrsine semiserrata*	Kalikath	52000	3.13	Grass species
10.	*Asparagus Racemosus*	Kurilo	50000	3.01	Grass species
11.	*Centella asiatica*	Ghod Taprey	55000	3.31	Grass species
12.	*Saccharum spontaneum*	Kansh	52777.77	3.17	Grass species
13.	*Arundo donax*	Narkat	70000	4.21	Grass species
14.	*Mikania micrantha*	Lahere Banmara	186588.23	11.24	Invasive species
15.	*Lantana camara*	Banfada	152365.14	9.18	Invasive species
16.	*Ageratine adenophora*	Kalo Banmara	126428.57	7.61	Invasive species
17.	*Ageratum conyzoides*	Seto Gandhey	55000	3.31	Invasive species
18.	*Ageratum houstonianum*	Nilo Gandhey	61981.98	3.73	Invasive species
19.	*Oxalis latifolia*	Chari Amilo	152068.96	9.16	Invasive species
20.	*Parthenium hysterophorus*	Pati Jhar	61935.48	3.73	Invasive species

Importance value index grass and invasive species in study area: The highest IVI in overall study area was 74.78 of *Lantana camara* (Banfada) followed by *Imperata cylindrica* (Siru) 41.78 and lowest is of *Cynodon dactylon* (Dudo) which IVI =5.17 The IVI of IAPS is very high comparing to local grass species as a result, invasive species are dominating the local grass species preferred by deer (Table 4).

Table 4: Overall status of grass and invasive species

Scientific name	Local name	Relative density	Relative frequency	Relative coverage	IVI	IVI Rank
Imperata cylindrica	Siru	21.84	21.42	0.15	43.42	2
Phoenix humilis	Thakal	2.21	5.89	5.68	13.79	8
Desmodium gangeticum	Ghantu	3.67	8.92	6.99	19.59	5
Flemingia macrophylla	Bhatmaase	2.92	6.42	6.54	15.89	7
Fern	Fern	0.72	1.42	1.47	3.62	19
Pogostemon benghalensis	Rudhilo	1.46	1.78	7.94	11.20	9
Cynodon dactylon	Dubo	5.39	3.66	0.00	9.06	11
Bauhinia vahlii	Bhorla	0.10	0.17	3.97	4.26	17
Myrsine semiserrata	Kalikath	0.44	0.89	24.44	25.78	3
Asparagus Racemosus	Kurilo	0.04	0.08	8.19	8.32	12
Centella asiatica	Ghod Taprey	0.09	0.17	0.00	0.28	20
Saccharum spontaneum	Kansh	0.82	1.60	1.69	4.12	18
Arundo donax	Narkat	0.06	0.08	4.70	4.85	15
Mikania micrantha	Lahere Banmara	13.70	7.58	3.31	24.60	4
Lantana camara	Banfada	31.72	21.51	10.29	63.54	1
Ageratine adenophora	Kalo Banmara	3.05	2.50	5.28	10.84	10
Ageratum conyzoides	Seto Gandhey	0.28	0.53	3.47	4.29	16
Ageratum houstonianum	Nilo gandhey	5.94	9.91	2.71	18.57	6
Oxalis latifolia	Chari Amilo Jhar	3.80	2.58	0.36	6.76	14
Parthenium hysterophorus	Pati Jhar	1.65	2.76	2.71	7.14	13
Total		100	100	100	300	

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Prominence Value: The result shown that, the grass species, *Imperata cylindrica* was the most abundant species with prominence value 10.41 and followed by, *Cynodon dactylon* with prominence value 5.95 (Table 5).

Table 5: Prominence value of grass species

Name of the plants	No of individuals	Frequency(fx)	Mean cover of individual species (Mx)	Prominence value (PV)
Imperata cylindrica	240	0.892	11.02	10.41
Phoenix humilis	66	0.245	2.62	1.29
Desmodium gangeticum	100	0.371	4.19	2.55
Flemingia macrophylla	72	0.267	4.80	2.48
Fern	16	0.059	5.56	1.35
Pogostemon benghalensis	20	0.074	8.5	2.31
Cynodon dactylon	41	0.152	15.24	5.95
Bauhinia vahlii	2	0.007	6	0.51
Myrsine semiserrata	10	0.037	5.8	1.11
Asparagus Racemosus	1	0.003	5	0.30
Centella asiatica	2	0.007	5.5	0.47
Saccharum spontaneum	18	0.066	5.77	1.49
Arundo donax	1	0.003	7	0.42

Effect of Invasive species on Deer habitat at buffer zone community forest:

***Effect of invasive species on Belsahar BZCF*:** The result sheds light that in this period the area of water bodies has gradually increased whereas grassland and forest area was decreased (Figure 1 to 10). Grassland and forest land covered 138.9ha (68.39%) and 62.89ha (31.10%) in 2010 respectively which decreased to 123.27ha (61.09%) and 59.96ha (29.73%) in 2020. Water areas which were 1.01ha (0.49%) in 2010 increased to 18.49ha (9.17%) in 2020.. The grassland and forest area has been converted either into water bodies or another land-use form. The place where deer used to catch sight i.e. grassland is fully or partially covered with *Lantana camara* and other invasive species. This has led to a shortage of food for the deer. The invasive species was dominating the local grass species which is very challenging in the present and future context. Deer didn't prefer invasive species. It is changing its food habit.

Effect of Invasive species on grass species at Batulipokhari buffer zone community forest: The place where deer used to be seen i.e. grassland is fully or partially covered by *Lantana camara* and other invasive species. The area of grass land was about 56.61 ha (61.77%) in 2010 but it was 7.71 (8.35%) in 2020. This was reduced by 48.9 ha (53.41 %) between 2010 and 2020.

Effect of Invasive species on grass species at Dakshankali buffer zone community forest: Here the area of grass land was approximately 87.26 ha (52.46 %) in 2010 while this area reduced by 6.17 ha (3.37 %) and reached to 81.09 (49.08%) in 2020.

Effect of Invasive species on grass species at Navajyoti BZCF: Most of the grassy areas were covered by invasive species like *Lantana camara, Ageratine adenophora, Ageratum conyzoides, Ageratum houstonianum* and others. The area of grassy area declined to 24.75 ha (38.86%) by 15.17 ha (23.41 %) in 2020 from 10.58 ha (15.44 %) in 2010. The invasive species are main causes of declining habitat of deer and hence the consequence was shortage of food.

Effect of Invasive species on deer habitat at Bandevi BZCF: The estimated grass land was about 107.21 ha (44.05 %) in 2010 which was increased by 36.79 ha (15.28 %) and reached to 144 ha (59.33 %) in 2020. This was increased by between 2010 and 2020. Although the grassland area has increased but it is fully covered by invasive species like *Lantana camara, Ageratine adenophora, Ageratum conyzoides, Ageratum houstonianum* and other species.

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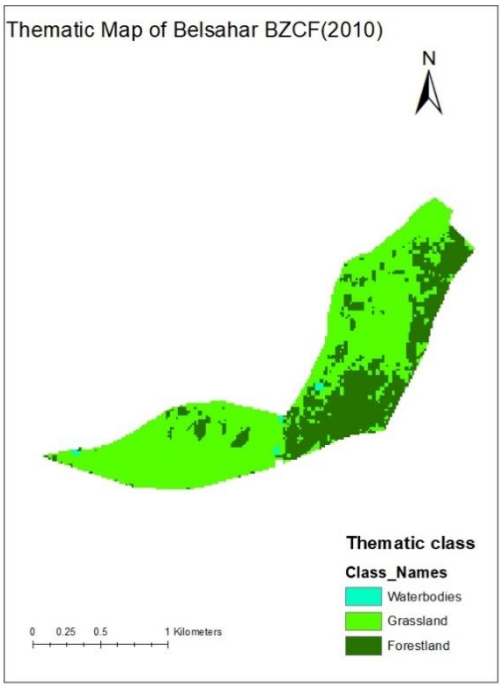
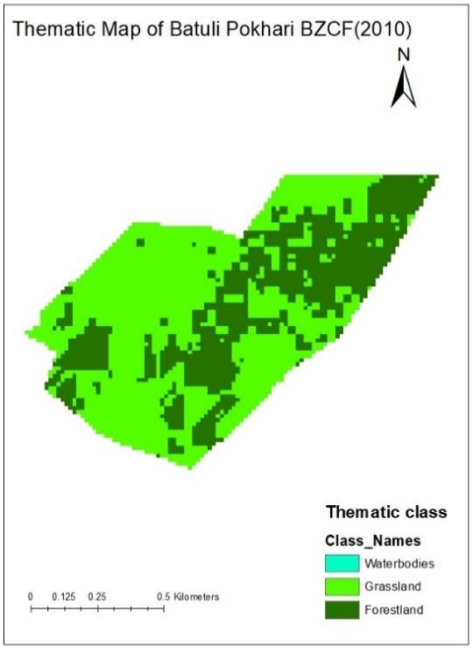
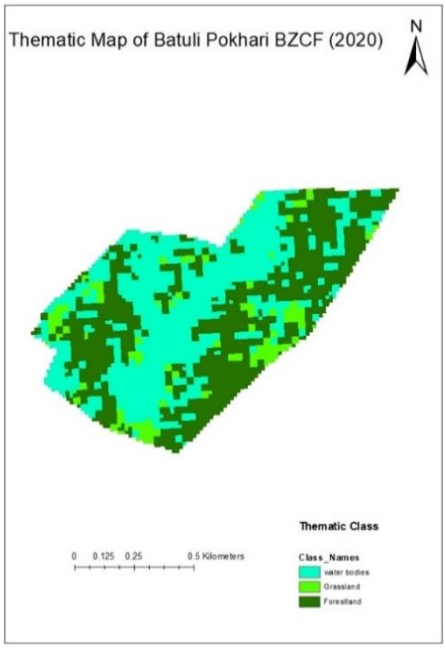


Thematic map of Belsaha BZCF (2010)

Thematic map of Belsaha BZCF (2020)



Thematic Map of Batuli Pokhari BZCF 2010



Thematic Map of Batuli Pokhari BZCF 2020

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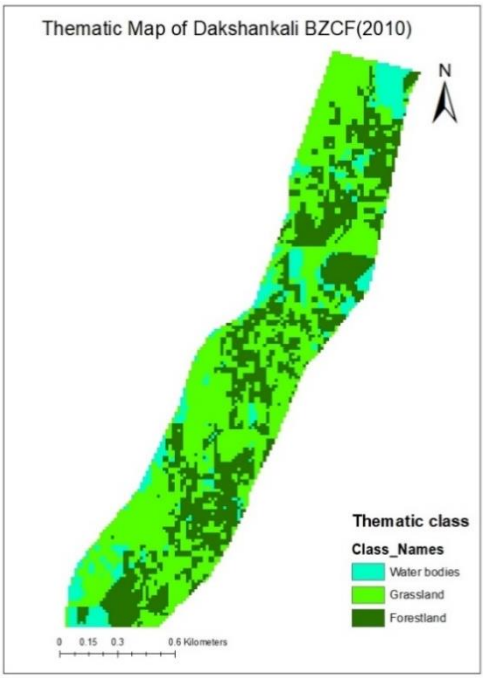
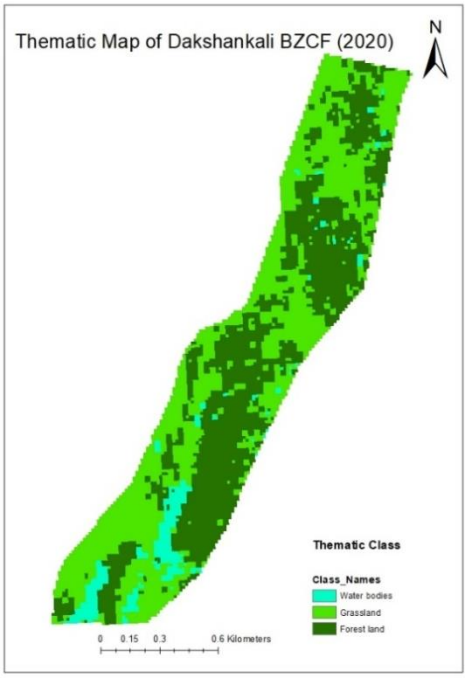
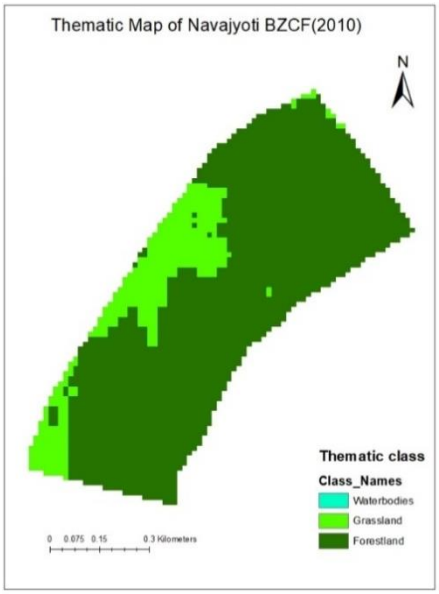


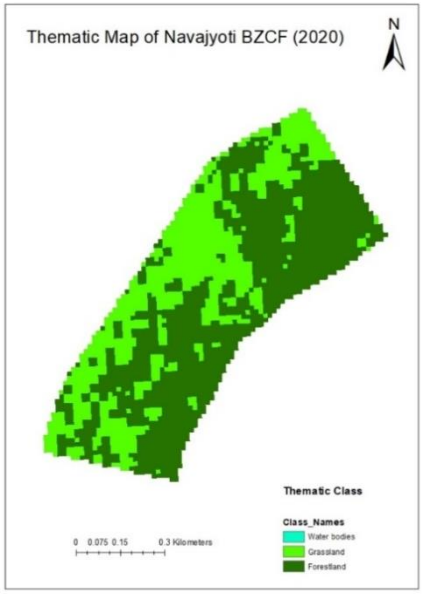
Thematic map of Dakshankali BZCF (2010)



Thematic map of Dakshankali BZCF (2020)



Thematic map of Navajyoti BZCF (2010)



Thematic map of Navajyoti BZCF (2020)

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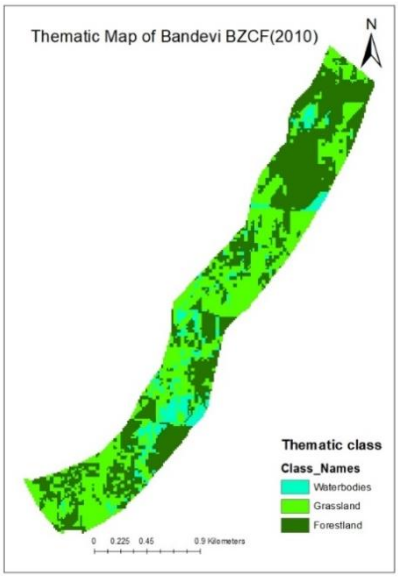
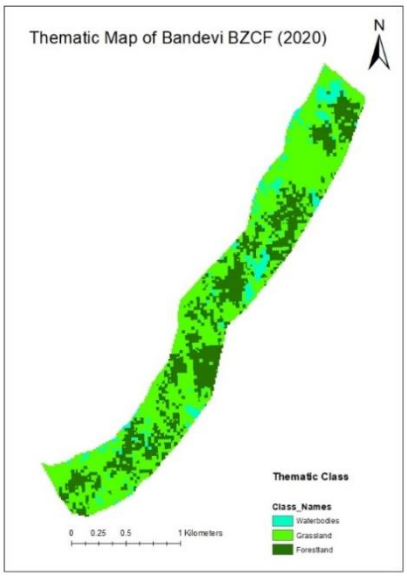


Thematic map of Bandevi BZCF (2010)



Thematic map of Bandevi BZCF (2020)

Figure 1 to 10: Comparison of grass land of 2010 and 2020 in thematic map

Effect of Invasive species on deer habitat in study area: The result showed that grassland is the major land cover in 2010 whereas forest land is the major land cover of 2020. The LULC status of the area in 2010 and 2020, as well as the LULC changes and conversions in the area from 2010 to 2020 is given below in figure 23, table 6. The image classification of 2010 revealed that 22.51 percent of total land was covered by forest whereas wetland occupying 12.29 percent in 2010 followed by 65.18 percent by grassland in 2010 which was the major land cover type in the study area, Image classification of 2020 shows that 49.60% land is covered by forest 39.85% by grassland and 10.54 percent by wetland. The grassland area has been converted into forest area which is covered by *Lantana camara*. The total grassland area decreased was 193.88 ha (25.33%) (Table 7).

Table 7: Overall status of different LULC class in 2010 and 2020

Thematic class	2010		2020		Change		Remarks
	Area ha	Percentage area	Area ha	Percentage area	Area ha	Percentage area	
Water bodies	94.14	12.29	80.68	10.54	-13.46	-1.75	
Grassland	498.62	65.18	305.24	39.85	-193.88	-25.33	
Forestland	215.37	22.51	422.73	49.60	+207.369	+27.08	

Spatial distribution of *Lantana camara* and *Mikania micrantha*

Lantana camara and *Mikania micrantha* in study area (figure 11 to 16): Total area of the study site was 778.6 ha. *Mikania* was domineered in water area whereas *Lantana* was domineered in grassland areas. Out of 269 plots *Mikania* was found in 55 plots (20.44%) whereas *Lantana* was found in 127 plots (47.21%). The invasive species was wholly or partially covered the grassland area. Although *Mikania* was in its initial stage of growth, it was found to be spreading rapidly in the study area. The plant species that were found under the *Mikania* was suppressed.

***Lantana camara* and *Mikania micrantha* in Belsahar BZCF**: The Belsahar Buffer Zone Community Forest covers a total area of 204.4 ha. Out of total 67 plots established in community forest 21 plots (31.34%) and 22 plots (32.83) covered by *Mikania* and *Lantana* respectively. Most of the water areas was invaded by *Mikania* and grassland by *Lantana*at the bank of Rapti River. The major grass species found in the invaded area include *Imperata cylindrical, Phoenix humilis, Desmodium gangeticum, Flemingia macrophylla,* Fern, *Pogostemon benghalensis, Cynodon dactylon, Myrsine semiserrata, Asparagus Racemosus, Centella asiatica, Saccharum spontaneum.*

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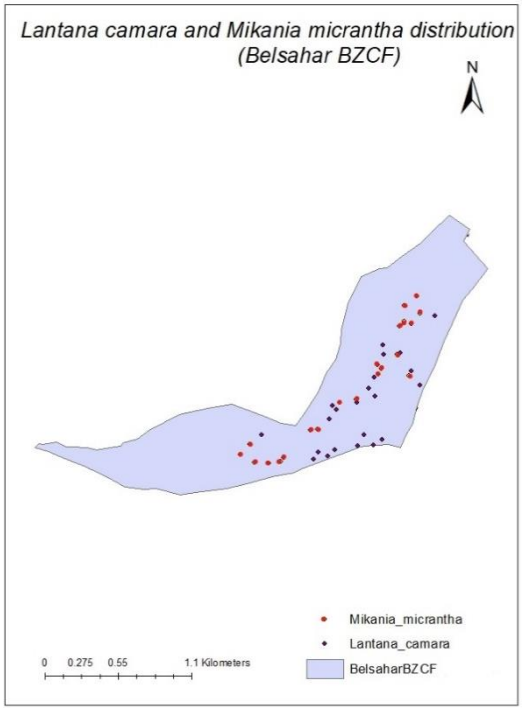
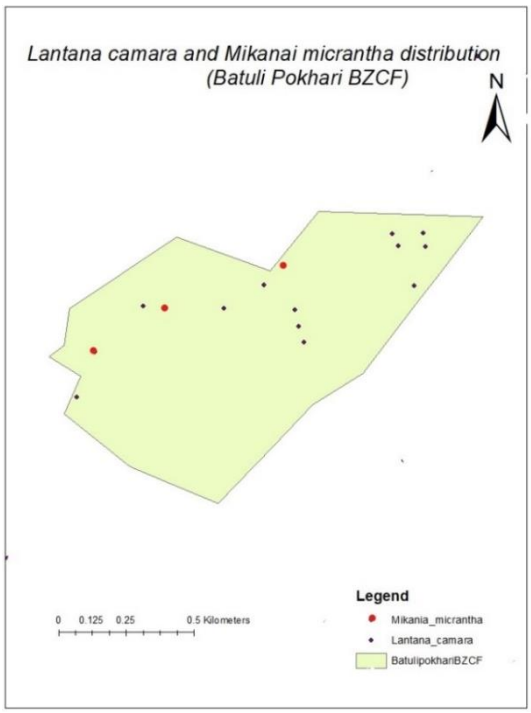
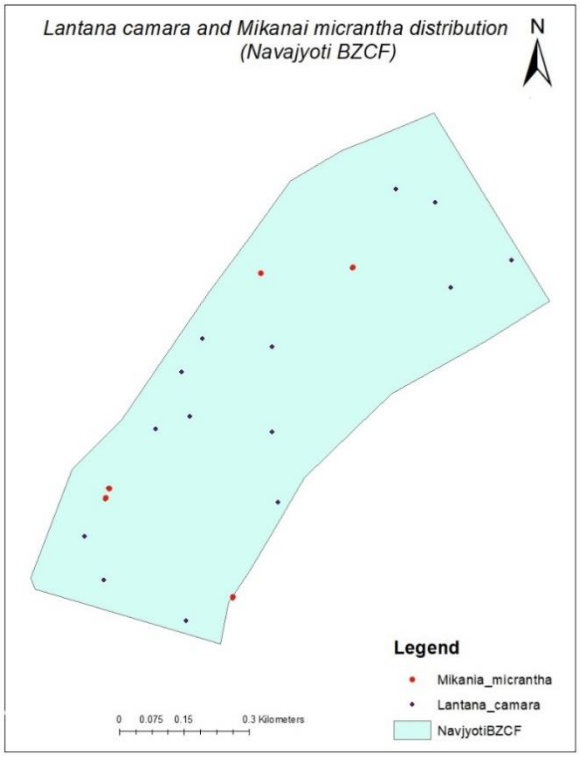


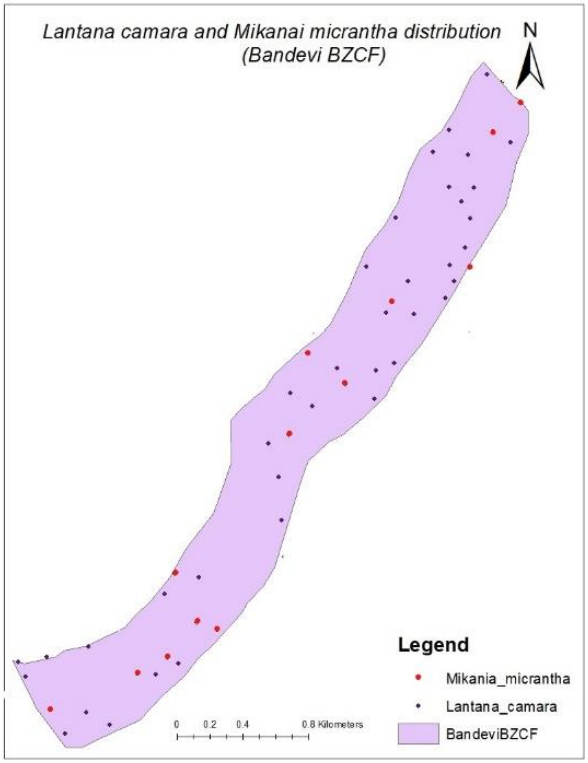
Spatial distribution of invasive spp in Belsahar BZCF



Spatial distribution of invasive spp in Batuli BZCF



Spatial distribution of invasive spp. in Navajyoti BZCF



Spatial distribution of invasive spp. in Bandevi BZCF

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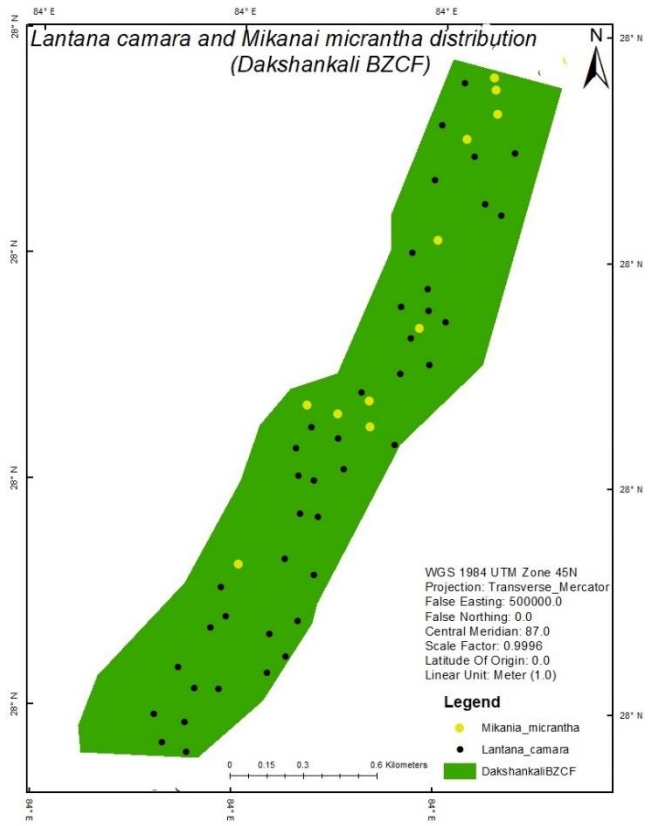
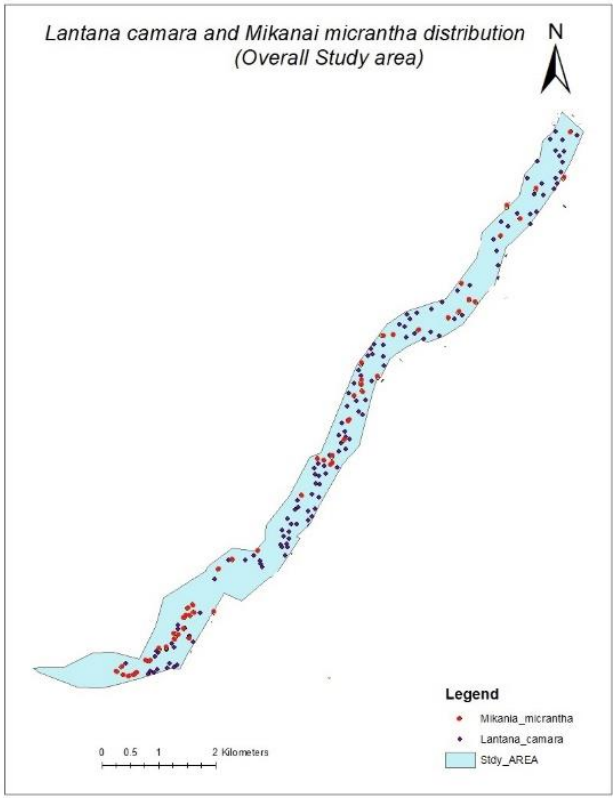


Spatial distribution of invasive spp. in Dakshinkali BZCF



Spatial distribution of invasive spp. in all BZCF

Figure 11 to 16: Spatial distribution of invasive species in bufferzone community forest

***Lantana camara* and *Mikania micrantha* in Batuli Pokhari BZCF:** The area of Batuli Pokhari Buffer Zone Community Forest was 92.90 ha. The result showed that 3 plots (7.14%) and 12 plots (28.54%) were covered by *Lantana camara* and *Mikania micrantha* respectively.

***Lantana camara* and *Mikania micrantha* in Dakshankali BZCF:** The estimated area of Dakshinkali buffer zone community forest was 165 ha. It was found that that 13 plots (20.63%) and 41 plots (65.07%) were covered by *Mikania* and *Lantana* respectively.

***Lantana camara* and *Mikania micrantha* in Navajyoti BZCF:** The coverage of Navajyoti BACF was 62.05 ha. The presence of *Mikania micrantha* was in 5 plots (20%) whereas *Lantana camera* was in 14 plots (56%).

***Lantana camara* and *Mikania micrantha* in Bandevi BZCF:** The are of Bandevi Buffer Zone Community Forest was around 254.25 ha. The wetland was invaded by *Mikania* while the grassland intimidated by *Lantana camara* with 18.05% and 52.88% resepctively.

4. DISCUSSION

The remaining grassland area was completely covered by invasive plants like *Mikania micrantha* (Lahere Banmara), *Lantana camara* (Banfada), *Ageratine adenophora* (Kalo Banmara), *Ageratum conyzoides* (Seto Gandhey) and *Ageratum houstonianum* (Nilo Gandhey). The area covered by water bodies was also decreasing which was the main habitat of deer. Deer prefer to graze near water areas in the morning and evening in order to drink water. Near water bodies, invasive plants like *Oxalis latifolia* (Chari Amilo Jhar), *Parthenium hysterophorus* (Pati Jhar) were grown rampantly.

The study done Laura (2012) showed the invasive species like *Mikania micrantha* can easily come in the open areas in the forest like grass land. It spread very fast and make a dense mats on the ground. The thick mat of *Mikania micrantha* hinders to the grass to germinate and grow as well. Another study done in Manas national park showed the effect of invasive species obstructs the development, structure and function of grass species (Lahkar, Talukdar, & Sarma, 2011). These results of these researches are similar to our research. The consequences are reduction suitable habitat of deer.

The *Mikania* invasion was observed more in riverine areas and on the edge of forest patches (Lahkar et al., 2011). Biswas and Mathur (2003) highlighted the invasion *Mikania micrantha* was generally found in grassland area. This is the fact that, higher the disturbance, the higher is the extent of invasion (Lahkar et al., 2011). These findings are supportive to our research result.

The importance value index was the highest of *Lantana camara* with 74.78 and it was followed by *Imperata cylindrical* (Siru) with 41.78. The lowest IVI value was *Cynodon dactylon* (Dudo) having 5.17. Similarly, the importance value index of invasive species specially *Ageratum conyzoides* (Seto Gandey), *Ageratina adenophora* (Kalo Banmara), *Lantana camara* (Banfada), *Oxalis latifolia* (Chari Amilo Jhar), *Parthenium hysterophorus* (Pati jhar) were becoming higher in buffer zone community forest (Davies and Sheley, 2007). Baidar et al. (2017) supports that the IVI of invasive species was dominantly increasing which seriously affect the grass species.

5. CONCLUSION AND RECOMMENDATION

Most of the areas were covered by *Mikania micrantha*, *Lantana camara* and *Ageratine adenophora* in the buffer zone community forests. The highest importance value index was found of *Lantana camara* and lowest IVI value was of *Cynodon dactylon*. These indicated the high infestation of *Lantana camara*. A thematic maps showed the distribution of invasive species was serious threat to grass species. The grassland was decreased between 2010 and 2020 in the buffer zone community forests (Belsahar, Batulipokhari, and Dakshankali). The evenly distribution of invasive species in the buffer zone community forest was threatening the grass species preferred by the deer. The study will be useful for scientific community and policy maker to manage the invasive species in buffer zone.

More studies are essential to show and compare the infestation of invasive species in the buffer zone community forest. The infestation and distribution of invasive species are threatening the grass species preferred by deer so attention should be given to increase the grassland and its enhancement. For the control of invasive species, the interventions such as mechanical control, chemical control, biological control should be applied in a combination depending upon the extent of invasion and impact that it has caused. Invasive species weed is not an over-night process management hence, it needs a lot of research, management strategy, and patience.

Conflict of interest

The authors declare that they have no conflict of interest.

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Data and materials availability

All data associated with this study are present in the paper.

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