WILD BOAR DISTURBANCE AT BARANDABHAR CORRIDOR FOREST, CHITWAN, NEPAL

Indra Bilash Ghimire

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Submitted to:

Central Department of Zoology

Institute of Science and Technology

Tribhuvan University

Kirtipur, Kathmandu Nepal

April, 2021

DECLARATION

I hereby declare that the work presented in this thesis 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).

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RECOMMENDATION

This is to recommend that the thesis entitled " **WILD BOAR DISTURBANCE AT BARANDHABHAR CORRIDOR FOREST, CHITWAN, NEPAL"** has been carried out by **Indra Bilash Ghimire** for the partial fulfillment of Master's Degree of Science in Zoology with special paper Ecology. This is his original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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LETTER OF APPROVAL

On the recommendation of supervisor **"Dr. Tej Bahadur Thapa"** this thesis submitted by mr. **Indra Bilash Ghimire** entitled **"WILD BOAR DISTURBANCE AT BARANDHABHAR CORRIDOR FOREST, CHITWAN, NEPAL "** is approved for the examination in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper ecology.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Indra Bilash Ghimire entitled "**WILD BOAR DISTURBANCE AT BARANDHABHAR CORRIDOR FOREST, CHITWAN, NEPAL** "has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Ecology.

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TABLE OF CONTENTS

LIST OF TABLE

LIST OF FIGURES

ABBREVIATION

BCF	:	Barandabhar Corridor Forest
CNP	:	Chitwam National Park
DHM	:	Department of Hydrology and Metrology
DNPWC	:	Department of National Parks and Wildlife Conservation
GIS	:	Geographical Information System
GPS	:	Global Positioning System
HWC	:	Human Wildlife Conflict
IUCN	:	International Union for Conservation of Nature
LC	:	Least Concern
MoFAGA	:	Ministry of Federal Affairs and General Administration
NTNC	:	National Trust for Nature Conservation
RPI	:	Relative Preference Index

ABSTRACT

The rooting behaviour of wild boar is the main cause of substrate disturbance. The excavation of the surface soil layers in the course of foraging for food, which creates a localized disturbance that appears similar to mechanical ploughing. In this study, data were collected using systematic plot sampling and sign survey method to investigate the sign distribution, disturbances, and habitat preference by the Wild boar in the Barandhabhar Corridor Forest, Chitwan. This study found the highest number of sign in sal forest habitat. A total of 107 plots, total of 10700 m^2 area was studied and 3.93 % area found rooted by wild boar. The grassland habitat was found to be more rooted compared to sal forest, wetland and riverine habitat in Barandabhar Corridor Forest. The average rooting depth by the wild boar was 13.5 cm (±5.7 SD). Moderate level of disturbance was high which change the soil properties and initially effect negatively like ploughing root, mechanical damage of plant, changing the physical structure of soil. This study recommends the further study of rooting impact on ecosystem and substrate utilized by the wild boar.

INTRODUCTION

1.1 Background

The Wild boar is the wild ancestor of the domestic pig (Fang et al. 2009) and is considered to increasing its population due to its adaptability, high reproductive rate, and secretive nature, still occupy much of its original range in Europe, Asia, and North Africa (Rosell et al. 2001).

Their disruptive feeding habit, primarily rooting disturbance causes impact on ecosystem in a variety of ways such as decreased water quality, increased propagation of exotic plants, increased soil erosion, modification nutrient cycle (Cuevas 2020), and damage to native plant species (Keller et al. 2001). Rooting adversely affect vegetation directly by displacing and killing seedlings or indirectly by altering physical properties of the soil, changing nutrient dynamics (Lacki and Lancia 1983, Singer et al. 1984, Ickes et al. 2001) and also wild boar may induce the spread of invasive plant species because invasive exotics typically favor disturbed areas and colonize more quickly than many native plants (Stone and Keith 1987, Cuevas et al. 2016). Wild boar can cause problems for other wild life species by competition for resources and habitat destruction with other animal as well spread of disease and parasite (Singer et al. 1984, Ruiz-Fons et al 2008).

Biotic and abiotic disturbances are widely recognized as key factors influencing the structure and composition of ecosystems (Archer and Stokes 2000). In terrestrial plant communities, disturbance plays an integral role in the spatial and temporal heterogeneity of vegetation and is an important agent for the maintenance of species diversity (Mohr et al. 2005). Soil disturbance, especially by animals, often has important effects on the dynamics of the native plant communities (Hobbs and Huenneke 1992, Ickes et al. 2001, Massei et al. 1996). When an organism directly or indirectly controls the availability of resources to other species by its ability to cause physical state changes in biotic and abiotic materials, since the rooting behavior has marked ecosystem-level effects, so Wild boars are considered as ecosystem engineers (Jones et al. 1994, Hone 2002, Cuevas 2020). The widespread impacts of rooting provide great scope for studying the role of wild boar as an allogenic ecosystem engineer (Jones et al. 1994, Wright et al. 2002).

The pattern of habitat use exhibited by the animal is adaptive such that animals using certain habitat types at a given time have a higher chance of survival. Food, predation, and climate

are the factors most likely to be important (Wirtz and Kaiser 1998). Habitats are commonly described in terms of vegetation types, food, water, and an area conducive to social gatherings are the main broad elements that habitat must provide to enable large herbivores to survive (Dasmann 1971, Smith 1974). Habitat of different species may be different according to their geographic range (Johnson 1980).

1.1.1. Geographic distribution

Wild boar, Sus *scrofa (*Linnaeus 1758), native species of Eurasia, occurs in all continents except Antarctica and many ocean islands (Long 2003). *Sus scrofa* has also been introduced in numerous locations outside their native ranges (Brook et al. 2014). The wild boar is one of the most widely distributed species in Nepal, distribution ranging from 100 m to 3500 m elevation (Shrestha 1997, Janwali et al. 2011, Pandey et al. 2016, Thapa and Kelly 2017, Bhandari et al. 2019).

1.1.2. Feeding behaviour and rooting

Rooting is the term given to the Wild boar's foraging activity, which occurs within surface layers of soil (Moody and Jones 2000). The wild boar's snout is narrow, long, and straight, making it ideal for rooting among soil surface layers (Iacolina et al. 2009).

Sus scrofa is an omnivorous species (Schley and Roper 2003, Herrero et al. 2006), the diet of Wild boar mainly consists of plants (80% to 90%) and also a range of animal species (Schley and Roper 2003). Wild boars spend a lot of time searching for tubers, roots, bulbs, and invertebrates, but they also consume fruit, mushrooms, carrion, a wide range of vertebrate and invertebrate animals, seeds, and, on and occasionally, eggs and livestock (Gerard and Campan 1988, Choquenot et al. 1996, Fournie et al. 2014). Diets vary greatly among habitats and geographic locations (Diong 1973, Klaa 1992). They consume a large variety of food depending on seasonal availability (Dardaillon 1987, Massei et al. 1996, Herrero et al 2006).

The activities of the Wild boar, such as nesting, feeding, and rooting, have been suggested to impact a wide range of taxa and ecological processes such as the chemical and physical properties of soil structures of soil, species richness and distribution of plants and associated fauna, and the creation of heterogeneity (Risch et al. 2010, Wirthner et al. 2011). The significant change in the soil environment is likely to impact the organization and

performance of both plant and animal elements of the community (Risch et al. 2010). Indirect impacts may occur when the soil disturbance selectively favors some microbial, animal, or plant taxa, or if the disturbance relocates soil nutrients or changes below-ground decomposition rates (Krull et al. 2013). While some effects might be positive if the disturbance creates sites suitable for seedling regeneration (Wardle 1984).

1.2. Objectives

1.2.1. General objective

To study the wild boar disturbance at Barandhabhar Corridor Forest, Chitwan, Nepal

1.2.2. Specific objectives

i. To determine the sign distribution of wild boar in BCF,
ii. To assess the substrate disturbances by the wild boar.
iii. To evaluate the habitat preference by the wild boar

1.3. Rationale of the study

The population of Wild boars is increasing (Carter et al. 2012) with a significant impact on biodiversity conservation (Schley et al. 2008, Barrios and Ballari 2012). This study help to quantify the disturbance caused by wild boar and its initial impact on biodiversity and soil condition which will improve our understanding of how a natural disturbance (wild boar) might alter the biological parameter, which will be useful to answer the question related to ecosystem stability/resilience, biodiversity and sustainable management.

2. LITERATURE REVIEW

2.1 Distribution

Wild boar, Sus *scrofa (*Linnaeus 1758), native species of Eurasia, occurs in all continents except Antarctica and many ocean islands (Long 2003). Wild boar have a wide global distribution and occupy diverse habitats (Long 2003, Brook et al. 2014). The wild boar has increased its population size and colonized new habitats in recent decades, causing more ecological and socioeconomic concern than perhaps any other ungulate species (Morelle et al. 2015).

Wild boars, due to their adaptability, high reproductive rate (Gamelon et al. 2013), and secretive nature, still occupy much of their original range in Europe, Asia, and North Africa (Rosell et al. 2001, Fonseca et al. 2011). Some of the main reasons for the considerable increase in the wild boar population are the remarkable adaptability of the wild boar to diverse environments (Massei et al. 1996, Acevedo et al. 2006, Jansen et al. 2007, Schley et al. 2008). *Sus scrofa* has also been introduced in numerous locations outside their native ranges and feral populations are well established in New Zealand, Australia, North America, Hawaii, the Galapagos, Canada, and numerous other islands (Baber and Coblentz 1986, Baron 1982, Brook et al. 2014, IUCN 2019).

Wild boar thrives in diverse habitat of the world (Long 2003), in Nepal, it is most widely distributed occurring from lowland (< 100 m) to the mid-hills (around 3500 m) (Jnawali et al. 2011, Pandey et al. 2016, Thapa and Kelly 2017, Bhandari et al. 2019).

2.2. Rooting impact of wild boar

Rooting is the term given to the wild boar's foraging activity, which occurs within surface layers of soil. Visually analogous to ploughing, this, "rototiller-like" foraging activity (Moody and Jones 2000) can be viewed as a severe form of soil disturbance. The main effect of its presence is an extensive disturbance that consists of turning over the soil while searching for underground feeding resources (Ickes et al. 2001). These disturbances affect directly some ecosystem elements, such as soils (Lacki and Lancia 1983, Barrios et al. 2012, Cuevas 2020) and vegetation, and may indirectly alter some ecosystem processes such as nutrient cycling and species turnover (Kotanen 1995, Ickes et al. 2001, Palacio et al. 2013).

Rooting fluctuates in area, depth, and intensity and, because boar tend to root in patches, the effects on soil are likely to be heterogeneous (Welander 2000). Consequently, the structural complexity of the soil surface can be increased as rooting exposes a variety of substrates (such as hummus, mineral soil, belowground plant biomass, rocks, and stones) in a patchy manner (Milton et al. 1997, Welander 2000). However, the structural complexity of the soil surface can also be decreased because like ploughing, rooting can destroy distinct soil horizons and can homogenise soil. Through mixing soil horizons, rooting can reduce vertical heterogeneity, over-turn leaf litter (reducing the surface build-up through incorporation into the soil), and remove or redistribute vegetation in a patchy manner (Bratton 1975, Singer et al. 1984, Bracke 2011). Rooting is typically seen as small patches of overturned soil ($1m^2$) (Kotanen 1995, Goulding 2003), these patches often overlap forming larger areas of rooted soil of up to a hectare (Kotanen 1995).

The below-ground foraging of Wild boars causes obvious disturbance of the soil (Palacio et al. 2013). Indirect impacts may occur when the soil disturbance selectively favors some microbial, animal, or plant taxa, or if the disturbance relocates soil nutrients or changes below-ground decomposition rates (Krull et al. 2013). While some effects might be positive if the disturbance creates sites suitable for seedling regeneration (Wardle 1984), it is generally assumed that the effects will be negative (Barrios et al. 2012). Intermediate levels of rooting frequency in the short-term may have modified resources (such as nutrients, light, and space) to levels that maximized the number of species (Cuevas 2020). Specific conditions produced through rooting are likely to favor some plants (such as disturbance-tolerant species) but not others (such as species sensitive to severe disturbance) and therefore some functional groups but not others (Aplet et al. 1991). Kotanen (1995) found annuals proliferated within one year after pig rooting in a Californian prairie. Welander (2000) found that the large numbers of small-sized, wind-dispersed seeds of annuals from the seed rain were ideal for the rapid establishment of recently rooted soil across several habitat types in Sweden, due to their relatively superior dispersal capacity.

The Wild boar can cause problems for other wildlife species by competition for resources and habitat destruction with other animals as well spread of disease and parasite (Ruiz-Fons et al. 2008).

2.3. Habitat preference

Habitat studies of the Wild boar have been conducted in many parts of Europe, and often show that wild boars frequently use the forest as a habitat (Welander 2000, Fonseca 2008). Marshes are also frequently used all year-round, which provides food, use of wallows, rooting, safe bedding sites, and farrowing nests. The use of marshes depends on the water level, especially for the rooting which is more frequent at low levels (Dardaillon 1986), and the use of farrowing nests which often are located near the water in areas with abundant vegetation cover (Dardaillon 1986, Fernandez-Llario 2004). The wild boars' activity pattern is related to sunset (Boitani et al. 1994, Lemel 1999). Most of the time is spent resting during daytime in forests (Boitani et al. 1994). The nocturnal activities of the wild boar are focused on foraging and travelling into pastures and cultivated areas, but for resting, they mainly use uncultivated pastures (Boitani et al. 1994). Seasonal changes in foraging patterns influence the frequency of the wild boar's use of open habitats; they prefer woodland and other habitats with safe resting sites (Wilson 2004). A study made by Fonseca (2008) showed that wild boar in Poland prefer mixed forests with European beech Fagus sylvatica and hornbeam Carpinus betulus, and avoid European silver-fir Abies alba forest. A study in central Sweden (Lemel 1999) showed that the preferred habitats of wild boar were dominated by agricultural land and mixed forest with Norway spruce, Scots pine (*Pinus sylvestris*) and silver birch (*Betula pendula)*.

3. MATERIALS AND METHODS

3.1. Study area

The study area is in Barandabhar Corridor forest and it is located between 84°22′30″-84°33′0″ E Longitude and 27°34′12″-27°43′30″ N Latitude, adjacent to the northern border of the Chitwan National Park (CNP), to the Mahabharat hill forest at the northern end of the Chitwan valley. The Barandabhar forest covers an area of 87.9 km^2. Barandabhar, a 29 km long forest patch, is bisected by the East-West Highway, resulting southern BCF, 56.9 km^2 area in the buffer zone of CNP and northern BCF, 31 km^2 is under the district forest office (Bhattarai 2003).

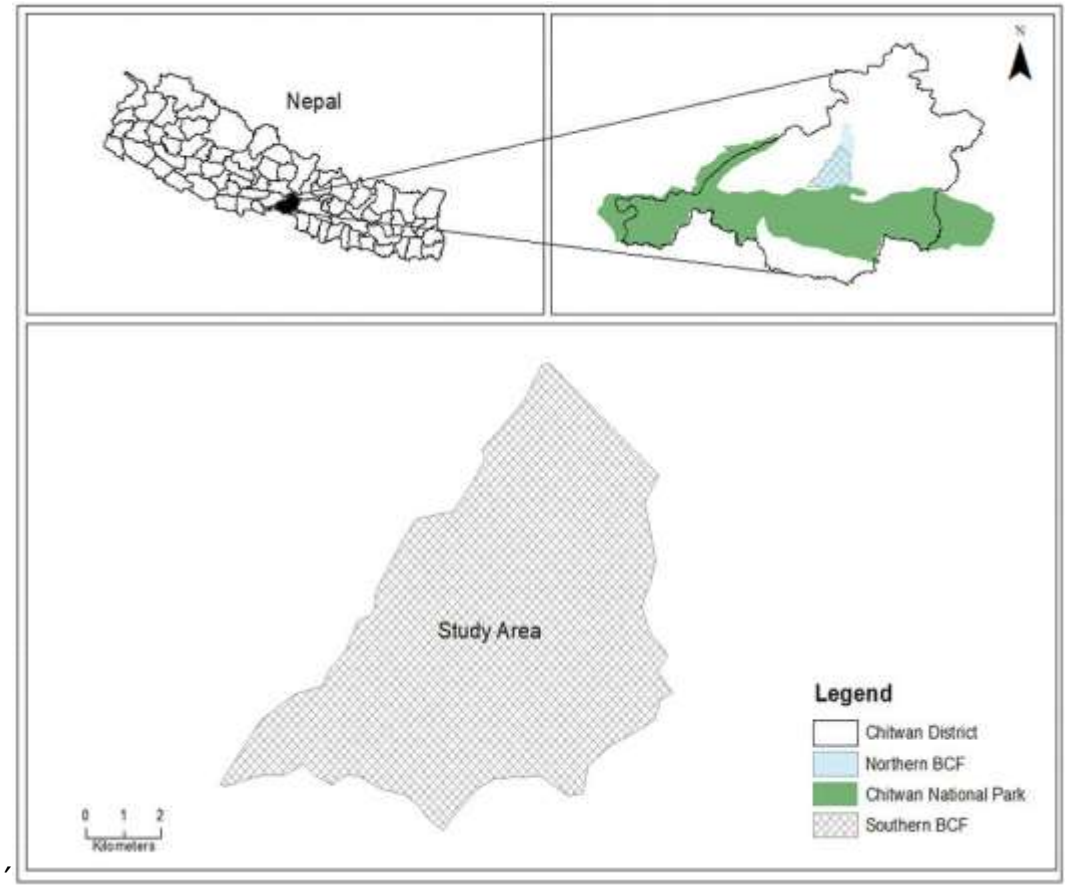

Figure 1: Map of southern part of Barandabhar Corridor Forest, Chitwan, Nepal

Barandabhar is an important biological corridor that connects Churiya with the Mahabharat range. Sal forest dominated Barandabhar forest contains 22 species of mammals including tiger, rhinoceros, Asian elephant, sloth bear, wild boar, sambar deer, spotted deer, hog deer, barking deer, and 280 species of birds. More than 45 species of herpetofauna represented

by frog, toad, lizards, python, and crocodile are found in Barandabhar Corridor Forest (Resource Himalaya 2000, KMTNC 2002) Barandabhar corridor may also function as critical climate refugia and has important wetlands including Beeshhazari Lake, a Ramsar site.

The buffer zone area of BCF holds 48.016 km^2 forest, 5.018 km^2 grassland, 3.276 km^2 shrublands, and 0.5 km^2 of water bodies known as Beeshazari Lake. The major rivers around the forest are the Rapti, Budhi Rapti, and Khageri, and four major vegetation types; Sal forest, riverine forest, tall grassland, and short grassland provide better natural habitats for the wildlife species of BCF (KMTNC 2002).

3.1.1. Climate

The forest has a range of climate seasons: summer, monsoon, and winter with a subtropical climate. The summer season, hot and dry period of the year extending from late February to mid-June. The monsoon season is hot and humid and lasts from mid-June to late September. Winter extends from late October to late February and is a cool season. The mean annual rainfall over the period from 2012 to 2017 was 2437 mm, 77.5% of which occurred within four months of monsoon season (May- September) (Figure 2). From April onwards sporadic thunderstorms and hailstorms occur. There is a continuous increase of rainfall from March to July which slightly decreases in August and peaks again in September and then decreases 14 till December (Figure 2). Winter months are relatively dry but a little rain occurs due to westerly wind.

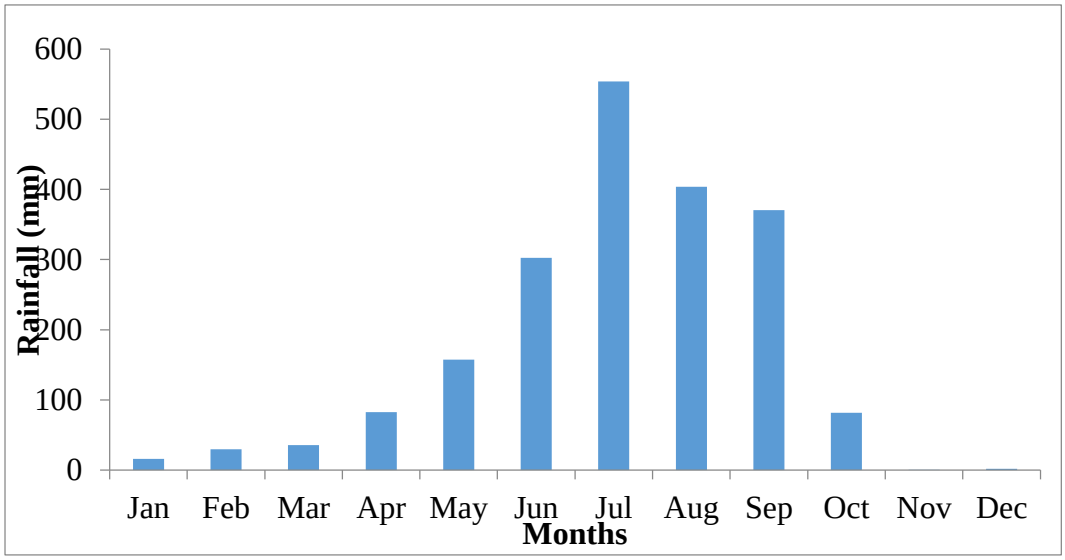

Figure 2: Variation in mean monthly rainfall from 2012- 2017 (Data source: DHM/GovN).

The winter months (November to February) are colder and the nights and mornings damp with heavy fog. January is the coldest month of the year with the mean minimum temperature recorded from 2012 to 2017 was 9.36^0 C (Figure 3). The temperature rises from January to Apr, stabilizes for four summer months, and again decreases from September till January (Figure 3).

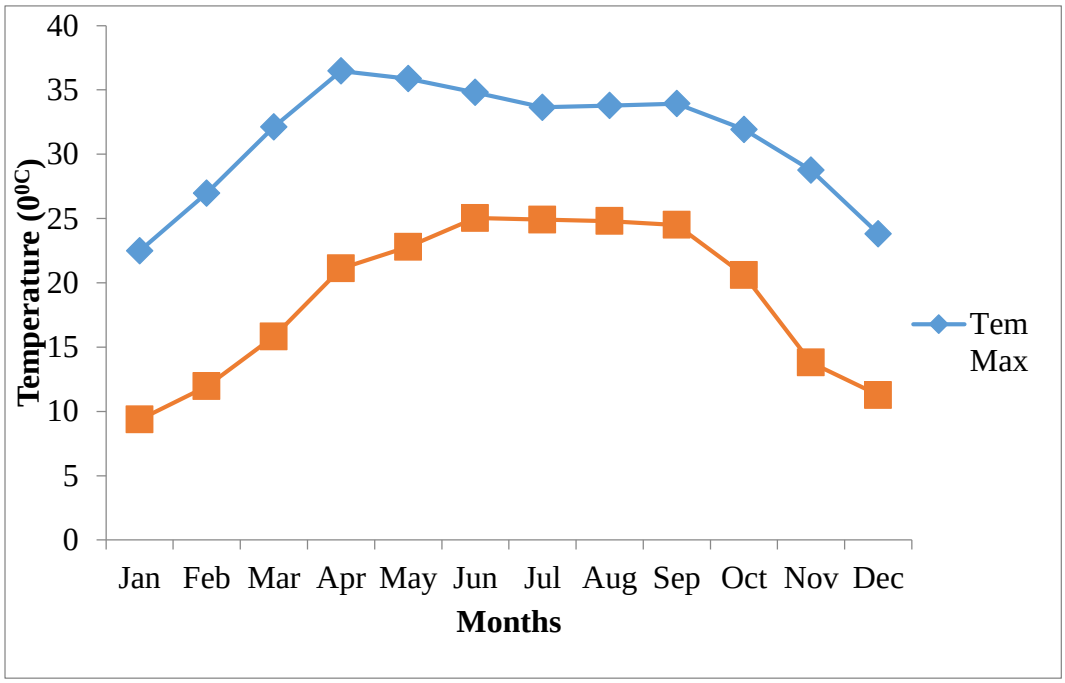

Figure 3: Variation in mean monthly temperature (0 C) from 2012- 2017 (Data source: DHM/GovN).

Humidity is high all the year round except three dry months (April- June), with early morning readings of 100% relative humidity being recorded frequently at Bharatpur Meteorological station. Mean monthly highest and lowest relative humidity at 8:45 am was 95.4% and 62.93% respectively. Similarly, the mean monthly highest and lowest relative humidity at 5:45 pm was 80.73% and 44.8% respectively (Figure 4). Mornings during the winter months are characterized by heavy mists which persist for several hours after dawn, particularly in the river valleys. Cool and dry northerly winds from the Greater Himalaya and the Trans Himalayan plateau reduce the daily temperatures. From February, winds from the west and southwest rise temperatures and reduces relative humidity to a minimum in May.

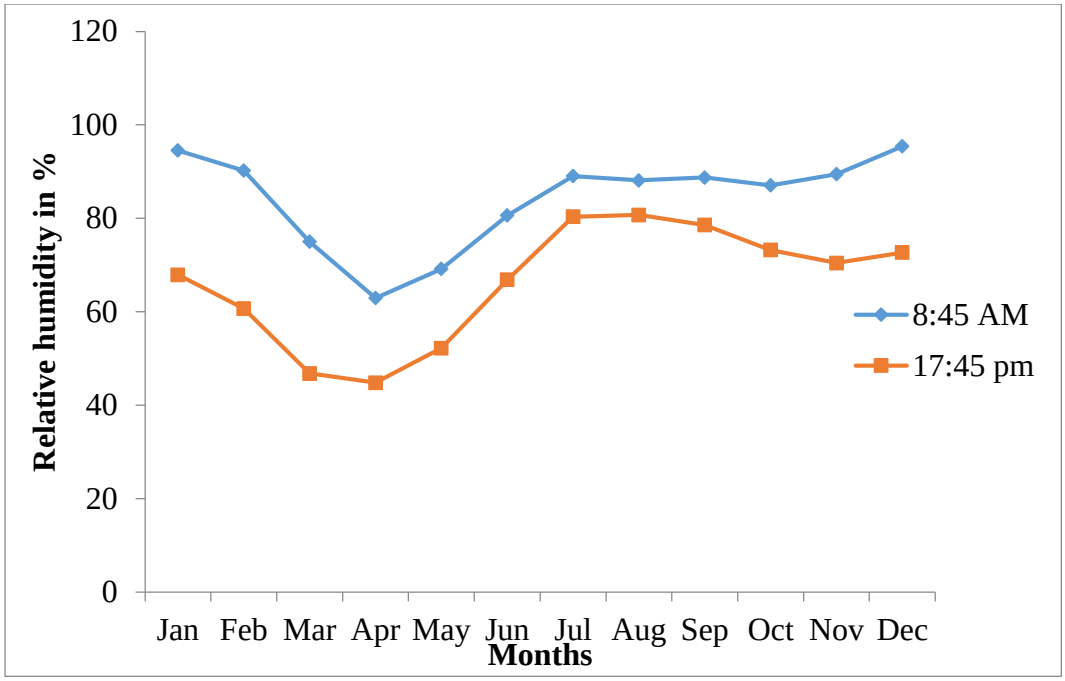

Figure 4: Variation of mean monthly Relative Humidity from 2012- 2017 (Data source: DHM/GovN)

3.1.2. Biodiversity

3.1.2.1. Flora

The flora of the Barandabhar forest is mainly dominated by almost monotypic *Shorea robusta* (Sal) and small fragments of riverine and mixed-hardwood forest. Shorea forest covers the majority of Barandabhar Forest, which stretches up to the Mahabharat range's foothills (NTNC 2003)**.** Disturbed or degraded Sal forest occupies almost the entire length of the edge on the northern section of Barandabhar forest where *Shorea robusta* is the dominant species.The dominant tree species of the riverine forest include Bhellar (Trewia *nudiflora*), Sindure (*Mallatus philippensis*), (*Listsea monopelata*), Simal (*Bombax ceiba*), *and* (*Sapium insignene*) and other. Barandabhar forest is also very important for short grassland, which is dominated by Siru. It is known as Siru Khar in Nepali, and it is the most essential grass, which is used by local people for thatching.

3.1.2.2. Fauna

BCF has a distinctive assemblage of rare and threatened fauna. BCF is an important corridor and provides a way for the movement of large mammals from CNP between the Churia hills and Mahabhart range.The CNP including BCF has a distinctive assemblage of rare and threatened fauna that supports more than 70 mammal species, 600 bird species, 56 species of herpeto fauna, 156 species of butterflies and 120 species of fish (CNP 2017).

Sal forest dominated Barandabhar forest contains 22 species of mammals including tiger (*Panthera tigris*), Rhinoceros (*Rhinoceros unicornis*), Asian elephant (*Elephas maximus*), Sloth bear (*Melurus ursinus*), Wild boar (*Sus scrofa*), Sambar deer (*Rusa unicolor*), Spotted deer (*Axis axis*), Hog deer (*Axis porcinus*), Barking deer (Muntiacus muntjak), Leopard (*Panther pardus*), Porcupine (*Erethizon dorsatum)*, Yellow -throated marten (*Marten flavigula*), Fishing cat (*Prionailurus viverrinus*), Jungle cat (*Felis chaus*), Jackal (*Canis aureus*), Common mongoose (*Herpetes edwardsi*) and Indian fox (*Vulpes bengalensis*). It is a critical habitat for many species of migratory birds (e.g., Siberian crane), aquatic birds, and Mugger crocodile (*Crocodylus palustris*). More than 45 species of herpetofauna represented by frog, toad, lizards, python, and crocodile are found in Barandabhar Corridor Forest (Resource Himalaya 2000; KMTNC 2002).

3.2. Materials used

- GPS (Garmin eTrex® 10)
- Topographic map (1:25,000)
- Measuring tape (100 m)
- Field stationary

3.3. Research design

This study was designed to quantify Wild boar substrate disturbance levels and patterns, distribution and habitat preference at Barandhabhar Corridor Forest (BCF) using field sign, with a particular focus on comparisons of disturbance among and within major habitat types, to gain a better understanding of Wild boar habitat use and the degree of substrate disturbance within the BCF.

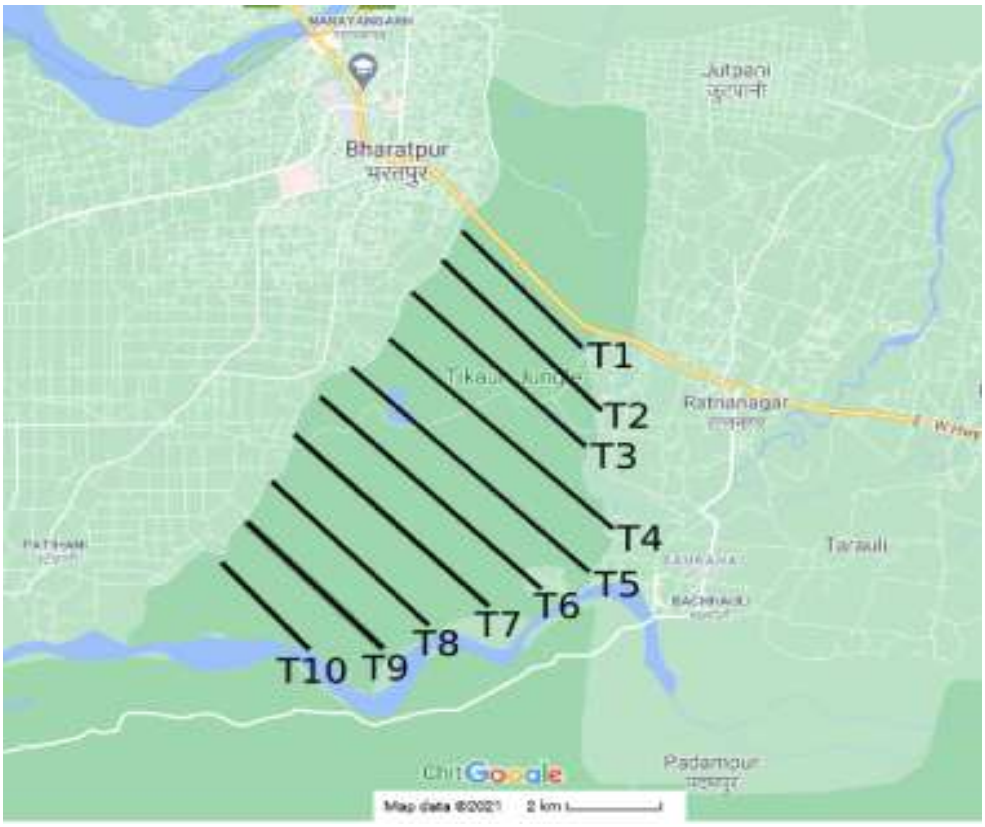

Figure 5: Showing the sample of transect setup on southern BCF

A total of 107 sample plots of 10m x 10m were surveyed at intervals ranging from 500m along 10 transects through the forest of southern part of BCF. The first transect (T1) was laid parallel just 200 m away from the east-west highway and other transects were laid (Figure 5), each at a distance of 1km from the preceding transect. The length of transect differed from each other because the width of the forest also varied in length (Table 1). All indirect signs, as well as habitat type and surrounding habitat, were noted in every 500 m distance by making a 10m × 10m plot. Transects were set up covering all areas of barandhabhar corridor forest rather than selecting a certain habitat type. Each transect crossed the whole forest from one side to another.

Table 1: Study plots and transect details.

Transect no	Transect length (km)	Habitat (no of plot)				Total
		Sal	Wetland	Grass	River	
T1	4	6	1	2	0	9
T2	4.5	6	0	4	0	10
T3	5	5	2	4	0	11
T4	5.5	5	3	4	0	12
T 5	5	7	1	3	0	11
T6	6	6	1	6	0	13
T7	6	5	2	5	1	13
T8	4	8	0	2	1	11
T9	4	6	0	2	1	9
T10	2	4	0	4	0	8
Total	**46 km**	**58**	**10**	**36**	**3**	**107**

3.4. Methods of data collection

A combination of preliminary surveys, an intensive study based on direct and indirect evidence of the animal were used to assess the distribution, substrate disturbance, and habitat use and preference.

3.4.1. Preliminary survey

The preliminary field survey was carried out in April 2018, to assess the potential sites in the study area from which habitat, disturbance categorization and transect were set for plot selection.

3.4.2. Distribution of Wild boar

Fieldwork was done from May 20 to June 10, 2018. In the time of field study, all signs (pallets, rooting, and footprint) as well as habitat type and surrounding habitat, were noted with GPS coordinate of location with the help of Gramin eTrex® s10 GPS.

3.4.3. Disturbances on substrate and vegetation caused by the Wild boar

Substrate disturbance by Wild boars is defined here as the removal or gross manipulation of vegetation, leaf litter, woody debris, and soils on the forest floor as a result of Wild boar behaviors such as rooting, typically resulting in uprooted or trampled vegetation, turning over of the leaf litter and soil surface, exposed soils, and the creation of substrate depressions and low mounds.

Every rooting area found in each plot (10×10 m) were studied and major parameters that were taken into consideration are:

i. The total area of substrate disturbances i.e. rooting area (m^2).
ii. Status of disturbance on soil and vegetation in the rooting areas.
iii. Old as well as new rooting sites were noted
iv. Maximum depth of rooting (cm)

3.4.4. Rooting categorization

Rooting of wild boar was categorized into Old, and New, according to their properties.

- Old: In the rooting area, plant succession started, soil in a tight position.
- New: In the rooting area, the soil is very loose in condition with the uprooted plant.

Rooting disturbance was distinguished into three general categories.

i. **High disturbance**

   Rooting depth between 20 to 30 cm, considered in this category, where the mixing of the field layer fragments with the soil and litter, and up-rooting of small trees with shallow roots. Plant are hard to identify, complete damage of plants presents on the rooting site.

ii. **Moderate disturbance**

The second type of rooting (10-20 cm) entails cutting and fragmentation of the field layer by tearing it up from the ground, translocation, and returning.

iii. **Low disturbance**

This level (0-10 cm) involves cutting the field layer along the animal's path. The plant not supposed to be damage. Mechanical such as breaking of the stem, a leaf may occur.

3.4.5. Habitat uses and preferences by the Wild boar

Wild boar presence sign was recorded (rooting, pallets, footprints) and surrounding habitat type was recorded.

3.4.5.1. Habitat classification

Four types of Habitat – Sal dominant forest, Wetlands, Grassland, Riverine forest were recognized in the study area. The flora of Barandabhar forest is dominated mainly by sal forest and partly by wetland, grassland and riverine.

a. Sal dominate forest:

Sal forest is dominated by sal (*Shorea robusta*) and the associated species with sal are *Semecarpus anacardium, Terminalia bellirica, Terminalia tomentosa*. A large number of other trees, shrubs, creepers, ferns, flowers, and grasses grow among or under the sal.

b. Wetlands:

A wetland is a distinct ecosystem that is flooded by water, either permanently or seasonally, where oxygen-free processes prevail. The primary factor that distinguishes wetlands from other landforms or water bodies is the characteristic vegetation of aquatic plants, adapted to the unique hydric soil. The major wetlands of this area (BCF) are three rivers (Rapti, Budirapti and Khageri) and lakes (Beeshazarilake- a Ramsar site, Ratomate lake, Batulpokhari, Rhino lake, Tiger lake, Tikauli lake, Gundre-Mandre lake) (Thapa 2011).

c. Grasslands:

The alluvial flood plains support a luxuriant growth of grasses interspersed with patches of riverine forest. These tall and dense stands of grasses are popularly called 'elephant grass'.

Tall grassland is dominated by kans (*Saccharum spontaneum*), and distributed along the Rapti and Budhi Rapti riverside. Barandabhar forest is very important for short grassland, which is mainly dominated by Siru (*Imperata* sps.). It is the most important grass for human beings called Siru Khar in Nepali, which is used by local people for thatching

d. Riverine forest:

Riverine forests grow along watercourses and their composition varies greatly from place to place. The riverine forest of the Barandabhar occupies a very small area located mostly in Khageri and Rapti river sites. The dominant tree species of riverine forest includes *Trewia nudiflora*, *Bombax ceiba*, *Mallotus philippensis*, *Listsea monopelata*, and *Sapium insignene*.

3.5. Data Analysis

All the collected information were categorized and tabulated according to the objective of the study to determine distribution, substrate disturbance and habitat preference. Data were manually processed and analyzed in a descriptive way as well as by statistical measure.

i. Chi-square test for goodness-of–fit ($\chi 2 -$ test):

A chi-square goodness-of-fit test was carried out to determine whether the sign (footprints, pellets and rooting) of the Wild boar were distributed according to the habitat types. The test was performed by setting hypothesis that the pig was uniformly distributed in all habitat type in BFC. The hypothesis was tested at 1% and 5% level of significance.

Under H_0, the test statistic is given by:

$$\chi 2 = \sum \frac{(O-E)^2}{E} \text{ (n-1) df} \qquad \text{(I)}$$

Where, O = observed frequency

E = Expected frequency

ii. Relative preference index (RPI):

The relative preference index was calculated by using methods of Stinnet and Klebenow (1986) to determine the habitat preference of the wild boar.

$$\text{Relative preference index(RPI)} = \frac{\text{percentage utilization}}{\text{percentage availability of the habitat}} - 1$$

Positive values of RPI indicate a preference, negative values between 0 and -1 indicate no preference, and -1 indicates no use.

4. RESULTS

4.1. Sign distribution of wild boar in BCF

4.1.1. Sign details across different habitat type

The presence of the wild boar was confirmed in Barandhabhar Corridor Forest (BCF), Chitwan district. A total of 107 plots summing 10700 m^2 were studied in different habitats (sal forest, grassland, wetland, and riverine forest) in BCF. The area for the sal forest habitat is 5800 m^2 (58 plot), grassland habitat is 3600 m^2 (36 plot), wetland 1000 m^2 (10 plot), and 300 m^2 (3 plot) in the riverine forest (Table 1). A total of 91 signs (rooting, footprint, and pellet) were recorded, whereas 59.34 % rooting, 20.88 % of the footprint, and 19.78% of the pellet (Table 2). Sign of wild boar had been found highest in sal forest followed by grassland and wetland. The lowest sign of wild boar was found in the riverine forests. (Figure 6).

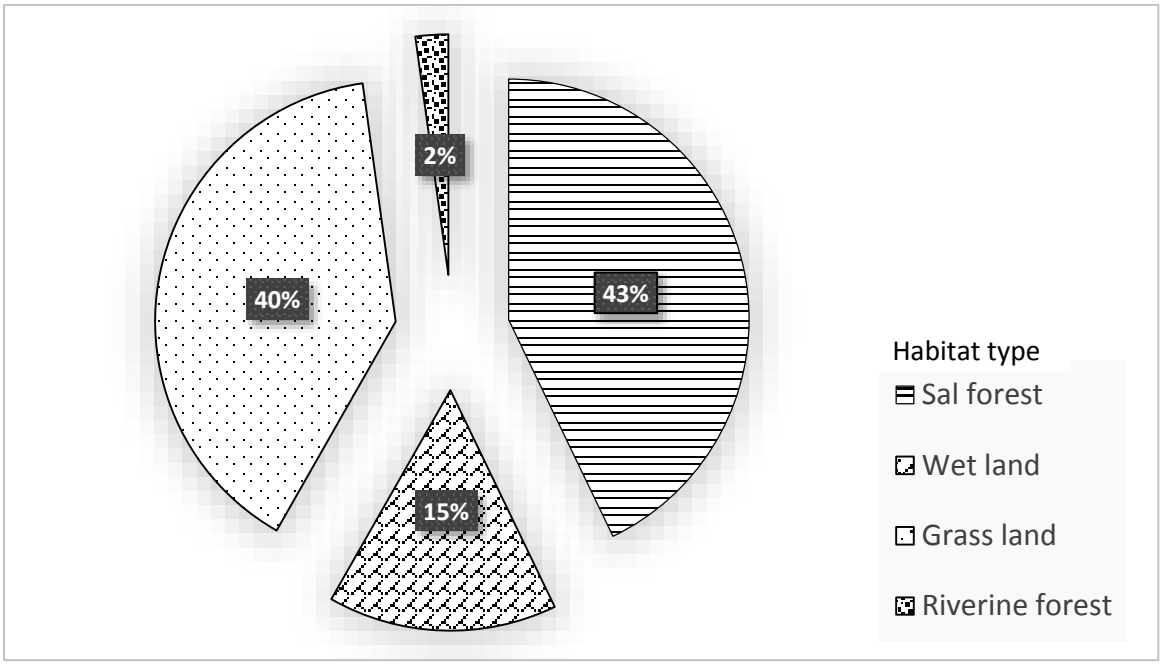

Figure 6: Sign details in a different habitat.

The majority sign of rooting was found in grassland followed by sal forest, whereas least in riverine forest. Similarly, the highest numbers of footprints were found in wetland and the lowest in riverine forest. Similarly, the pellet was abundantly found in sal forest but not in the riverine forest (Table 2).

Different signs with different habitats showed that the footprint of the Wild boar had a significant difference which shows a strong association between different habitats (χ^2 = 30.298, $p<0.05$) whereas rooting and pellet were not (Table 2).

Table 2: Frequency of sign (rooting, footprint, and pellet) of wild boar in sal forest, wetland, grassland, and riverine forest**.**

Sign	Sal forest	Wetland	Grassland	Riverine forest	Total	χ^2 value
Rooting	23	5	25	1	54	5.5141
Foot print	6	8	4	1	19	30.298
Pellet	10	1	7	0	18	0.1235
Total	39	14	36	2	91	

4.2. Substrate disturbance by wild boar on BCF

A total of 420.1m^2 (3.93%) area had been found rooted among 107 plots (10700 m^2) in this study. New rooting (79.3%) was dominant than old rooting (20.7%) (Table 3). Where old rooting was absent in wetland and riverine forests. In all four types of habitat new rooting was dominant over old rooting.

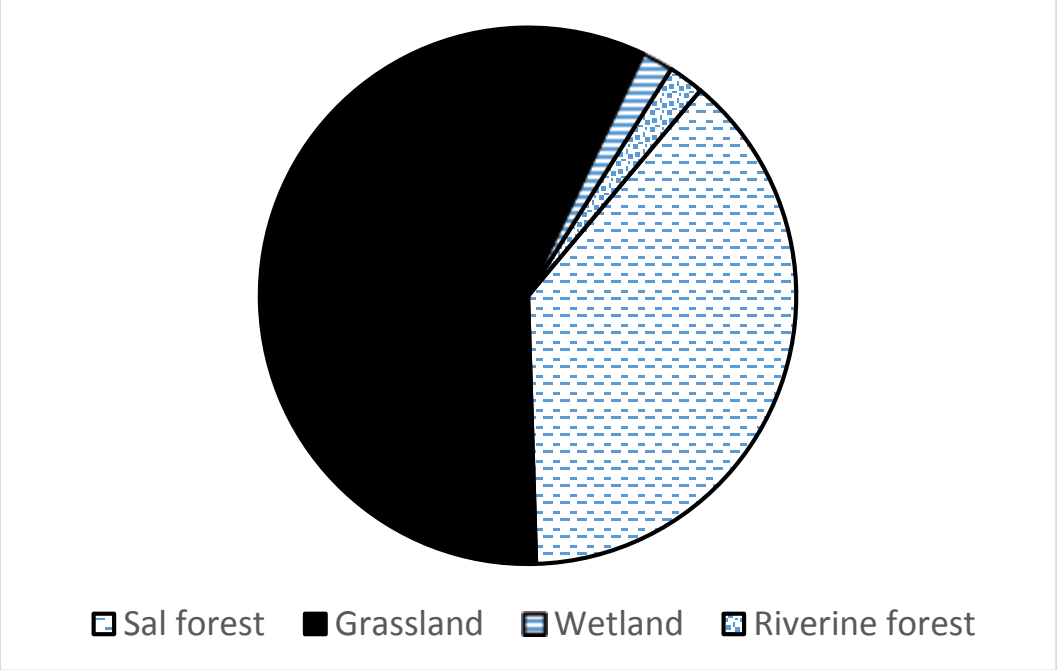

Figure 7: Area of rooting by wild boar in the different habitat of BCF

A total area of rooting (Old and New) recorded highest in grassland followed by sal forest, wetland, and riverine forest (Figure 7). Where the area of new rooting is found highest in grassland followed by sal forest, riverine, and wetland habitat (Table 3).

Table 3: Total area of rooting in Sal forest, Wetland, Grassland, and Riverine habitat.

Habitat	Sal forest (m^2)	Wetland (m^2)	Grass Land (m^2)	Riverine (m^2)	χ^2 Value
Old Rooting	10.5	0	76.5	0	41.833
New Rooting	150.8	8	165.8	9	41.346
Total Rooting	161.3	8	241.8	9	121.07

All three types of disturbance (High level, Moderate level, and Low level) were recorded in the new rooting site, where a moderate level of disturbance was found highest followed by the high level of disturbance and low level of disturbance (Table 4).

Both old rooting (χ^2 value = 41.83, $p < 0.05$) and new rooting ($\chi^2 = 41.34$, $p < 0.05$) shows significantly strong association. Among the three disturbance level, only high level of disturbance was not significantly associate ($\chi^2 = 5.6603$, $p > 0.05$) where as both moderate and low level of disturbance was significant (Table 4).

Table 4: New rooting area and percentage of disturbance level caused by wild boar

Habitat		Sal forest (m^2)	Wetland (m^2)	Grass Land (m^2)	Riverine (m^2)	χ^2 Value
Level of disturbance	High	24.6	2	40.5	0	5.6603
	Moderate	70.2	6	123.3	9	32.26
	Low	56	0	2	0	74.746
Total		150.8	8	165.8	9	41.346

4.2.1. Disturbance pattern of rooting in different habitat

The study showed the preference for rooting was found higher in Grassland (4.6 %) followed by Riverine (3%) and Sal forest (2.6%) whereas lowest in Wetland (0.8%) (Figure 8).

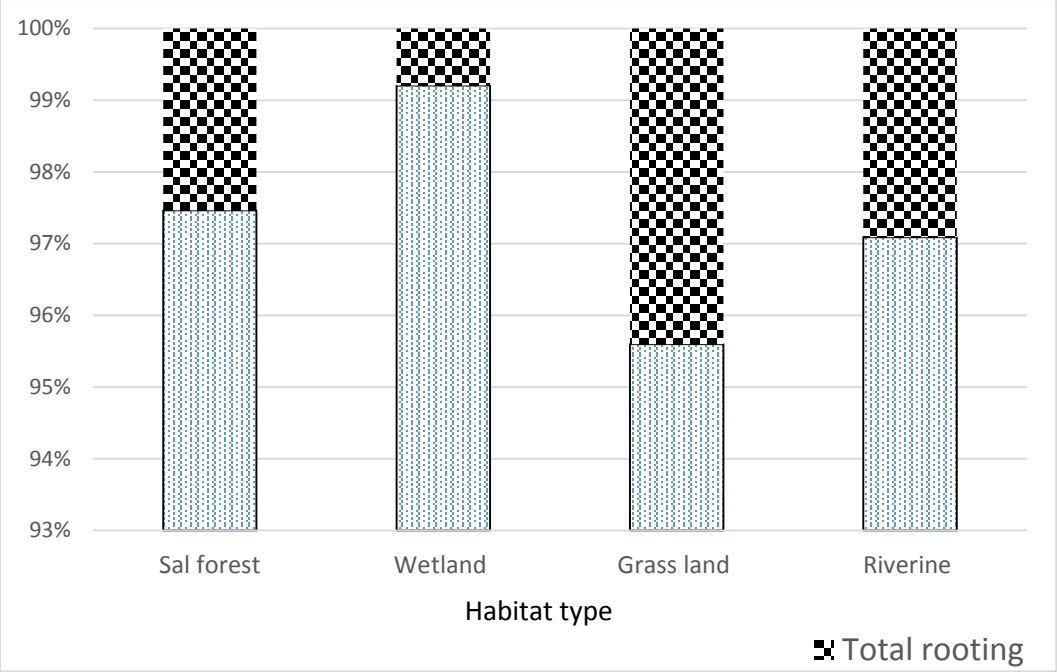

Figure 8: Study area vs rooting area across habitat type

Among three different types of disturbance moderate level of disturbance recorded highest in all habitat types. The majority of high-level disturbance was recorded in wetland followed by grassland, sal forest. The low level of disturbance was recorded highest in sal forest followed by grassland and in the riverine forest, only a moderate level of disturbance was observed (Table 5).

Table 5: Comparing the level of disturbance in different habitat

		Level of disturbance (%)		
Habitat	**Total rooting area (m^2)**	**High**	**Moderate**	**Low**
Sal forest	150.8	16.34	46.51	37.15
Wetland	8	25	75	0
Grass land	165.8	24.43	74.37	1.2
Riverine forest	9	0	100	0

4.2.2. Variation of rooting depth in a different habitat of BCF

A total of 54 number of the rooting sign was recorded, among them 45 were new rooting and 9 old rooting (Table 2). Variation of depth was found in the new rooting site, where the Depth of rooting varies from 7 -28 cm (average 13.5, ± 5.7 SD). This study found the frequency of rooting depth highest in a range of 10-20 cm (Mean 13.0, ± 2.0 SD), followed by range 20-30 (Mean 23.1, ± 1.3 SD), cm and 0-10 cm (Mean 5.3, ± 2.9 SD).

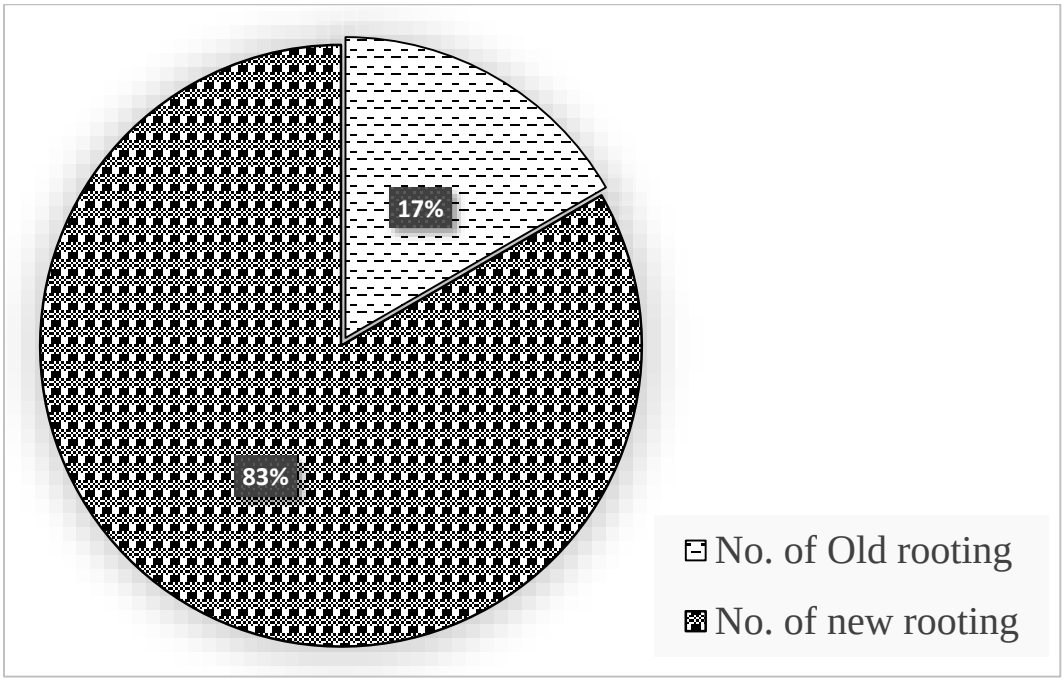

Figure 9: Frequency of new and old rooting sign found in BCF

In range 0-10 cm, the highest frequency of rooting depth was observed in Sal forest, whereas the frequency of rooting depth in wetland and grassland habitat found same and absent in riverine forest habitat (Table 6). Similarly, in the range, 10-20 cm, the highest frequency of rooting depth found in Sal forest followed by grassland, wetland, and absent in riverine forest.

Whereas rooting depth in series 20-30 cm, highest frequency found in grassland, followed by Sal forest, and riverine forest, wherein wetland habitat no rooting frequency was observed in between 20-30 cm (Table 6).

Table 6: Variation in depth of rooting frequency across different habitat

Habitat	Rooting depth (cm)		
	0-10	**10-20**	**20-30**
Sal forest	4	14	2
Wetland	3	2	0
Grassland	3	10	6
Riverine	0	0	1
Total	10	26	9

4.3. Habitat use and preference by wild boar

A study of the Relative preference index showed a positive value of wetland and grassland. Likewise, the negative value of Sal forest habitat and Riverine forest habitat showed low preference for wild boar in BCF (Table: 7). But Chi-Square test showed there is no association between availability of habitat and utilization according to habitat type (Table 7).

Table 7: Relative preference index (RPI) table

Habitat type	Availability of habitat (%)	Utilization (%)	RPI	χ^2 Value
Sal forest	54.21	42.86	-0.21	2.1
Wetland	9.35	15.38	0.64	1.12
Grass land	33.64	39.56	0.18	0.51
Riverine forest	2.8	2.20	-0.21	$1.14e^{-30}$

5. DISCUSSION

5.1. Distribution of wild boar

Wild boar is widely distributed in Barandabhar Corridor Forest and is one of the most widely distributed species in Nepal, occurring from low land to the mid-hills and up to snowline (Jnawali et al. 2011, Pandey et al. 2016) and in diverse habitats of the world (Long 2003).

This study found the highest number of signs in sal forest followed by grassland and wetland. The reason could be due to the high availability of sal forest in BCF (Aryal et al. 2012) or could be linked to soil depth, soil hardness, and the diversity of feeding resources available, as well as other factors such as topography and distance to primary resources. Pokhrel and Thapa (2008) found the distribution of wild boar and their sign was high in grassland of Shukhlaphata national park. Different researches also find the distribution of the wild boar was associated with the forest type and altitude (Dardaillon 1986, Jnawali et al. 2011, Ballari and Barrious 2014). One of the reason behind the distribution in different habitat could be they are habitat generalists, highly adaptable and can live in many different habitat types throughout a landscape or region and can tolerate a wide range of different climates (Engeman et al. 2013)

All these study indicate that wild boar are found in diverse habitat types and distribution might be correlated with the local ecology, disturbances, and resource availability.

5.2. Substrate disturbance

The various type of rooting was found in BCF, with different level of substrate disturbance. The rooting behavior of wild boar is the main cause of substrate disturbance (Lacki and Lancia 1983).The excavation of the surface soil layers in the course of foraging for food, which creates a localized disturbance that appears similar to mechanical ploughing (Sims et al. 2014).

In this study, a total of 420.1 m^2 (3.93%) area had been found rooted among 10700 m^2 area of BCF. In BCF the area covered by rooting can be considered less compare to the study done by Risch et al. (2010) his study found 11 % of the area was affected by rooting in the hardwood / mixed hardwood forest of Switzerland. Similarly, Bueno et al. (2009) Conducted research in three areas of alpine and sub-alpine grasslands in the Spanish Central

Pyrenees, where the Spanish Pyrenees, 7% of the 5104.3 ha area had been disturbed by wild boars, Sesa (11.5% of 1673.7 ha) and Goriz (5.9% of 2189.3 ha), were the most extensively affected areas, and Aisa was less affected (2.1% of the 1241.3 ha). The preference for rooting in different habitat might be associated with its soil depth, soil hardness and diversity of feeding resources. One of the few comprehensive studies of the environmental impact of wild boar was conducted in the Great Smoky Mountains National Park, USA, which showed that rooting at a specific site can occur as many as 3 to 7 times per growing season, and 80% of the surface area of mesic hardwoods can be rooted every year (Howe et al. 1981).

The reason behind the rooting is to be wild boars are omnivorous and obtain a considerable proportion of their diet by rooting (grubbing) in the soil searching for plant seeds, roots/bulbs, and vertebrates and invertebrate animals (Baber and Coblenz 1987, Hone 1988).

This type of disturbance may affect the ecosystem, in different ways: accelerates the decomposition of organic matter by incorporating forest litter into the soil (Jezierski and Myrcha 1975). Indirect impacts may occur when the soil disturbance selectively favors some microbial, animal, or plant taxa, or if the disturbance relocates soil nutrients or changes below-ground decomposition rates (Krull et al. 2013). Also, Wild boar rooting produces disturbed areas that are prone to colonization by few species able to reproduce vegetatively as was observed in the Gray Beech Forest of the Great Smoky Mountains (Bratton 1975).

The proportion of new rooting is high (79.3%) in BCF, which indicates in BCF sufficient level of substrate for rooting is available, or may be hard to quantify old rooting. Results showed, new rooting is highest in grassland followed by sal forest, riverine, and wetland habitat which indicates grassland is more prefer for rooting by wild boar. Bueno et al. (2009) reported a similar type of result, where the grassland is preferred (12%) in Spanish Central Pyrenees. The apparent preference for grasslands might be associated with its soil depth, soil hardness, and diversity of feeding resources and other variables, such as topography, distance to primary resources or, was site-dependent (Kotanen 1995, Welander 2000, Vittoz and Hainard 2002).

All three types of disturbance were recorded in a new rooting site, where a moderate level of disturbance was found highest followed by the high level of disturbance and low level

of disturbance. Which indicate that moderate level of rooting is dominant in sal forest, grassland, wetland and riverine forest habitat of BCF, Moderate level of rooting mix the soil horizons through rooting modifies soil properties and processes (Singer et al. 1984, Lacki and Lancia 1986, Bialy 1996, Moody and Jones 2000, Mohr et al. 2005), which could affect the re-establishment of the plant community. These alterations in soil carbon and nutrient cycling can consequently affect understory vegetation growth and composition. Also, boar rooting may directly (adversely) affect understory vegetation properties through foraging (seed predation), displacing and uprooting, or mechanical damage of plants.

The majority of high-level disturbance was recorded in wetland followed by grassland, which indicates that in wetland rooting is more intense, the reason behind the high-level disturbance is wetland habitat provides the invertebrate animal such as earthworm (Hone 1988, Baubet 2004). A high level of rooting fluctuates in area, depth, and intensity and, because boar tend to root in patches, the effects on soil are likely to be heterogeneous (Welander 2000). Consequently, the structural complexity of the soil surface can be increased as rooting exposes a variety of substrates. A low level of disturbance was observed high in sal forest followed by grassland, which may be due to dry soil and high probability of predator or less availability food. The low level of disturbance is very superficial affecting only the litter layer, but typically impacts the top of the organic and mineral soil layers (Genov 1981, Kotanen 1995).

This study found rooting depth is variable in a different habitat, found in range7-28 cm (Mean 13.5, ± 5.7 SD), similar type result is also found by welander (2000) in south-central Sweden, depth of rootings averaged 10 ± 0.2 cm (varying between 3 and 25 cm). Many researchers suggested rooting depth between 5 -15 cm (Goulding 2003, Mohr et al. 2005) which shows a similar result with this study.

Sal forest, wetland, and grassland observed a greater number of rooting in the range of 10-20 cm depth. Falinski (1986) found that rooting was shallowest in the deciduous forest (8cm), coniferous and mixed forest (6-16cm), and deepest in grassland ecosystems (up to 22cm) but this study found up to 28 cm deepest rooting in grassland. Availability of food in soil surface may be the cause of variation in rooting depth (Calengeet al. 2004).

A typical rooting depth between 5-30 cm will expose both the temporary and long-term seed banks (Thompson and Grime 1979, Thompson et al. 1997) leading to germination and emergence of elements of the exposed seed bank (Kotanen 1994), which could substantially

alter the structure and size of the plant community. While direct consequences on plant communities have been widely studied, their effects on soil seed banks have received little attention although rooting is assumed to determine the successional processes and ultimately the ecological recovery of the communities (Bueno et al. 2011). The long-term effects of frequently applied rooting are difficult to predict without long-term research.

5.3. Habitat preference

Wild boar was found in different habitat of BCF and they are generalist in habitat use (Spitz and Janeau 1990, Abaigar et al. 1994, Virgo 2002) but this study indicate wild boar preference has a relatively highest to the wetland (RPI= 0.64) followed by grasslands (RPI=0.18), Likewise the negative value of Sal forest habitat and Riverine forest habitat indicates a low preference for wild boar**.** Habitat studies of the Wild boar have been conducted in many parts of Europe, and often show that wild boars frequently use the forest as a habitat (Welander 2000, Fonseca 2008). Marshes are also frequently used all year-round, which provides food, use of wallows, rooting, safe bedding sites, and farrowing nests.

Whereas the study of Pokhrel and Thapa (2008) shown a similar result where the wild boar high preference for grassland and the lowest in riverine forest. The preference of wild boars for grasslands can be related to their characteristic deep soils, which provide a high quantity of foods, such as rhizomes, invertebrates, and small mammals or their hoards of bulbs, distance to primary resources (Kotanen 1995, Welander 2000, Vittoz and Hainard 2002) and bedding site in grassland could be the reason for its high preference in grassland.

6. CONCLUSION AND RECOMMENDATIONS

The study conducted on May 20 - June 10, 2018, In Barandabhar Corridor Forest, the Presence of wild boar was conformed and distributed high in the sal forest habitat with rooting activity. The rooting activity of wild boar had created a certain level of disturbance and Grassland is more disturbed or rooted in BCF. This type of disturbance changing the soil properties which initially affects negatively like ploughing root, mechanical damage of plant, changing the physical structure of soil. The most preferred habitat of wild boar was wetland followed by Grassland habitat and limited distribution of the wild boar nearby riverine forest, conclude that habitat preference of the wild boar could be affected by the various characteristics; such as soil and habitat type and food availability and distance to other primary resources.

Overall, this study finds the current situation of substrate disturbance, distribution, and habitat preference of Wild boar at BCF which will help to make a strategy for proper management of biodiversity.

The following are some of the recommendations arising from the study which will help to conserve and well manage the wild boar.

1. This study recommends further study of rooting impact on ecosystem and substrate utilized by the wild boar.

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PHOTOPLATES

A. Old rooting of wild boar

B. New rooting by wild boar

C. Measuring the depth of rooting

D. Wild boar in Barandabhar Corridor forest

E. Pellet of Wild boar in BCF