ASSESSMENT OF SWAMP DEER HABITAT IN PILIBHIT HABITAT BLOCK, UTTAR PRADESH

Dissertation submitted to the

Saurashtra University

Rajkot, Gujarat

In partial fulfillment of

Master's Degree in Wildlife Science

By

Lovepreet Singh

Under the Supervision of

Dr. Samrat Mondol

July, 2021

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

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DECLARATION

I, **Lovepreet Singh**, hereby declare that the research work entitled **"Assessment of swamp deer habitat in Pilibhit habitat block, Uttar Pradesh"**, carried out in partial fulfillment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot is an original piece of research work. This research work was carried out under the supervision of **Dr. Samrat Mondol** and co-supervision of **Dr. Bivash Pandav**, at the Wildlife Institute of India from January 2021 to July 2021. I hereby declare that this work has not been submitted for any other degree of any university.

Lovepreet Singh

[Lovepreet Singh]
(XVII M.Sc. Course in Wildlife Science)

Date: 16-08-2021

Place: Dehra Dun

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CERTIFICATE

This is to certify that **Mr. Lovepreet Singh** has conducted this original research in partial fulfillment of Master's Degree in Wildlife Science of the Saurashtra University, Rajkot, Gujarat. The topic of his dissertation is **"Assessment of Swamp deer habitat in Pilibhit Habitat Block, Uttar Pradesh".** The study was carried out under my supervision from January 2021 to July 2021. I hereby certify that this work has not been submitted for any degree to any university

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Date: 16/08/2021

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Introduction

Large herbivores are crucial for the functioning of ecosystems attributing significantly both to top down as well as bottom up impacts they exert. They influence vegetation in a top down approach by controlling vegetation growth, distribution, regeneration, composition & structure and nutrient recycling, while they are inevitable for the survival of large carnivores which chiefly prey on them (Ripple et al 2015). Swamp deer along with hog deer, wild buffalo, Indian rhinoceros, hispid hare, pygmy hog, Bengal florican, swamp partridge etc are obligate dwellers of grassland and swampland habitat in north India and are vital for proper functioning of these ecosystems (Sankaran 1990). Swamp deer is the third largest deer of the Indian subcontinent and along with brow-antlered deer and Kashmiri deer has witnessed sharp decline in both population and distribution during the course of last one hundred years (Ahmad & Nigam 2014). During the 20^{th} century its range has decreased to 4 % of its original extent (Mukherjee 1974) and currently less than 5000 individuals of swamp deer survive in India and Nepal (Qureshi et al 2004). Locally called barasingha, swamp deer is a Schedule 1 species under Indian Wildlife Protection Act 1972 and assessed 'vulnerable' by IUCN (Sharma et al 2013). It is also listed in Appendix I of Convention on International Trade of Endangered Species (CITES) (Duckworth et al 2015). It is a habitat specialist deer thriving in mosaic of grasslands, swamplands and to some extent in open forests (Blanford 1891).

Before the advent of modern firearms and blatant expansion of agriculture transcending grasslands and swamps, barasingha was known to occur widely between Sind in the west to Assam in the east, as well as numerous blocks between Ganga and Godavari rivers as far south as

Bastar (Forsyth 1889, Blanford 1891). Central Indian population, which is also the poorest of all the three subspecies in population and distribution, is now limited to Kanha national park (Schaller 1967) and has been recently translocated in Satpura Tiger Reserve in Madhya Pradesh. Swamp deer was once abundant in Sunderbans (Blanford 1891) from where they are now extinct meeting the same fate in Pakistan's Sind province, historically the westernmost range of this deer (Qureshi et al 2004). Hunting, habitat loss and conflict with humans are the largest threats to Barasingha which is compounded due to poor population densities and limited availability of required habitats (Paul et al 2020). Unregulated grazing and extraction of resources like grass for thatching, wetland plants for food, and fishing etc are other inimicalities to these habitats. Construction of barrages and various other obstructions leading to change in hydrological dynamics viz. change in river course, siltation and flooding etc are other serious threats to swamp deer habitat (Nathani et al 2018).

Barasingha is endemic to India and Nepal and now three subspecies are recognized, of which *Rucervus duvauceli duvauceli* or northern swamp deer is one and constitute 80% of the total population of the species (Qureshi et al 2004). The northern subspecies is limited in its distribution to Ganga habitat block (Jhilmil Jhil Conservation Reserve, Hastinapur Wildlife Sanctuary, Bijnor barrage area etc) and Sharda habitat block (Dudwa, Katerniaghat, Kishanpur, Pilibhit, South Kheri and North Kheri) in India (Paul et al 2018). Among these two major habitat blocks, Sharda part holds larger population as well as bigger and more compact habitat. In the past most of the work on swamp deer in Sharda region has come from Dudhwa national park, which is a stronghold of barasingha in the country. Meanwhile, exact distribution, population structure, vegetation composition and habitat use are poorly known in other areas of this landscape.

The western part of Sharda catchment connecting Shuklaphanta with Kishanpur through Pilibhit and North-Kheri Division has been recently designated as one among the four Priority Conservation Areas (PCA) for swamp deer in northern India. This designation was based on substantial area under grasslands, confirmed species presence and strategic position in the landscape (Paul et al 2020). The same study identified this PCA to be the most promising site for barasingha conservation and stressed upon the importance to understand habitat and swamp deer population dynamics. Pilibhit is one important unit for barasingha conservation in western Sharda block and a considerable part of it encompasses in the priority conservation area. Sukhlaphanta, renowned for the largest swamp deer population in the world (Poudel 2007) abuts into Lagga-Bagga section ($25Km^2$) of this PCA in the north and strengthens the potential of this area for barasingha conservation. Adjacent small and large patches of unprotected areas which falls in the PCA are equally important, as some of these large blocks play a crucial role for long term survival of the species while other small pockets act as an excellent corridor habitat (Paul et al 2020). Notably, numerous blocks of unprotected areas connect Lagga-Bagga with Kishanpur WLS along the bank of the Sharda River and hold their own significance. A sizeable population of this deer lives outside of the protected area network in western Sharda block. These unprotected areas here are either forest divisions, wastelands around rivers or agriculture areas, or are owned by individual proprietors but rendered fallow owing to poor drainage, effecting swampy conditions.

Grasslands and marshlands are the most important habitat units for the survival of this habitat-specialist deer which are under very high pressure of grazing, and degradation by plantations, particularly in the unprotected areas (Sankaran 1990). Unfortunately, most of the available

habitats here are degraded in quality as large-scale plantations were taken in grasslands of almost all of these protected and unprotected areas in the past when they were managed for commercial purpose (Mathur 1960, Singh & Prashad 2013). In the study area alone, around 57sq.km of grasslands are densely or sparsely planted with khair, shisham, teak, eucalyptus, arjun, jamun and gutel monocultures (Source: Working Plans of various Forest Divisions), consequently, which has either completely changed the vegetation structure on the ground or degraded the grasslands, invariably injuring the swamp deer habitat. This makes understanding swamp deer habitat structure here very important. Equally important is fine scale mapping of all potential habitats in this landscape which are highly under threat. This will not only help in analysing present and historical distribution and contraction of grasslands but will equally necessary for keeping track of change in their character in coming time, planning conservation measures and selecting potential and vital blocks for barasingha conservation, particularly when clubbed with other field data. Moreover, presently the biggest threat to swamp deer is inherent in its small and isolated population most of which is unconnected to each other. Isolated populations are always vulnerable to extinction due to demographic and environmental stochasticity, genetic drift as well as any chance events (Ghimire et al 2019). This makes conservation and linkage of these populations crucial and to achieve this in the case of swamp deer authentic habitat inventory and information on their fine scale occurrence, population structure and habitat composition is warranted.

Referring to the above background this study aimed at fine-scale mapping of swamp deer habitats in Pilibhit habitat block (north western part of the Sharda habitat block) with intensive ground truthing; it had under its scope both state reserved forest as well as other habitats not under the forest department i.e. nazul/waste lands, gram sabha areas as well as private properties

of sufficient sizes. Studying grassland structure and composition of the study area was the second important objective of this work.

Review of literature

Swampdeer is one among the 9 species of family *Cervidae* found in India and classified Vulnerable by the IUCN given its sharply declined population during the last century (Sharma et al 2013). Swampdeer was described in some length by Jerdon in his monumental work 'Mammals of India in 1867' followed by Blandford in 1891 during revision of the mammalian fauna of the country. In 1927, Dunbar Brander described the natural history of this animal in great depth including morphological details, size, weight, breeding habits, behavior, fawning and feeding habits. He also made distinction between the northern and southern subspecies of this deer on morphological and behavioural attributes based on which Ellerman & Morrison-Scott (1951) defined two subspecies, *Cervus duvauceli duvauceli* or the north Indian swampdeer and *C.d. branderi* or the hard ground swampdeer of the central India. In 1982, Groves described the third subspecies *C.d. ranjitsinhii* from Assam. So now there are three subspecies of swampdeer, the northern, central and eastern. In northern India, Gangetic plains all the way south from the base of the Himalayas was their stronghold during mid-19th century (Baldwin 1877, Blanford 1891), but trophy hunting badly depleted their numbers (Champion 1933a). In the late 1880s and early 20th century they were only known from Oudh's reserved forests and a sizeable population existed in Haldwani Forest Division in Kumaun (Wilmot 1910). In 1965 only 11 populations could be traced in northern India declining to 8 in 1972 (Holloway 1973). Today swampdeer occurs in the riverine jungles and grasslands around Ganga River in Uttarakhand and Uttar Pradesh (Jhilmil Jheel Conservation Reserve and Hastinapur Wildlife Sanctuary) and in Pilibhit, Kheri and Bahraich districts of Uttar Pradesh (Qureshi 2004, Paul et al 2020). Barasingha was

rediscovered in Uttarakhand from Haridwar Forest Division in 2005 (Sinha & Chandola 2006) and subsequently from Banganga wetland in Haridwar district (Tewari & Rawat 2013).

Sports hunting for stag's antler were imminent before the wildlife protection law came into force, however habitat loss and deterioration are mainly cited responsible for sharp decline in barasingha population (Holloway 1973). Following independence large grasslands straddling in the lowland terai were surveyed, mapped and gradually cleared to lease permanently to the landless farmers migrating to this region from Punjab, eastern Pakistan and eastern Uttar Pradesh (Mathur & Midhha 2008). Only the best promising patches and miscellaneous forest tracts were retained and transferred to the forest department under zamindari abolition regulations. In Puranpur tehsil alone an area of 450 sq.km of lowland grasslands was cleared for this purpose during 1950s and 1960s (Garg 1959). This area was the stronghold of swampdeer in what was known as United Provinces in those days (Baldwin 1877, Hewett 1938). Swamp deer is rarely poached for meat which is defined tough and coarse with pungent flavour (Holloway 1973) and post-independence clearance of grasslands and deterioration of remnant patches was the major threat. A considerable extent of grasslands in the Sal forests were planted with *Teak*, *Eucalyptus* spp., *Acacia* sp., *Trewia nudiflora* etc for establishing monoculture stands facilitating the assumed revenues. In the sal forests of Pilibhit Forest Division alone the grasslands shrunk from 120km^2 in 1923 (Hall 1924) to merely 43km^2 in 2000 (Kumar & Chandra 2000). Sarda canal and its branches which traverses throughout the length of Pilibhit TR (68 km) created numerous small and large marshlands around it preparing excellent habitat for Barasinga (Holloway 1973), unfortunately, much of it has been planted with *Terminalia arjuna*, *Syzygium cumini* and *Eucalyptus* spp. (Kumar &Chandra 2000), the plants known to survive inundating and damp conditions as well as dry them over time. The populations in Haldwani Forest Division at Lalkua,

Jaulasal and Maldan were wiped due to intense plantations of *Eucalyptus* resulting in habitat loss (Holloway 1973).

Swamp deer habitat has been studied in Hastinapur wildlife sanctuary by Khan et al 2003; they divided the habitat into scrubland, dry short grasslands and tall wet grasslands and worked out vegetation structure of these classes. Schaff (1978) studied the population structure and habitat use of swamp deer in Shukla Phanta wildlife reserve of Nepal. Habitat use and population structure has been also studied in Dudhwa by Qureshi et al (1991) and Ahmad (2007); in Bardia NP of Nepal by Pokheral (1996) and Bhattarai (2015) and in Jhilmil Jheel CR by Tewari & Rawat (2013). Qureshi et al (1991), Pokheral (1996), Ahmad (2007), Tewari & Rawat (2013) and Bhattarai (2015) have studied feeding behaviour of barasinga in various parts of Terai in India and Nepal. Our understanding on southern subspecies comes mainly from the work of Schaller (1967) and Martin (1977).

Swamp deer is an animal of open grasslands, marshes and swamps infested with aquatic vegetation (Sankaran 1990) and use riverine forests for resting during the summers (Ahmad 2007, Bhattarai 2015). In the central India where they are now limited to Kanha and Satpura national parks they use similar habitat, except permanent swamps, and additionally open sal-savannah areas (Brander 1923). It is also noted to visit open grassy hill tops during rutting season (Forsyth 1889), however, *C.d. duvauceli* is an inhabitant of the terai-savannah forests ranging in altitude between 100-300m in elevation (Duckworth et al. 2015) and never ventures in the neighbouring undulating Bhabar tract and the hills (Blanford 1891). In Royal Bardia NP they were seldom seen venturing into Sal and miscellaneous type of dense forests (Pokheral 1996). Two individuals collared in Bardia were confined to floodplains and never entered the sal forest

(Moe 1994). They are also known to inhabit sugarcane fields; in Sathiana area of Dudhwa they move to this crop before monsoons for fawning and return back to forests during early winters (Ahmad 2007). Paul et al. 2020 studied the current distribution status of northern swamp deer in Upper Gangetic Plains which included both the Ganga and Sharda habitat block and identified four Priority Conservation Areas for its conservation. They also studied movement ecology and home range of swampdeer in Ganga habitat block by collaring two individuals as well as employing camera traps. They found barasinga using agriculture areas quite frequently where small blocks of grasslands existed for shelter during diurnal hours. These small grassland patches were also used for breeding and fawning. Swampdeer also frequent sugarcane fields in Puranpur and Palia tehsils as numerous small patches of forests, swamps and grasslands straddles in every direction of this lowland region playing excellent role for seasonal refuge when crops are harvested (pers. observ. Lovepreet Singh). The study done in Dudhwa found positive correlation between swampdeer pellet density and grass diversity, richness, herb density, cover and distance from water; while negative correlation was found between pellet densities and shrub height, shrub cover, shrub richness and tree cover (Ahmad 2007). This concludes open short grassy areas with rich grass and herb composition devoid of trees favoured by barasinga.

Swamp deer is known to feed mainly on grasses and aquatic plants and rarely reported to browse like chital and sambar (Brander 1927, Bhatta 2008). They converge in large herds during springs following the managed burning of the grasslands and resort to the short newly sprouting grasses (Schaaf & Singh 1977). Studies done in Dudhwa national park in Uttar Pradesh and various protected areas of Nepal Terai has found *Imperata cylindrica* as most preferred grass for feeding along with *Saccharum spontaneum, Cynodon dactylon, Narenga porphyrocoma, Phragmites*

karka, Sclerostachya fusca, Apluda mutica, Bothriochloa odorata, Oryza rufipogon and Hygroryza spp. (Moe 1977, Ahmad 2007, Bhatta 2008, Bhattarai 2015). The hard ground barasingha of central India shows same preference for grasses (Martin 1977). Plants of family Fabaceae, Cyperaceae and Typhaceae are other important constituents of swampdeer diet (Ahmad 2007, Tewari & Rawat 2013). The study from Jhilmil Jheel CR found *Typha* spp. to be preferred over all other plants (Tewari and Rawat 2013). They mainly fed on tender leaves of these grasses and other plants throughout the year but also on the roots of *Typha* spp. during the monsoons. Typha roots are rich in Ca and this supplements the animals with nutrient wanting in grasses (Boyd 1969). Continental fodder plants are poor source of Na (Hutton 1958) which is an important element required by mammalian species. To compensate for this loss, herbivores employ strategies to consume mineral soil or selectively feed on aquatic vegetation rich in Na (Staaland 1992). The former is not used by swamp deer as understood in its behaviour which unlike chital and sambar rarely visits the salt licking sites in the forests (Ahmad 2007). Instead they have specialized for feeding on aquatic vegetation (Schaller 1967, Martin 1977). Studies have found *Hydrilla verticilliata, Potamogeton pectinatus* and *Carex* sp. as major aquatic flora consumed by northern subspecies (Moe 1994, Ahmad 2007, Tewari & Rawat 2013), and *Najas* sp., *Vallisneria* sp. in Kanha NP by the central subspecies (Martin 1977). Comparing with highest quality of preferred terrestrial grasses in March-April in Royal Bardia NP, the aquatic plants had 3-100 times more Na, while Ca content was 11-128 times higher (Moe 1994). This makes protection of aquatic areas vital for barasinga conservation forming an integral part of its habitat (Laurie 1982). Large water pools and jheels are important for the supply of aquatic vegetation and drinking. Swampdeer are known to drink twice a day in winters and at least thrice in summers (Bhatta 2008). This further stress on the importance of swamps, marshes and other wetlands for barasingha conservation. However, vegetation structure of these aquatic habitats in

terai are poorly known and are under threat due to weeds, construction of barrages and other mechanical impediments and plantations.

The oldest work on the extent and distribution of grasslands was done during 1892-93 by Imperial Forest Survey Branch of the British Government (Hall 1924). These intensive surveys were done mainly to map all the reserve forests on a 4 inch to mile maps and to properly understand the forest stock, crop density, blank areas and other important elements of forest survey and management. Area of different categories including grasslands were also computed compartment wise and given in the Appendix 'Divisional area statement' in all those working plans of various forest divisions. Later again in 1960s this process was repeated at the revision of working plans. Moreover, this time compartment wise forest area was computed in more detail, covering grasslands, area under water and other blank portion, species wise forest stock etc (Asthana 1962). Since then no new survey has been done and during course of last 40-50 years a large area of grasslands has been taken over for monoculture plantations in almost all forest divisions of terai and bhabar. Consequently, the divisional area statement of these forest divisions, unfortunately, which is the only source of grassland statistics of many of these areas, stands obsolete. For areas outside the realm of state reserved forests, i.e. waste lands zamindari areas, private forests as well as common village lands, Survey of India sheets mapped on a scale of 2 inch to mile are the only historic source of grassland distribution. The oldest Survey of India sheets dates back to 1920s for the terai region of Uttar Pradesh, which were revised in 1960s following independence.

The advent of modern technology viz. remote sensing using satellite data and other GIS tools saw appearance of vegetation distribution studies in some parts of Terai. The most important works of this sort come from Dudhwa tiger reserve. Singh (1982) used satellite imagery from Landsat to classify various vegetation types from Dudhwa national park including grass lands. More detailed and accurate vegetation classification was performed by Kumar et al (2002) using satellite imageries from Indian Satellite IRS IB LISS ll. This study included Dudhwa NP, Kishanpur WLS and South-Kheri and North-Kheri Forest Divisions under its scope. Mathur & Midha (2008) again classified seventeen vegetation classes using high resolution satellite data and produce maps at a scale of 1:25000. This study also included Katerniaghat Wildlife Sanctuary. Similar studies have also been done in Assam terai by Sarma et al (2008) in Manas national park and Kushwaha (2008) in Kaziranga national park.

The riverine grasslands of terai are known for high productivity and assemblage of unique megafauna and is home to numerous obligate mammals and birds (Lehmkuhl 1989). However, understanding regarding the vegetation ecology of this region is still poor, for very few studies have come up to settle this question. The inventory of grassland flora with notes on their basic ecology is found in the works of Symonds (1886), Duthei (1888), Hooker (1872-97), Hole (1911), Bor (1941 & 1961) and Kanjilal et al (1938-40). Hole wrote extensive notes on the more common grasses of terai, bhabar and siwalik hills of United Provinces (now Uttarakhand and Uttar Pradesh). Bor (1941) also described habitat, economic uses and basic ecology of hundred most important and common grasses of United Provinces. Dabadghao and Shankarnarayan (1973) studied the grasslands of the country and proposed classification of the same based on species composition. This is the most important work on grassland classification of the country

ever done but lacks sufficient coverage of diversity of grassland types met in the terai region (Lehmkuhl 1991, Peet et al 1999, Kumar et al 2002). To deal with this insufficiency way was shown by work done in Nepal's Chitwan national park by Lehmkuhl (1989 &1991). He proposed a classification of terai grasslands of the park into eight grassland associations (with ten phases) and two riverine forest associations. Another important research of this nature came from four protected areas of Nepal terai in 1999 (Peet et al. 1999). This study identified nine species associations with eight phases from the grasslands of Shukla Phanta, Royal Bardia, Kosi Tappu and Chitwan protected areas. Kumar et al (2002) produced interesting results from data collected in Dudhwa tiger reserve and nearby forest divisions (North and South Kheri), identifying nine assemblages of terai grasslands. This was the first work of this nature from Indian terai and notably contained three assemblages which were not represented in Nepalese terai.

Apart from classifying grasslands based on the most abundant species, the structure and composition, including associations of trees, shrubs and herbs has been studied by Lehmkuhl (1989), Peet et al (1999), Poudiyal (2000), Pokharel (2003) etc. in Nepal terai and Kumar et al (2002), Mathur and Midha (2008) etc in India. Kumar et al (2002) and Peet et al (1999) also studied consequences of different management implications on the composition of grasslands.

Eucalyptus and teak plantations have destroyed a considerable area of grasslands in Terai Arc Landscape (Mathur & Midha 2008). Despite threats to biodiversity, *Eucalyptus* has been favoured by state forest departments given its wide range of climatic tolerance, fast growth and vast industrial demand (Poore & Fries 1985). Not much work has been done to understand the impacts of these plantations on biodiversity, particularly with reference to grasslands and

marshlands. Plantations are decried for low plant diversity at all strata level producing poor niches for different organisms living in otherwise a similar stand of natural forest (Harikrishnan et al 2012). They are also insignificant as regard cover for animals is concerned and create open spaces for weeds to colonise (Semwal 2005). Ground vegetation is not only poor in diversity under a plantation but its cover and density is equally inferior. Teak is second most widely planted monoculture species in reserved forests both in moist and slightly dry areas of the country and comprises of 8.7% of the total monoculture plantations in India (Harikrishnan et al 2012). Studies done in various parts of the country have found that teak plantations are poor in faunal diversity than similarly standing natural forests; this trend has been shown for frog diversity (Saravanakumar 1995), Butterfly diversity (Kunte et al 1999), bird diversity (Beehler et al1987), and rodent density and biomass (Chandrasekar-Rao & Sunquist 1996). Teak plantations are also avoided by herbivores given that ground cover is absent or sparsely developed. Studies are non-existent as to understand the impacts it has on grassland cover, diversity and composition in terai region.

Species are the products of their natural habitats (Smith 1974), and understanding the habitat features and managing it in that condition becomes crucial for wildlife conservation and management. The conservation and management initiatives are often stopped short of success in lack of species' distribution and habitat characteristics (Kushwaha & Roy 2002). Swamp deer habitat parameters in the grasslands and swampland systems of Pilibhit and North Kheri are not studied; neither there is any baseline data on fine scale distribution, population and population structure of barasinga in these reserved forests and non-reserved areas. Lack of data on grassland distribution in the study area is a big impediment for a conservation strategy, particularly in the

unprotected areas where still plantations are continuously encroaching a considerable area under grasslands every year.

Objectives and key questions

Objective 1. Mapping of Swamp deer habitat in the Pilibhit habitat block

Question.1. what is the status (distribution, area, mean patch size) of grasslands in the Protected (Pilibhit TR) and unprotected areas (North-Kheri FD and non-reserved areas) of Pilibhit habitat block of swamp deer? Digitization of grasslands and production of range wise high-resolution maps of grassland distribution.

Objective 2. Swamp deer habitat structure and composition in the Western Sharda habitat block

Question.1. what is the vegetation structure of the prime swamp deer habitat (grasslands and marshlands) in the study area?

The Study Area

Surroundings and Location- the study was carried out in terai region of Uttar Pradesh covering the Pilibhit Tiger Reserve (PTR) and those areas of North Kheri Forest Division (NKFD) which fall between Pilibhit TR and Kishanpur Wildlife Sanctuary and are part of Priority Conservation Area for swamp deer, identified by Paul et al (2020). Consequently, the whole Sampurnanagar range (except Singaha and Balpur beats), and North Kishanpur and Maharajnagar beats of Bhira range comes under its scope. The study area is located between latitudes 28°49.727' N and 28°17.426' N and longitudes 79°52.989' E and 80°23.190' E. This area, 877Km^2 in extent, falls in Pilibhit and Kheri districts of Uttar Pradesh and is an integral part of terai arc landscape (Semwal 2005). The PTR is managed under the Field Director assisted by a Deputy Director and is divided into 5 forest ranges, Mala, Mahof, Deoria, Barahi and Haripur. The North Kheri is managed under its Divisional Officer, based at Kheri and have been recently declared buffer area to the Dudhwa TR. North-Kheri is mostly a tract of fragmented and mutilated blocks running parallel to Sarda, Kauriala and Ghaghra Rivers, most of them adjoining Pilibhit, Kishanpur, South Kheri, Dudhwa and Katerniaghat on the opposite banks of these rivers (Gaur 1982). All the forest blocks in Pilibhit TR and North Kheri Division are reserved and qualify as state forests. Numerous small patches of unreserved jungles and grasslands straddle around Pilibhit TR and NKFD producing prime

Table 1. Detail of the Study Area

No.	Division	Area (Sq.km)
1	Pilibhit Tiger Reserve	730.24
2	North-Kheri Forest Division	113.99
3	Non-Reserved Areas	32.70
Grand Total		**876.93**

habitat for barasingha as well as for other species. Some of these patches belong to neighbouring gram sabhas, others are private properties rendered fallow mostly due to floods, heavy siltation or marshy conditions and one big patch belongs to the irrigation department. The most prominent patches of these unreserved areas include Puraina grassland, Chuka marshes, flood prone areas around Sarda River, and some large jungle tracts falling between NKFD and PTR, legal status of which is doubtful. In the north it is covered with Surai forest range of Terai East Division (Uttarakhand) which connects Pilibhit with the rest of terai arc landscape. Shukla Phanta wildlife reserve of Nepal shares its boundary on the north-east while Kishanpur sanctuary is located on the southern boundary of this landscape.

Topography, Drainage and Climate-This landscape has been included among Globally Important 200 Ecoregions of the world by WWF mainly for its high biodiversity, its conservational importance and assemblage of many large mammals (Semwal 2005). This tract falls in Terai-Bhabar biogeographic subdivision of the Upper Gangetic plains (Rodgers & Panwar 1988) and can be conveniently divided into two regions: the high bank or old alluvium forests and the lowland or new alluvium forests. A very sharply demarked high bank locally called *dhaya* or *damar* separates these two areas (Keshavanand 1896). The high stable alluvium forests (uplands) are mostly flat with slight undulations along the course of small rivers, Mala, Katna, Kulai, Sakri, Bakri, Khawa and Khannaut in Pilibhit and Ull in North Kheri, which drains this region. These small rivers are merely dry beds of dense and tall reeds during the dry season with petty water pools and impenetrable morasses, and flow in a continuous channel only during wet season. The ground slopes very gently from 208 meter above mean sea level in the extreme northern point of the landscape in Chuka block, to 162 meter in the south-western tip near Khannaut River in Deoria range. The high bank forests are very well traversed with straight

forest roads connecting almost all the parts of the forests. The low alluvium or the lowland terai is a moist flat area cut and eroded badly around the large rivers (Gaur 1982). It lies sharply 8-12 meter below the high bank and slopes from 183 meter in north (Lagga-Bagga) to 163 meter in the lowland tracts of Bhira range near Sharda River. Numerous small perennial rivers like Chuka, western Sutiya, Kunda, Bamini among others traverse this tract. This lowland belt, unlike highland, lacks any good forest roads and becomes completely inaccessible during monsoons when some of the lower regions are inundated. Many small to large sized oxbow lakes, locally called bagahars or baghandars straddles the lowlands formed in the abandoned channels of Sharda River. They are usually long waterbodies settled in morasses and characterized of deep water, copious growth of hydrophytes and linear belts of tall *narkul* reeds. Unlike Dudhwa, this landscape does not have many large *tals* in the highland forests; some worth mentioning are Jhand tal, Barasinga tal, Durraina tal and Badhaila tal in the uplands, and Khirkia bagahar, Salgadda, Nagin kunda and Hazara kunda etc in the lowlands. The Sarda canals traverses the interiors of the sal jungles and through seepage over decades have created many large wetlands and marshes. The main canal divides into Kheri, Sarda sagar inlet and Hardoi branches at Bifurcation which travels through the forests for considerable length.

The climate of Terai is characterized of severe winters from mid-November to mid-March; during this time dense fog, evidently retaining visibility to just some meters, enshroud the open areas. Heavy due falls and frost occurs during the dry spells of January and February. Temperature can drop down to 2° C and the mean low is 4°C in January, which is the coldest month of the year. The summers reign supreme from April to May when tortuous hot westerly winds called *loo* blow violently the whole day. May is hottest month of the year and temperature could rise to 44°C. South-western Monsoon winds arrive by the last week of June and till their

retreat in the late September precipitate heavily, averaging 1125mm annually. Western depression, or the winter monsoon, causes several spells of troublesome weather from December onwards to the onset of monsoons, and on average precipitates 65mm of rainfall. These rain spells are always preceded by episodes of strong thunderstorms and dust devils during summer months and cause a great loss to life and property, large trees often lying prostrate in the forest (Weather data source: Bhatt 1992).

Forest Types and Vegetation- the classification of Champion & Seth (1968) places the forests in the study area into four major sub-groups, the northern moist deciduous forest (types- moist Bhabar sal forest, moist plains sal forest, alluvial savannah-woodlands and *chandar* sal forests), northern tropical semi-evergreen forests (type- cane brakes), tropical seasonal swamp forests (type- *Syzygium cumini* swamps and *Barringtonia* swamps) and northern tropical dry deciduous forest (type- dry plains sal forest, northern dry mixed deciduous forest and khair-sissoo forest) (Champion & Seth 1968, Gupta 1971). The high bank forests located on old alluvium consists of Sal *Shorea robusta* forests while the lowland areas are of typical terai-savannah and grasslands always straddling on the banks of Sarda River or mutilated in small chunks around it. These riverine new alluvium country (or lowland) is dominated with large grasslands, marshy areas, khair-sissoo and mixed deciduous forests. The high bank Sal tract is located 8-12 meter higher than the lowlands and are known for dense Sal woods mixed variably with other tree species. Many small rivers drain the interiors of these Sal areas and create narrow courses of impenetrable swamps and marshes along their drainage.

Within the Sal forests a considerable area is under a unique type of forests and grassland system endemic to only Pilibhit and South Kheri, the *Chandar* sal forests (Troup 1911). These forests

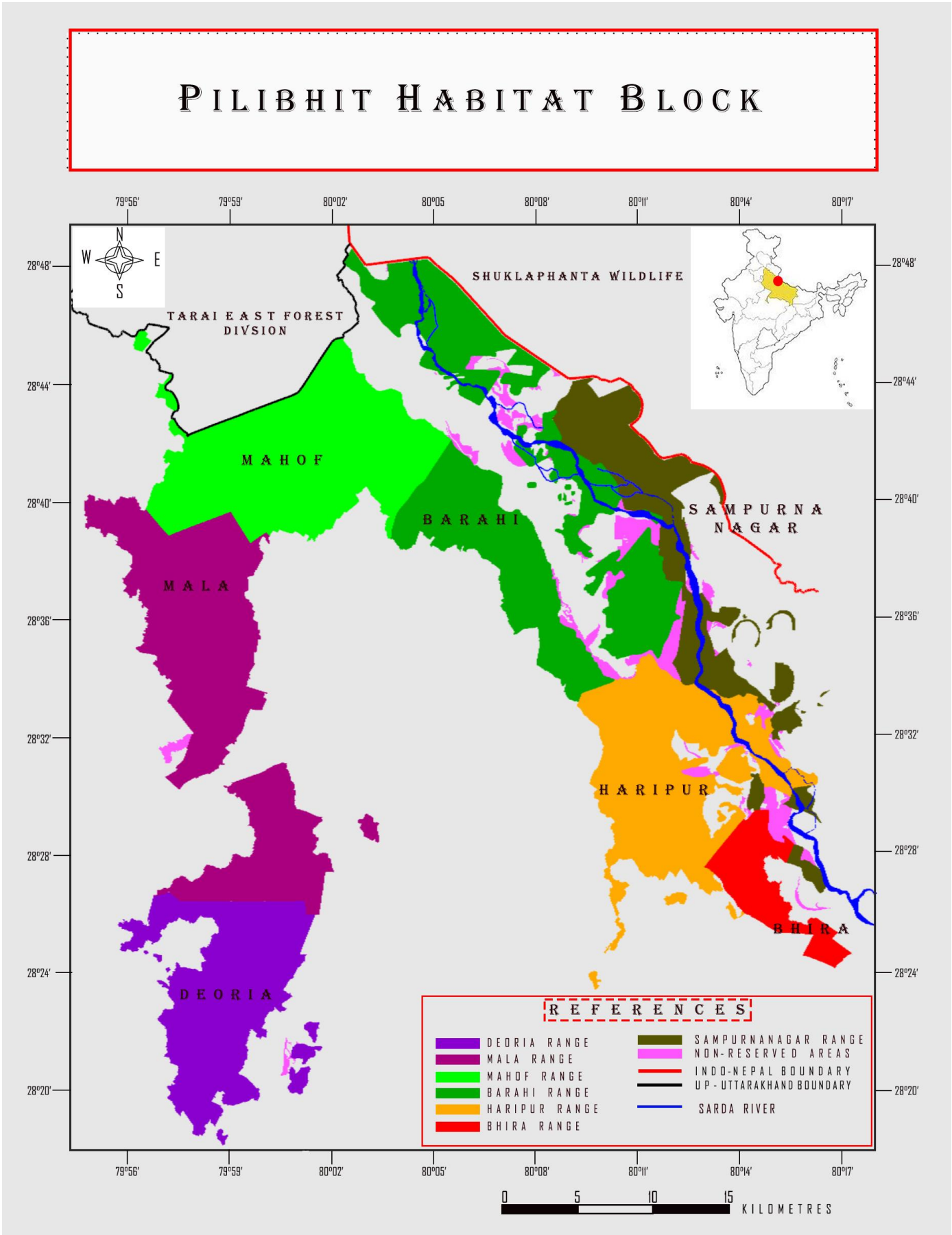
are a mixture of stunted sal regeneration and grasslands managed by frosts and fire; the sal trees grow vigorously for 8 months from March onwards up to a height of 10-15 feet but soon dies on the onset of frost at the ground level in December-January. The roots never die and keep on growing in volume producing new shoots every year from the base and some old ones grow to great size and are hollow inside (Troup 1911). Along the boundary of the tall forest where they are protected from frosts these saplings sometimes emerge to a height safer from frost and converts into a good forest (Hall 1924, Chaturvedi 1954). Likewise, a large amount of *chandar* sal tracts have become today's sal-savannah kind of forests while in other *chandars* sal has expunged due to continuous fires and only grass survives. Consequently, this forest type is now very limited in extent and found in small patches.

The associates of sal are *Lagerstroemia parviflora, Terminalia alata, T. bellirica, Mallotus philippensis, Bridelia retusa, Diospyros melanoxylon, Miliusa velutina, Ficus rumphii, F. bengalensis, Semecarpus anacardium, Bauhinia malabarica, Careya arborea, Garrruga pinnata, Casearia graveolens, C. tomentosa* and *Grewia hainesiana*. The ground floor is flamboyant with *Pogostemon benghalensis, Milletia auriculata, Glycosmis pentaphylla, Clerodendron viscosum, Helectres isora, Callicarpa macrophylla, Colebrookia oppositifolia, Grewia sapida, Grewia hirsuta, G. sclerophylla, Antidesma diandrum, Desmodium laxiflorum, Flemingia strobilifera, F. chappar* etc. The lowland forests are mainly of two compositions, the *khair-sissoo* forest and the mixed woodlands. Mixed patches are composed of *Dalbergia sissoo, Acacia catechu, Trewia nudiflora, Hymenodictyon excelsum, Bridelia retusa, Ficus palmata, F. hispida, F. glomerata, Celtis tetrandra, Aldina cordifolia* etc. Thickets of *Calamus tenuis* make these mixed jungles extensively dense and impenetrable at some places. The damp and marshy areas along rivers are dominated with *Syzygium cumini, Barringtonia acutangula, Bischofia javanica* and *Salix*

tetrasperma; dense clumps of *Calamus tenuis, Pharagmites karka* and *Typha angustata* flourish in these belts. A considerable area in the study region is under grasslands. Grasses like *Saccharum spontaneum, Imperata cylindrica, Vetiveria zizanioides, Themeda arundinacea* etc dominates the dry and slightly wet grasslands, while damp areas show prominence of *Phragmites karka* and *Sclerostachya fusca*.

Fauna- This tract is rich in fauna and is an important unit for conservation of rare species like tiger, leopard, sloth bear, swampdeer, hog deer, hispid hare, swamp francolin, Bengal florican, lesser florican and sarus crane among others. The terai region in wetern UP is rich in its faunal wealth and is represented by around 42 species of mammals, 450 species of birds, 42 of reptiles and 10 species of amphibians (Das et al 2012, Singh & Prashad 2013). Tiger *Panthera tigris tigris* is the most important flagship species of the area. Leopard *Panthera pardus*, leopard cat *Prionailrus bengalensis*, fishing cat *Prionailrus viverrinus*, rusty spotted cat *Prionailrus rubiginosa* and jungle cat *Felis chaus*, are the other species of *felidae* family found here. Jackal *Canis aureus*, Indian fox *Vulpes bengalensis*, sloth bear *Melursus ursinus*, Asian palm civet *Paradoxurus hermaphroditus*, small Indian civet *Viverricula indica*, large Indian civet *Viverra zibetha* (Rohit WWF-India per. comm.) small Indian mongoose *Herpestes javanicus*, common mongoose *Herpestes edwardsii*, smooth coated otter *Lutrogale perspicillata* and ratel/honey badger *Mellivora capensis* are other major carnivores. This landscape hosts the presence of five deer species namely barking deer *Muntiacus muntjac*, sambhar *Rusa unicolor*, spotted deer *Axis axis*, hog deer *Axis porcinus* and swamp deer *Rucervus duvaucelii*, and two species of antelope the bluebull *Boselaphus tragocamelus* and chausingha *Tetracerus quadricornis*. Indian pangolin *Manis crassicaudata*, Indian porcupine *Hystrix indica*, rhesus macaque *Macaca mulatta*, terai grey langur *Semnopithecus hector*, northern palm squirrel *Funabulus pennantii* are the other

interesting faces of wilderness in this landscape. Elephant *Elephas maximus* and One-horned Rhinoceros *Rhinoceros unicornis* visit the Barahi and Sampurnanagar ranges seasonally from Shuklaphanta reserve of Nepal, particularly during the monsoons and paddy harvest season. Some rare birds seen here are grey-headed fish eagle *Icthyophaga ichthyaetus,* osprey *Pandion haliaetus*, Eurasian eagle owl *Bubo bengalensis*, spot-bellied eagle owl *Bubo nipalensis*, Bengal florican *Houbaropsis bengalensis,* lesser florican *Sypheotides indicus,* swamp francolin *Francolinus gularis*, red spurfowl *Galloperdix lunulata*, great slaty woodpecker *Mulleripicus pulverulentus*, jerdon's bushchat *Saxicola jerdoni*, great pied hornbill *Buceros bicornis*, black necked stork *Ephippiorhynchus asiaticus*, painted stork *Mycteria leucocephala*, lesser adjutant *Leptoptilos javanicus* etc. Lowlands of Pilibhit and North-Kheri are stronghold for Red-headed vulture *Sarcogyps calvus*, cinereous vulture *Aegypius monachus*, Himalayan griffon *Gyps himalayensis*, Eurasian griffon *Gyps fulvus* and black rumped vulture *Gyps bengalensis*.



Map- 1- The Study Area

Methodology

Question.1. Grassland Mapping

Mapping of grasslands on a landscape level has been mostly done before through remote sensing data. This is achieved by giving training points to the satellite image assorting to various land use/land cover categories of interest and running a digital classification. Using the reflectance values of these Points of Interests the applications assort pixels of similar values to the given classes with a certain amount of accuracy. To be accurate two different classes (say grasses and crops) need to have appropriately dissimilar reflectance values and a good many reference points is a must to develop point of interests.

In the Pilibhit habitat block (PHB) as mentioned elsewhere, a good amount of grassland straddles outside the boundary of reserved forest and is quite tortuous in outline. Moreover, these areas are widely spread out in space, are numerous in quantity and badly interspersed with cultivation. Among the cultivated crops sugarcane (*Saccharum officinale*) covers the maximum proportion, particularly in the lowlands. This crop highly resembles native wild grasses like *Erianthus ravennae, Narenga porphyrocoma, Saccharum bengalense* among others, producing overlapping reflectance values or values which are only narrowly separated. The reserved forests in Pilibhit and North-Kheri, those in lowlands are equally fragmented and are highly zigzagged on the margins. Much of the area is fragmented due to encroachments and agriculture fields occupy space intermittently within the

grasslands. Given the geographical constraint of dampness in the lowland terai, many private agriculture lands are tilled only once in the season and are rendered fallow for the rest part of the year. These damp areas assume character of grasslands post monsoon and remain like this up to next cropping season i.e. May-June. Lands mooted fallow in this way creates a big disturbance in image classification for they are important to be separated out given their temporary nature and private ownership. The uplands, or the sal tract, which is more compact and well demarcated from the cultivation has an issue of *baib* cultivation. In the Madhotanda and Bisalpur development blocks, lands adjacent to Mahof, Barahi and Deoria ranges are put to *Eulaliopsis bipinnata* (baib) cultivation. This native grass is the only disturbance in the uplands merging with numerous small grassland patches on the boundary of reserve forests.

Given these constraints of classifying grasslands digitally, this study instead employed intensive ground truthing using a GPS device and on-screen digitising grasslands on Google Earth Pro platform. “Google earth is a computer program that integrates a global digital model with base surface imagery to create a 3D mirror representation of the earth” (Bailey 2010). This platform uses high resolution imageries from Landsat-8 satellite and has a freely available temporal and spatial repository. All the data produced on this platform is stored in Keyhole Markup Language (KML) format and stores both vector as well as raster data. Consequently, points, lines and polygons can be created in this format. This is easy to work with

and has an added advantage of being easily shared, is reusable and could be edited and changed any number of times on the Google Earth interface.

Google Earth platform provides free access to vast arena of imageries on a temporal scale. Clean images were selected from the period April 2021 for digitization, ensuring that they were free from merging issues and warping, a common problem encountered in google earth imageries. Grasslands were easily separated from the forest cover visually, and were confused only where they abut into or intergrade with croplands. In the lowlands, savannah areas (grasslands infested with low to moderate density of trees) sometimes appeared similar to open miscellaneous forests with bushy understory. All these disturbances, given the aim to digitise grasslands intensively as well as extensively with high accuracy, entailed a lot of ground truthing work in the field.

The upland tract (sal region) is divided into 195 compartments ranging in area from 80 ha to 1000 Ha and well demarcated on ground with forest roads, fires lines and natural features. Only half of them had any area under grasslands. This upland tract is extensively accessible with roads and trails traversing to every part of these compartments. All these compartments having grasslands were visited individually and GPS points were collected for later reference. Data was also collected for level of the grasslands, broad composition of vegetation (tall or short grasses, main dominating species, infestation of shrubs, presence/ absence of trees and recording status of plantations).

Data on these parameters was interpreted visually. Levels included three categories with reference to the surrounding forest/croplands, they were upland (in level with surroundings), slightly depressed (hollow blanks) and depressed (around rivers and seasonal *nalas*). This data gave a fair idea on origin of these grasslands. Categories for presence of trees was classified into sparsely dense and moderately dense. Patches with moderate to high density of trees where grasses grew along with bushes were not considered as grasslands. *Typha angustifolia* patches, although not a Gramineae was recorded as grassland. Similar treatment was given to open *Tamarix* patches dominated on the ground with short (*Cynodon* and *Imperata*) and tall (*Saccharum spontaneum* and *Typha angustifolia*) grasses.

In intermixed areas where grasslands abutted into agriculture matrix, and at few places with open miscellaneous forests, they were completely separated out with tracks made on GPS set by traversing them on the boundaries. All these GPS points and tracks were imported to Google Earth Pro application. Digitisation of all the grasslands was done directly on Google Earth Pro. The outlines of grassland patches were traced at a specific zoom level, keeping it constant for all the work, to create a polygon and files were saved in KML format. Each patch was named after its local name or after the block or compartment in which it was situated or on some local landmark like forest chauki, river, canal, bridge or a village. A total of 1080 polygons were made from the study area region. These polygons were assorted range wise for the reserved forests. Further, all 1080 polygons were clubbed and converted

into shapefiles (.shp) having a universal transverse mercator CUTM) coordinate system. Finally, the area of the whole study region grasslands was analyzed and calculated patch wise in application ArcGis.

Maps of the study area as well as of individual forest ranges were produced from these polygons and corrected shapefiles of the tiger reserve and forest divisions using applications Google Earth, QGiS, and Adobe Photoshop, showing every patch of grasslands digitised. The maps clearly show the grasslands which are outside the reserved forests and not included under the jurisdiction of the Forest Department.

Question.2. Habitat structure and composition

2.1. Field Method

To understand the structure and composition of swamp deer habitat unbiased systematic sampling was employed. Sampling plots were located on transects which ran diagonally along the longer axis of the habitat patches joining each other through the center of the patch. This would ensure coverage of both margins as well as interiors of the patches. Sampling sites on these transects were predefined to be taken at every 300m distance, while every starting point was to be taken 30m away from the edge of the surrounding matrix (example forest). A middle point on transect was selected for grasslands smaller than 300m in length. The sampling plots were assigned a class based on the dominant grass species having largest coverage (ex. *Saccharum spontaneum* dominated class). Likewise, plots were done on

transects traversing the grasslands diagonally and list of species for assigned classes were maintained. Sampling effort in each class (dominant grass class) was ascertained considering its extent and the pattern on species accumulation curves. At a point of asymptote on the species accumulation curve for a particular dominant class, sampling was stopped. A total of 165 plots were done in the study area, of these 85 were located in the lowlands and 80 in the uplands. All grasslands larger than 1 km in length were taken for sampling at a priority basis, while shorter grasslands which are too numerous in the upland were chosen selectively, given the logistics and time.

Majority of the grasslands in the study area are burnt in the late winters or early summers, by the forest department in core zone and by cattle herders in the buffer. The sampling was done during the months of March-April when grasses reached a height of 2-3 feet and herbaceous flora was in flowering stage. This was not a case, however, in *Sclerostachya fusca* dominated patches in the depressed areas. Being highly moist these grasslands present a special problem in firing and stands taller than 8 feet during springs, other than the areas where they were cut for thatching purpose. *Sclerostachya* grasslands are also heavily dense and penetration is inadvisable. So, only single 1m into 1m plot was done in *Sclerostachya* patches. Apart from the dry and moist grasslands in the study area, a good amount is also ensconced in the marshlands along rivers Mala, Chuka and some *bagahars* in Lagga Bagga. These areas, infested with perennial morasses are difficult to access and were given a differential treatment. These patches are mostly in the form of narrow strips. Points of entry were selected after walking 300 meters along their edge and

attempt was made to enter as deep as possible. In these morasses only one plot of 1m by 1m was established.

Quadrate plots of 10m sides were laid at each sampling interval distance (i.e. 300m) and following data was collected:

1. Date, territorial (Division, Range and Beat) and GPS location of the plot.

2.Surroundings of the grassland patches (viz. Sal forest, miscellaneous forest, river, agriculture etc)

3. Note on soil and level of the patch. For soils, four broad categories were defined, clayey, loamy, sandy and morasses (quagmire). The level also had three broad classes with relation to the surrounding matrix (forest or cropland etc), they were depressed, slightly depressed and upland. The depressed areas were those situated around a river and remain inundated during monsoons, while slightly depressed areas saw seasonal influx of water but have efficient drainage never remaining inundated for any significant length of time.

4. Within the 10m quadrate data was collected on trees; on species, individuals and canopy cover. All woody plants more than 6m height and with single stem from the base were considered as trees.

5. A 5m quadrate was made inside the 10m quadrate and data for shrubs were collected. All woody plants less than 6m in height and those having numerous stems flourishing from the ground level were put in this category. They were enumerated for species and individuals per species.

6. Four small 1m square quadrates were put on the four corners of the 5m quadrate to collect data on herbaceous plants, including grass and non-grass plants. Non-grass plants excluding sedges were counted as well as their cover was also estimated visually. For grasses and sedges only coverage was estimated (species wise).

7. Most of the plants, particularly trees and shrubs, some herbs and grasses were identified in the field itself through local floras (Duthie 1902, Kanjilal 1933, K.K. Singh 1997, etc). Other species, mainly grasses and herbs, which were not known were given systematic code names. These were also properly photographed showing patterns and features of their morphology and identified by experts at Wildlife Institute of India and elsewhere.

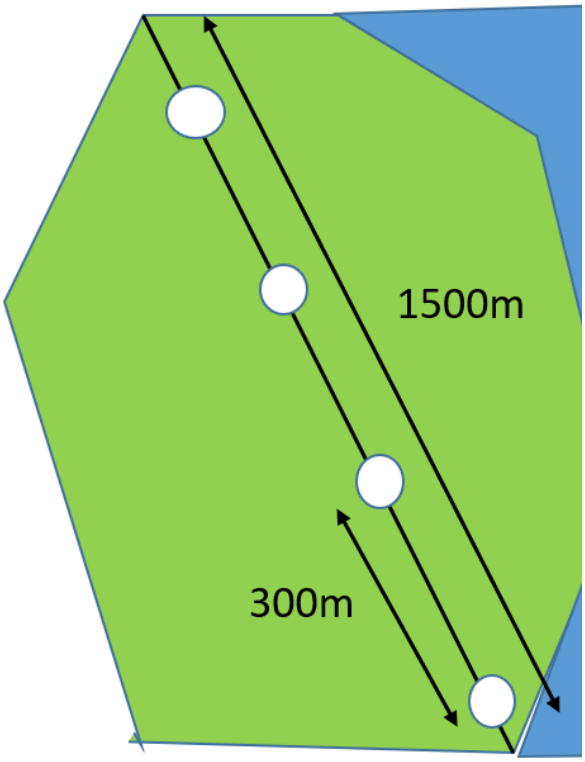


Fig. 1 showing the transect line and vegetation plots

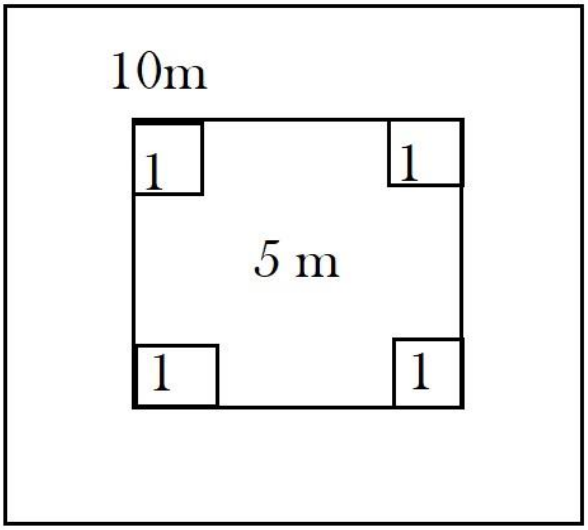


Fig.2. The shape and size of vegetation plot

2.2. Statistical Analysis

Data collected, as mentioned above, was entered in excel spreadsheet in a particular format. This data was put to analysis to understand the diversity of plants in the study area, density of trees, shrubs and herbs, coverage of herbs and grasses and percentage frequency of all plants in the grasslands. These parameters were also calculated for various dominant grass classes. Non-metric Multidimensional Scaling ordination was also performed to visually understand the pattern of similarity and dissimilarity in species compositions of various dominant grass classes. All the analysis for vegetation composition was done using applications Excel, R and PAST.

Density is the number of individuals of a given species per unit area. Densities of trees, shrubs and herbs were calculated using the following formula in excel;

$D= (n/l^2)*10,000$

Given that, D= density,

n= no. of individuals and

l^2= area of the quadrate plot

Coverage is the average spread of a species over the plot area as viewed from the top. It is calculated by dividing the total coverage of a species in all the plots in which it occurred with grand total number of plots.

Frequency is the measure of occurrence of a species in all the plots and is independent of abundance; it is calculated by dividing number of plots in which a species occurred with total numbers of plots. The percent frequency simply tells the percentage of plots in which a particular species occurred.

Pielou's Evenness index was used to calculate the evenness using following formula:

$H' = -\Sigma pi \ln pi/$

Where, pi is defined as the proportion of individuals (ni) found in the ith species out of total individuals (N) of all the species. The value of this index range between 0 to 1.

Non-Metric Multidimensional Scaling (NMDS) analysis was performed on the groups of dominant grass species in R. NMDS works on the basis of a dissimilarity

matrix and creates ordinations to show how similar or dissimilar points of two or more groups are from each other. It analyses relationship between samples and species and display them in such a way that points which are similar are clustered closer based on the magnitude of their similarity and vice-versa. This helps in understanding large data visually on a 2-dimensional view with great ease and derive conclusion from a large and complex data. This analysis can be done using both presence-absence data as well as quantitative data. We used latter approach.

Results

1. Grassland Area, Distribution & Mapping

1.1. General distribution of grasslands:

The area under grasslands in the study region amounted to 154 sq.km, sharing 17.57% in the total extent of Pilibhit habitat block. The study area, as mentioned elsewhere, is formed of government reserve forests and areas that are non-reserved or over which the forest department has no legal control. This category included lands classified as *nazul* lands, *gram samaj's* lands, land abandoned by Sarda River as well as few private properties, which have been rendered fallow due to various reasons. Pilibhit Tiger Reserve (PTR) had highest share among these units (92.47 km^2), followed by North Kheri forest Division (NAFD) (36.64 km^2) and non-reserved areas (25.27 km^2). Non-reserved areas which contains very little forest cover had highest percentage under grasslands (72.27%), followed by North- Kheri Division (32.15%) and Pilibhit TR (12.66%).

Lowlands were much more significant in occupation of grasslands, and major portion, i.e. 105 km^2, of the grasslands were in the lowland blocks, straddling in the floodplains of Sarda River; uplands had only 49 km^2 cover of grasslands. Conclusively, 68% of the grasslands were in lowlands and the rest 32% in the uplands. Lowlands, renowned for large phantas, savannahs and mixed forests had a high percentage of area under grasslands (40%), this being quite lower in the uplands

(8.01%). Unfortunately, a big chunk of grasslands, comprising of 97.18 sq.km (or 63%) in the study area falls in buffer zones coming under the jurisdiction of Pilibhit and Dudhwa Tiger Reserves, as well as non-reserved areas. This was particularly a grave case in the lowlands, here 90% of the grasslands were in buffer zone. In the uplands only an iota of 0.68 sq.km (or 1.38%) formed part of buffer zone.

The total number of grassland patches in the study area were 1075, and the mean patch size was 14.33 hectares (or 35.39 acres). Majority (591) of grassland patches were <1 hectare in size but commanded only 1.4% of the total grassland area. Grasslands over 500 Ha (or 5sq.km) in size were very few and numbered 7, commanding an area of 87 sq.km, constituting 57% of the total grassland coverage. Some of the largest grasslands in the study region were Simra phanta (21.76 sq.km), Chaugebi chandar (17.25 sq.km), Tatargunj phanta (13.73 sq.km), Binaura phanta (12.27 sq.km), Lagga-Bagga phanta (8.52 sq.km) and Hazara phanta (8.11 sq.km). All these massive grasslands were ensconced in the lowlands except Chaugebi, which is an upland *chandar*.

The lowland grasslands were on an average much larger than the upland ones. Average patch size of lowland grasslands came to be 55.62 ha, which was only 5.63 ha for the uplands. The number of patches larger than 500 ha were 6 in the lowlands, while in the uplands except Chaugebi not a single patch was larger than 271 ha.

Table.2. Statement of grassland area in the Pilibhit Habitat Block (All areas in hectare)									
Category	**Total Area**	**Grass land Area**	**% of Grass lands**	**No. of patches**	**MPS**	**Largest patch**	**Smallest patch**	**BZ**	**CZ**
UL	61148.53	4847.88	7.92	889	5.63	1725	0.012	221.47	4621.41
LL	26626.84	10562.03	39.66	191	55.63	2176	0.023	9450.93	1111.1
Total	**87775.37**	**15409.91**	**17.56**	**1080**	**14.26**	**2176**	**0.012**	**9672.4**	**5732.51**
UL- Uplands **LL**-Lowlands **MPS**- Mean Patch Size **CZ**- Core Zone **BZ**- Buffer Zone									

Table.3. Distribution of grassland patches in Pilibhit Habitat Block (all areas in hectare)			
Patch size	**Total number of patches**	**Total area commanded**	**% of total area**
>1000	4	6501.88	42.19
500--1000	3	2283.31	14.81
100--500	14	2189.68	14.2
50--100	20	1503.11	9.40
1--50	443	2708.73	18
<1	591	222.69	1.4
Grand Total		**15495.39**	**100%**

Table.4. Distribution of grassland patches in upland portion of Pilibhit Habitat Block (all areas in hectare)			
Patch size	Total number of patches	Total area commanded	% of total area
>1000	1	1725	35.58
500--1000	0	0	0
100--500	6	888.67	18.33
50--100	5	388.14	8
1--50	341	1645.61	33.94
<1	536	200.46	4.13
Total	**889**	**4847.88**	**100**

Table.5. Distribution of grassland patches in lowland portion of Pilibhit Habitat Block (all areas in hectare)			
Patch size	Total number of patches	Total area commanded	% of total area
>1000	3	4776.81	45.22
500--1000	3	2283.31	21.61
100--500	9	1365.89	12.93
50--100	15	1114.96	10.55
1--50	104	997.82	9.44
<1	57	23.24	0.2
TOTAL	**191**	**10562.03**	**100**

1.2. Distribution of grasslands in various units of the study area is discussed as follows:

1.2.1. <u>Pilibhit Tiger Reserve</u>- Pilibhit Tiger Reserve had largest area under grasslands (92.47sq.km) among all the units included in the study, however, percentage wise it had lowest area under grasslands (12.66%). Uplands and lowlands shared almost equivalent area under grassland coverage (46.21 and 46.26 sq.km respectively), although a big portion of lowlands was covered by grasslands than the uplands. Range wise detail of the grasslands in PTR is provided as follows:

1. <u>Mahof Range</u> - An area of 2459 Ha. (Or 24.59 km2) was under grasslands in Mahof range, being 16.68% of its total area. It had 192 patches of grasslands with mean patch size of 12.74 ha. The largest and smallest patch size in the range was 1523 ha and 0.030 ha respectively. Chaugebi *chandar* situated in the central portions of Mahof is the largest grassland (1523 Ha) of the range as well as largest upland grassland of the whole study area. Interestingly, the main body of the chandar is a compact block and sends narrow ramifications to all directions. These ramifications connect it with Mala marshy grasslands towards south and east and creates a continuous habitat (grassland) from Uttarakhand boundary in the north to the Pilibhit-Puranpur highway in the south. It is continuous on the north with Damna *chandar* in Surai Range of Tarai East Division (Uttarakhand) across the boundary. Mala River and Ladsia nala drains the eastern and western edge of this *chandar*. The interiors are sparsely planted with *Eucalyptus, Tectona grandis, Albizzia chinensis*

among other species. Chaugebi is the finest upland swamp deer habitat in the Pilibhit habitat block and hold a sizeable population of this deer. Other important grasslands in the range are Chuka *chandar* (155 ha), Bhimtal *chandar* (113 ha) and Jhand *chandar* (105 ha). None of the other grassland was over 100 ha in the range. All the grasslands in Mahof are upland grasslands, and except a minuscule area of 52.61ha, all are within core zone.

2. Mala Range- grassland coverage in the Mala range was 1445 Ha (or 14.45 sq.km), being 8.77 % of its total extent. Total number of patches were 324, amounting to a mean patch size of 4.45 Ha. The largest and smallest patches were 201 ha and 0.027 ha respectively. A part of Chaugebi *chandar*, covering Mala River as a marsh, enters it from north and is the largest patch of the range (201 Ha.) Two grasslands covering the Mala River in the south were 112 Ha and 107 Ha in size respectively, none other being larger than 100 Ha. Majority of the grasslands here straddles around Mala, Katna and Khannaut Rivers. Like Mahof all patches in Mala assort to Uplands, and none are in Buffer zone.

3. Deoria Range- Deoria had the lowest area under grasslands among all the ranges of Pilibhit tiger reserve, amounting to 588 ha (5.88 km2). Grasslands cover only 5.51% of the total area of the range. The number of patches were also large (314) and mean patch size was insignificant (1.87 ha); the largest patch size was just 32.35 ha. All the grasslands are upland *chandars* and tiger reserve notification assorts them to

core area. Unfortunately, a big part of them are on the boundaries and cutting and grazing pressure from the villages in neighbourhood is quite high.

4. Haripur Range-an area of 869.00ha was covered by grasslands in Haripur range, being 6.72% of the total range area. Haripur has both upland as well as lowland tracts under it. Interestingly, majority of the grasslands of the range are in lowlands (95%); very negligible area of 42.63 hectare was found in the upland tract, which is completely dominated with class I sal forests. A total of 42 patches produced mean patch size of 20.69 ha in the area, largest and smallest being 187 Ha and 0.056 Ha, respectively. Upland grasslands are all situated either on the boundaries or in the fragmented blocks of the range, and consequently are poor and degraded, given the high grazing and cutting pressure. Lowland portion of the range has a very considerable area under encroachments which was earlier big grasslands continuous with those existing today. Two large *jheels,* Khirkia (48 ha) and Salgadda (23 ha) are within the ambit of the range. These largest lakes of the study area are rich in morasses and hydrophytic vegetation, consequently signifying a prime habitat of swamp deer. Non-reserved areas of Khirkia, consisting of miscellaneous forests, cane brakes and grasslands are continuous with Haripur in the south-east.

5. Barahi Range- Barahi is the largest forest range of the study area (183 km^2) and have blocks of both upland and lowland belts. Large area of 3886.80 ha (or 38.86sq.km) in the range was grasslands standing at first position among all the ranges of the study area. Grasslands made 21.23% of the range. Total number of

patches were 121 and mean patch size was 32.11 ha. Largest tract of grassland in the range was part of Simra phanta (1132 ha) which spreads over Barahi and Sampurnanagar ranges and neighboring non-reserved areas. Smallest patch recorded was only 0.11 ha in size. Barahi's upland tract of sal dominated forest had only 87.16

Table.6. Statement of grassland area in Pilibhit Tiger Reserve (All areas in hectare)

Range	Category	Total Area	Grass land Area	% of Grass lands	No. of patch es	MPS	Largest patch	Smalle st patch	BZ	CZ
Deoria	UL	10664	588	5.51	314	1.87	32.35	0.012	0	588
	LL	000	000	0	0	0	0	0	0	0
	Total	**10664**	**588**	**5.51**	**314**	**1.87**	**32.35**	**0.012**	**0**	**588**
Mala	UL	16472	1445	8.77	324	4.45	201	0.027	0	1445
	LL	000	000	0	0	0	0	0	0	0
	Total	**16472**	**1445**	**8.77**	**324**	**4.45**	**201**	**0.027**	**00**	**1445**
Mahof	UL	14712	2459	16.71	192	12.74	1523	0.038	52.61	2406
	LL	000	000	0	0	0	0	0	0	0
	Total	**14712**	**2459**	**16.71**	**192**	**12.74**	**1523**	**0.038**	**52.61**	**2406**
Barahi	UL	7149	87.16	1.21	38	2.29	35.52	0.12	00	87.16
	LL	11190	3799	33.94	83	45.77	1132	0.11	2717	1082
	Total	**18339**	**3886.16**	**21.19**	**121**	**32.11**	**35.52**	**0.11**	**2717**	**1169**
Haripur	UL	9071	42.63	0.46	15	2.84	13.78	0.23	18.1	24.53
	LL	3847	827.16	21.50	27	30.63	187	0.05	798.06	29.1
	Total	**12918**	**869.79**	**6.73**	**42**	**20.70**	**187**	**0.05**	**816.6**	**53.63**
GRAND TOTAL	UL	58068	4621.79	7.95	880*	5.25	1725	0.012	70.71	4550.69
	LL	15037	4626.16	30.09	110	42.05	1132	0.05	3515	1111.1
	TOTAL	73105	9247.95	12.65	990*	9.34	1725	0.012	3585.7	5661.7

UL- Uplands LL-Lowlands MPS- Mean Patch Size CZ- Core Zone BZ- Buffer Zone

ha area under grasslands amounting to Puny 1.2 % of the total area of this sal belt. Of the uplands, Bifurcation block alone contained all these small chandars, while Barahi block (southern part of the upland belt) had only one small grassland. Notably, 34% of the lowlands in the range are grasslands, while miscellaneous forests and encroachments make the other portion. A valuable part of the range also consists of sandplains and main channel of the Sarda River.

Largest grasslands in the range were Simra phanta (1132 Ha), Lagga- Bagga Phanta (852 ha), Gunhan phanta (199 ha.) and Chandpur phanta (180 ha). Barahi is surrounded with many non-reserved forests and grasslands in all directions, more important ones with substantial coverage are Chuka marshlands on the east of main upland belt, Baruwa and Dhanaraghat grasslands on south and south-east, Puraina grasslands (in Sarda sagar), Paliya grasslands, Simra grasslands and Gunhan grasslands.

1.2.2. North-Kheri Forest Division- only two forest ranges, Sampurnanagar and Bhira of this division were included in this study. This portion of the division has a large area under grasslands (36.35sq.km) with high percentage cover (31.88%). Range wise detail is given in the following paragraphs:

1. Sampurnanagar Range- by virtue of its location completely around the floodplains of Sarda River, Sampurnanagar had 3222.72 ha (or 32.22 sq.km) area covered by grasslands. This made up 39% of the range being highest in the study area. Barahi

and Sampurnanagar together commanded 71 km2 of grasslands, or 46% of the whole study area's grasslands. It had only 46 patches producing highest mean patch size of 70.04 ha for any range included in this work. The largest and smallest patch size in Sampurnanagar was 1149 ha and 0.037 Ha respectively. Some largest patches in the range were Tatargunj Phanta (l149 ha), Hazara phanta (537 ha), Hazara phanta (northern) (405 ha), part of Simra phanta (332 Ha) and part of Binora phanta (167 Ha).

Table.7. Statement of the grassland area in North-Kheri Forest Division (All areas are in hectare)

Range	Category	Total Area	Grass land Area	% of Grass lands	No. of patches	MPS	Largest patch	Smallest patch	BZ	CZ
Sampurna Nagar	UL	0	0	0	0	0	0	0	0	0
	LL	8189	3222.72	38.92	46	70.04	1149	0.037	3222.7	0
	Total	**8189**	**3222.72**	**38.92**	**46**	**70.04**	**1149**	**0.037**	**3222.7**	**0**
Bhira	UL	2949	150.76	5.11	8	18.84	128.66	0.25	150.76	0
	LL	261.51	261.51	100	7	37.35	241	0.02	261.51	0
	Total	**3210.5**	**412.27**	**12.84**	**15**	**27.48**	**241**	**0.02**	**412.27**	**0**
GRAND TOTAL	**UL**	**2949**	**150.76**	**5.11**	**8**	**18.84**	**128.66**	**0.25**	**150.76**	**0**
	LL	**8450.5**	**3484.23**	**41.23**	**53**	**65.74**	**1149**	**0.02**	**3484.2**	**0**
	TOTAL	**11399.5**	**3634.99**	**31.88**	**61**	**59.59**	**1149**	**0.02**	**3634.9**	**0**

UL- Uplands **LL**-Lowlands **MPS**- Mean Patch Size **CZ**- Core Zone **BZ**- Buffer Zone

Apart from grasslands, a small area is covered with dense miscellaneous forests with cane brakes, while a considerable portion is encroached and other is under sandplains and main channel of Sarda River. Numerous rivers, marshes and oxbows infest the range and produce one of the finest swampdeer habitat in the lowland part of the

study area. Nagin Kunda, Chaundhar Kunda and Hazara Kunda are the most important large oxbows in Sampurnanagar. Many non-reserved grasslands, notably Sidhnagar grasslands, Hazara grasslands, Kabirganj grasslands, Binaura grasslands and Kanp grassland surrounds it on the edges.

2. Bhira range- Bhira was the smallest range covered in the study area (32 km^2), for the major portion of this range are situated south to Kishanpur wildlife Sanctuary which were not included in the present study. Bhira recorded 412.17 ha of grasslands, covering 12.84% of its total extent. Total numbers of patches were 15, and mean patch size came to 27.48 ha. Largest and smallest patch size was 241 ha and 0.023 ha in size, respectively. Binaura phanta (241 ha) in the lowland and Allengunj *chandar* (128 Ha) in the upland were the two largest grasslands. Major portions of the upland grasslands were located on the catchment zone of Ull River.

1.2.3. Non-Reserved Areas- A total of 3270.87 ha area is composed of grasslands, miscellaneous forests and waterbodies which comes under the category of non-reserved areas. All these blocks abut into neighbouring reserve forests, and except Nawadia Banki patch are all situated in the lowlands. A considerable extent of grasslands (2527.17 Ha) was recorded from this category. Grasslands covered 77.27 % of its total area which was highest among all the units. Total number of patches were 69, having a mean patch size of 36.62 ha. Largest patch was of 459 ha and smallest being 0.1 ha. Some giant patches of grasslands in non-reserved areas were

part of Binaura phanta (459 Ha), part of Simra phanta (323 ha) and Dhanara phanta (northern) (167 Ha).

Table.8. Statement of grassland area in Non-Reserved Areas (all areas in hectare)

Category	Total Area	Grassland Area	% of Grasslands	No. of patches	MPS	Largest patch	Smallest patch
UL	131.53	75.53	57.42	3	25.17	72.8	0.35
LL	3139.34	2451.64	78.09	66	37.14	459	0.1
Total	**3270.87**	**2527.17**	**77.27**	**69**	**36.62**	**459**	**0.1**

UL- Uplands LL-Lowlands MPS- Mean Patch Size
All non-reserve areas are functionally falls in buffer zone

Some of the important non-reserved areas are described as follows:

1. Binaura phanta- Binaura (1227 ha) is one of the largest grasslands in the study area and is spread over Bhira, Sampurnanagar and Haripur ranges as well as a big portion in non-reserved area. It is a recent patch abandoned by the Sarda River and remains seasonally inundated. Many small nalas and marshy depressions occupy this patch. *Typha angustifolia, Saccharum spontaneum*, along with light scrub of *Tamarix dioca* dominates the vegetation. Except a small savannah near Sarda, the whole grassland is devoid of any tree. It is a compact block situated between high bank of sal woodland and Sarda River, and has a good population of Barasingha. The non-reserved areas of this phanta belongs to the *gram samaj* as well as private ownership of village Nehrosa, now located across the Sarda River.

2. Simra grassland- this patch of NRA is 453 ha in extent, of this 323 ha is grassland. It is located on the northern point of the Tarai and Faizullagunj forest blocks (Barahi range) and Simra phanta occupies majority of its portion. The legal status of this patch is doubtful, but is not a part of reserve forest. However, presently, it is under the control of Forest Department. Two cattle stations have established in this patch and grazing pressure is tremendous. Swamp deer presence was not recorded from this patch, but it is an important ancillary habitat and connects Barahi range with Bamanpur-Bagirathi block of Sampurnanagar across the river.

3. Puraina grassland- a patch of 139 ha has developed within the south-western part of the Sarda Sagar Reservoir near the village of Puraina. Incessant siltation has created an elevated mound here in the reservoir, now colonised with dense and tall *Phragmites karka* reeds. This patch is continuous with Barahi range (Bifurcation compartment 61) on the west. Two water channels, Sarda sagar feeder canal and Sarda sagar outlet, skirts the patch. Moreover, many perennial and seasonal ponds have also made presence in this grassland. Currently, barasinga status in this block is not known but habitat appears quite suitable for it. This land belongs to the Irrigation Department.

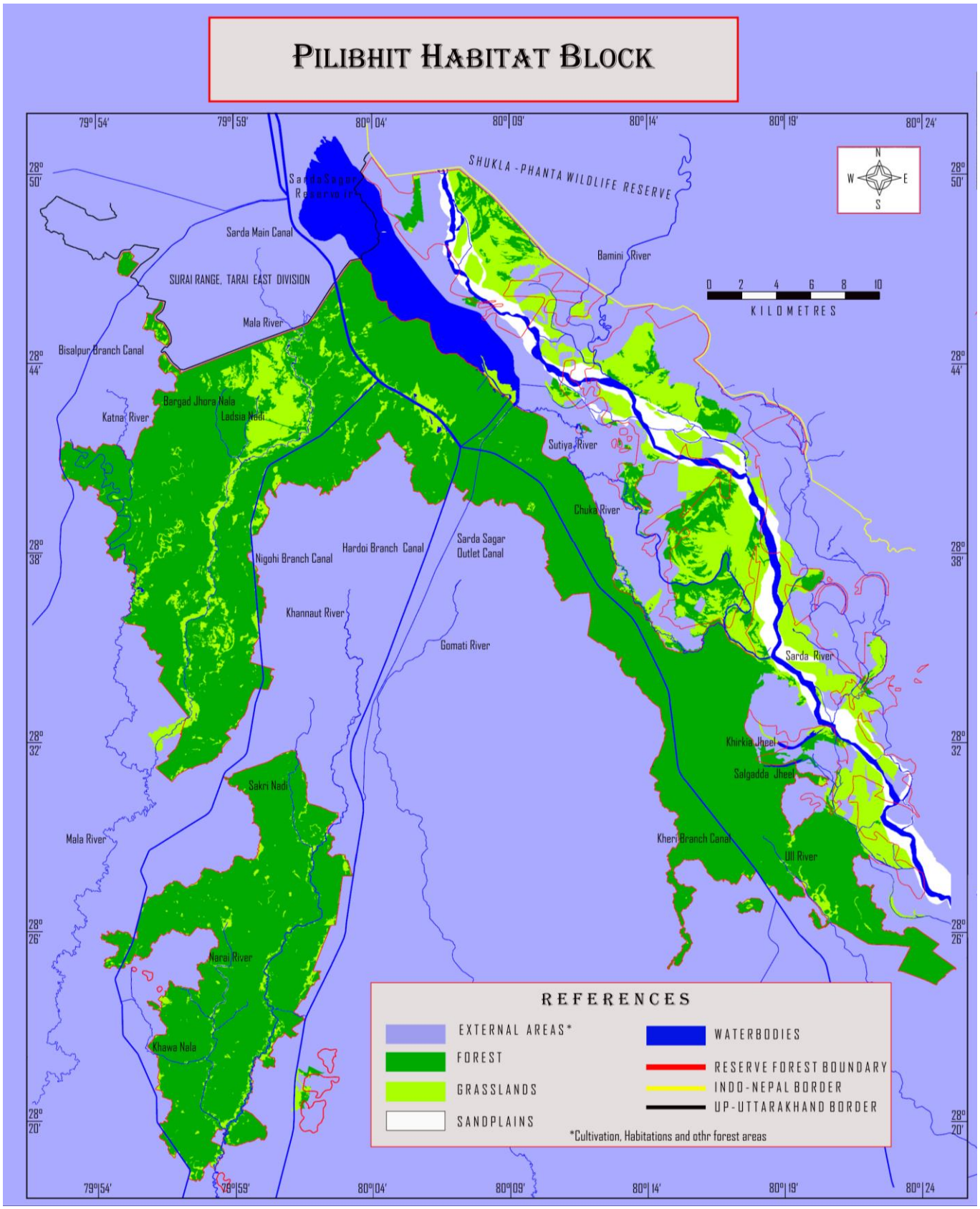
4. Dhanaraghat grasslands- a block of 392 ha of grasslands (327 ha) and open miscellaneous forests (65 ha) occupies a wedge between Barahi, Haripur and Sampurnanagar ranges, some miles north-west to Dhanaraghat. The divisional maps of both Pilibhit and North-Kheri does not show this patch in their ambit. However,

currently it is under management of Barahi range. No village has claimed rights over this patch but the actual status is doubtful. All the grasslands in this block are part of great Simra phanta and good population of Swamp deer still thrives here. Interestingly, this is the only patch of non-reserved areas which lies in the interiors away from any habitation. Consequently, it is a prime wildlife habitat in the study area, including barasingha.

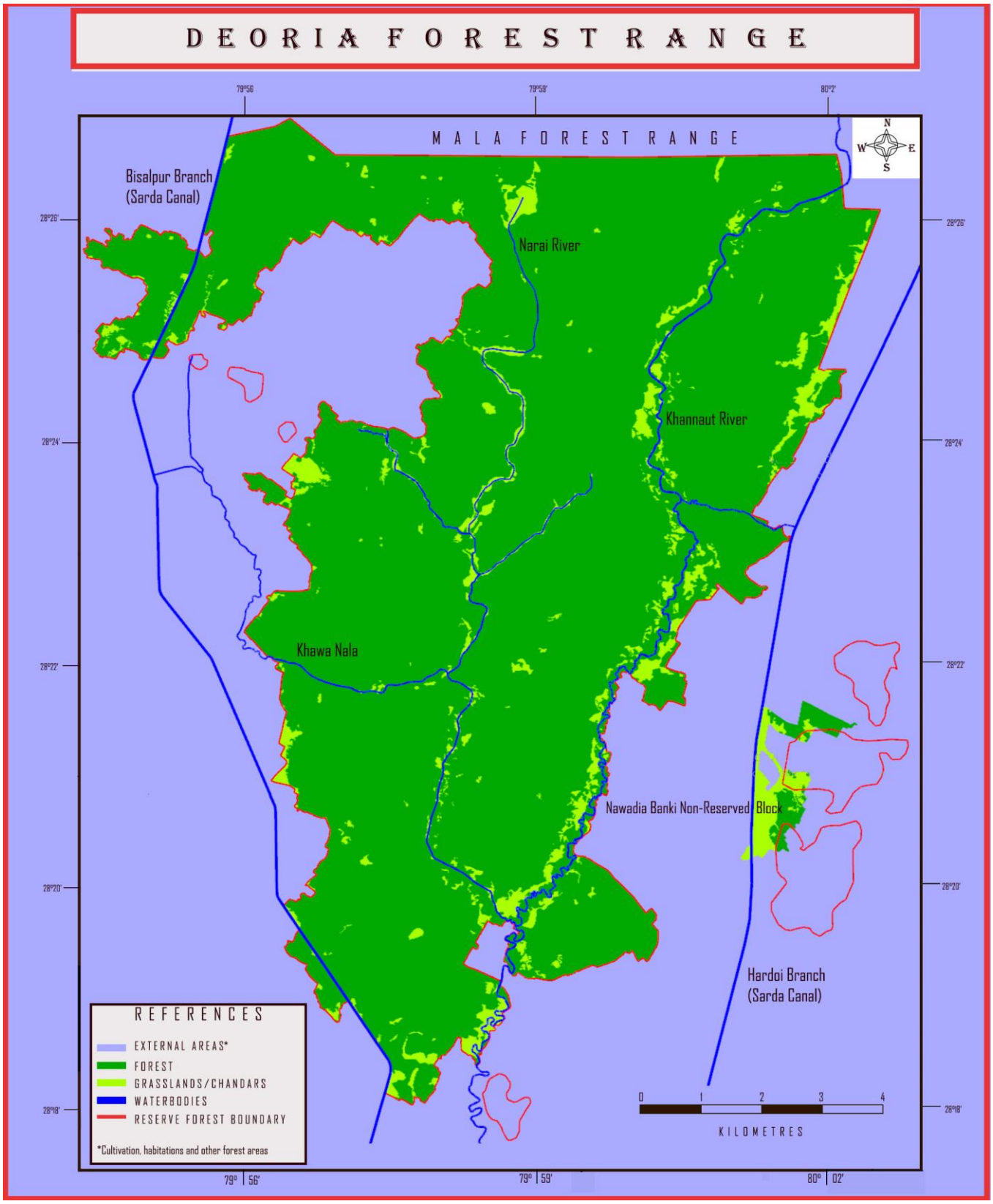
5. Chuka marshlands- this is a narrow belt stretched for 8 km along the eastern edge of Barahi's upland belt. Total area of this marsh is 387 ha, 50% of this is grasslands while rest of the part is made up of *Syzygium cumini* and *Salix tetrasperma* swamps, numerous ponds and recently a miniscule area taken for paddy cultivation. Chuka River and its various tributaries and distributaries are webbed throughout this patch producing quagmire and rendering much of it waterlogged perennially. Chuka marshlands mostly belongs to *gram samaj* of the neighbouring villages and some areas have recently been distributed to landless people on *patta*. Barasinga were reported from Nawadia Kundri and Hagnia stretches of this marsh.

1.3. Geography of the grasslands

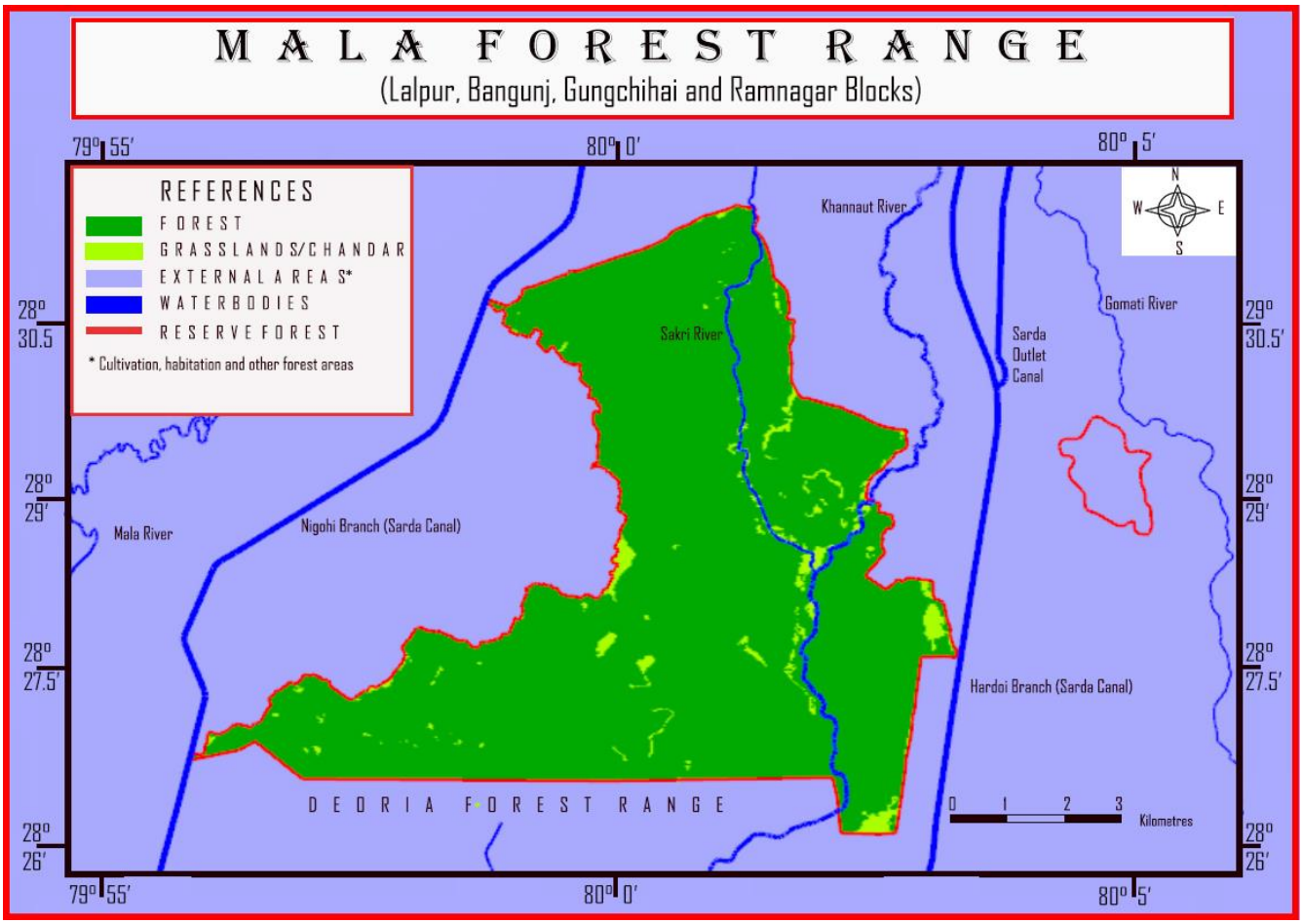
Observations taken of the level of grassland patches in the upland revealed an interesting information on the character and origin of these grasslands. Out of the 889 different patches, 791 were located in a depression where water would fill during monsoons. This was true, particularly for all 531 patches smaller than 1 ha in size. The second major category was the patches located in level with the neighbouring forests or other land (85 patches). This included 6 chandars in the interiors and rest 79 on the boundaries where agriculture abuts into forestland. These patches on the boundaries are probably maintained as grasslands, despite conducive for tree growth, due to excessive grazing and fires, which take place annually. Grasslands developed on elevated mounds signified the third class numbering 13 patches. Undeniably the first category traces its origin to edaphic elements; here soil is too damp and rich in clay to support trees or shrubs and consequently grasses reign supreme. The other two categories are artificial in nature. Literature reveals that in many blocks poorly stocked inferior Sal and miscellaneous forests were clear felled to be replaced with artificial plantations (monoculture) during 1970s and 1980s (Tiwari, 1992). In some areas these monocultures did not see success and were taken over by grasslands. Major portion of Chaugebi chandar in compartment 104, 105 and 106 assigns to this category. The third class of patches, i.e. on a raised ground, were all from Barahi range and formed over mounds created by soil excavated and heaped from the Sarda Sagar outlet canal.



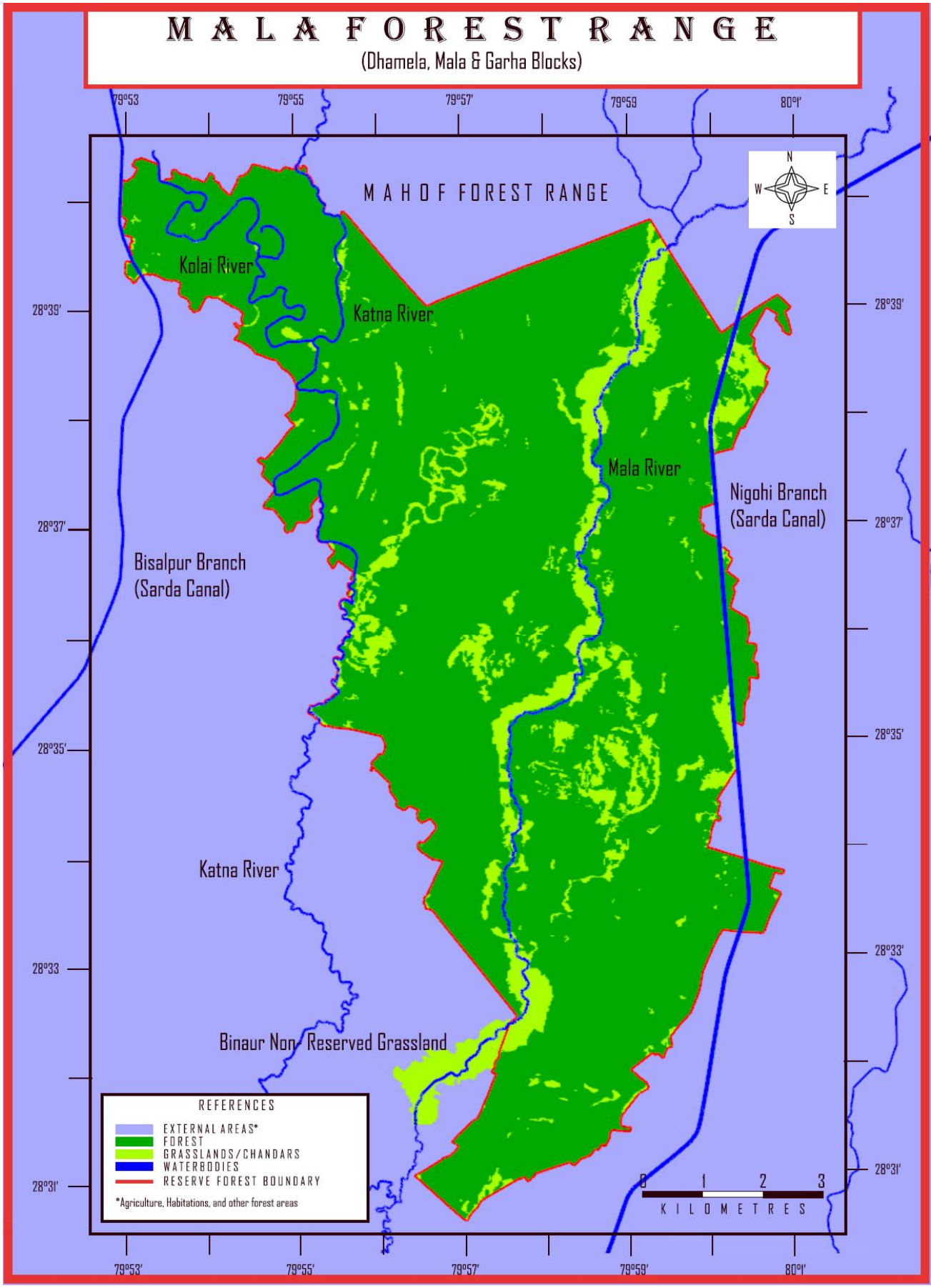
Map:2. Grassland distribution map of the study area



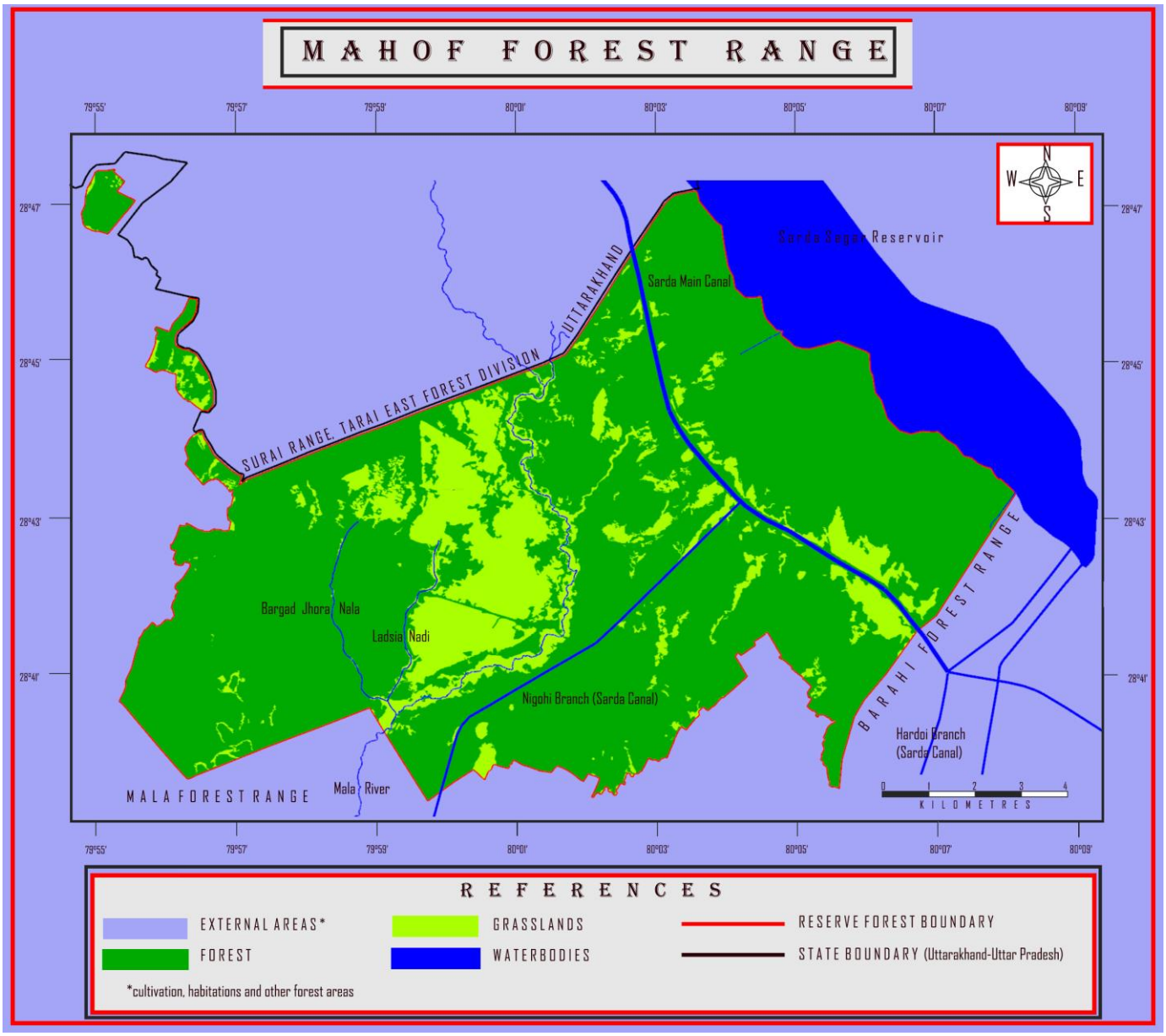
Map 3 Grassland distribution map of Deoria range



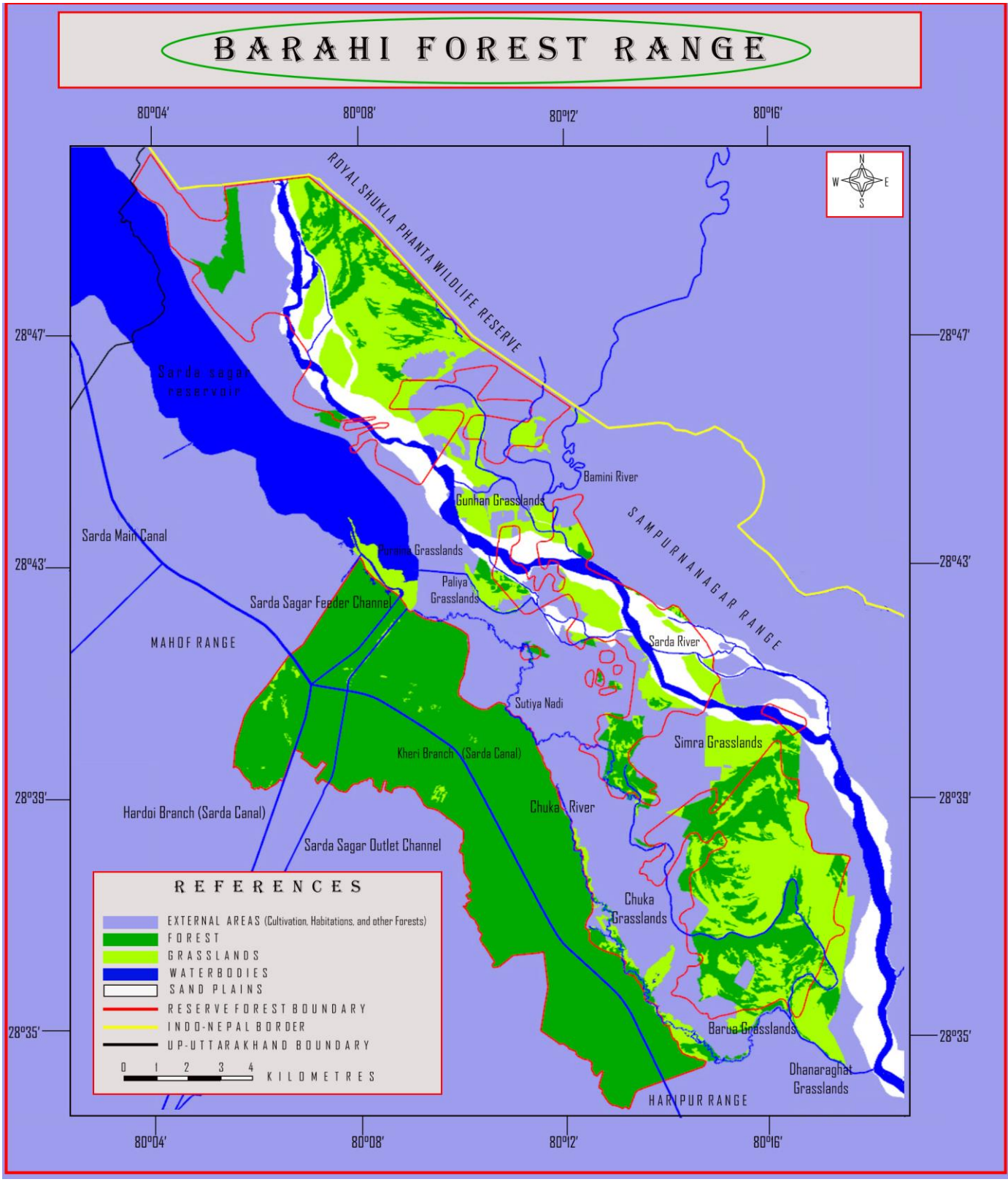
Map.4. Grassland distribution map of Mala range (southern parts)



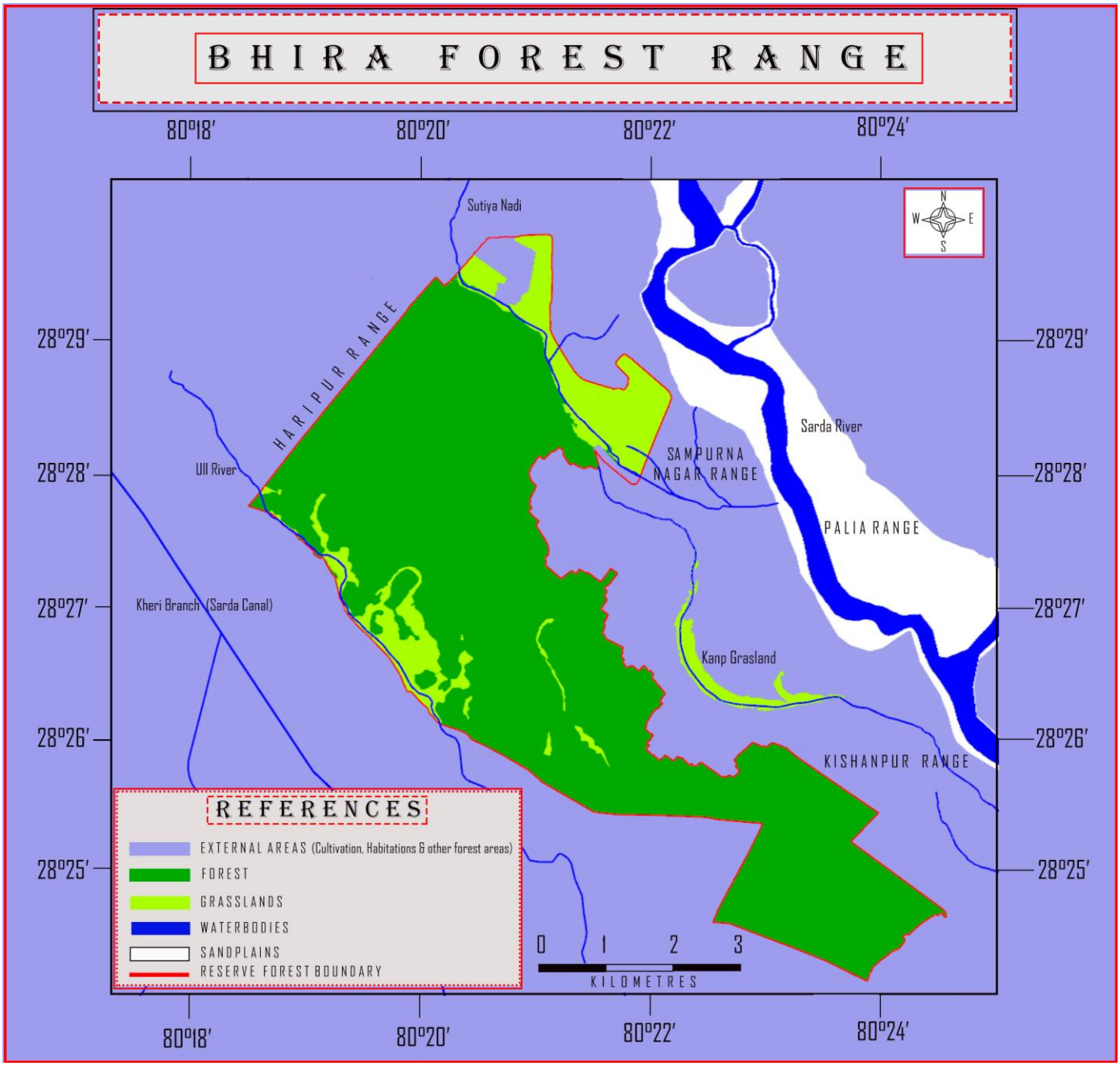
Map.5. Grassland distribution map of Mala range (northern part)



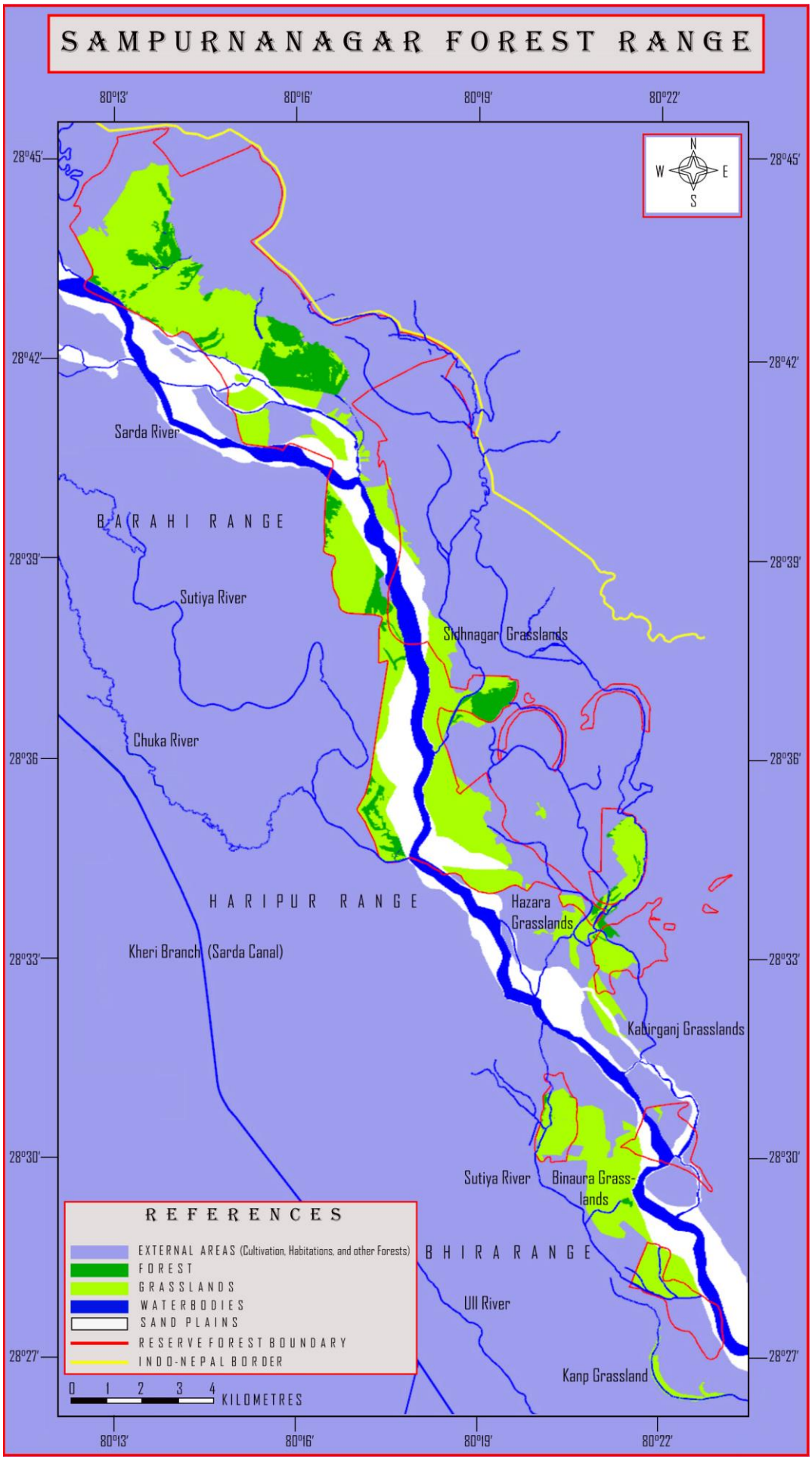
Map 6 Grassland distribution map of Mahof range



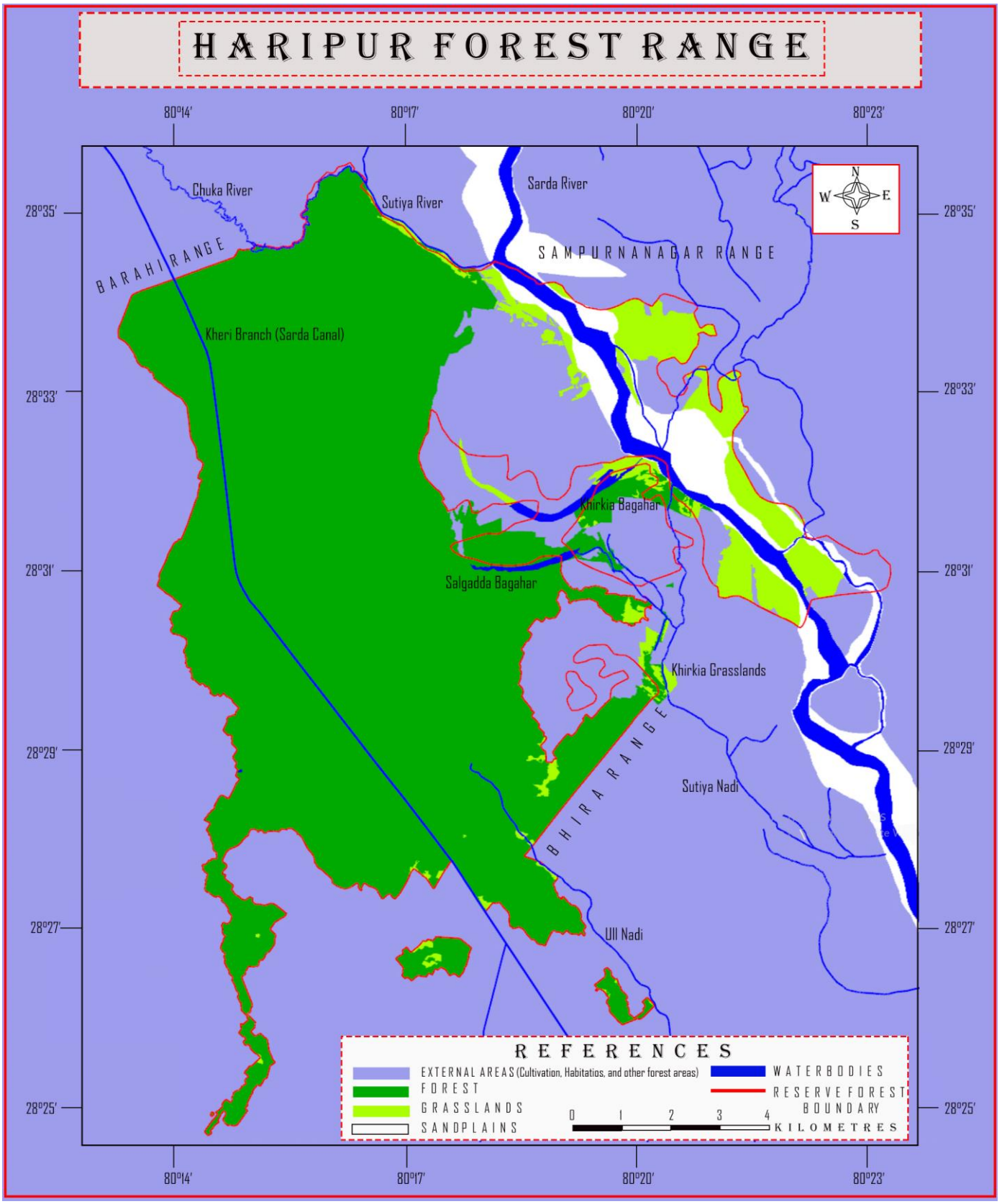
Map 7 Grassland distribution map of Barahi range



Map.8. Grassland distribution map of Bhira range



Map 9. Grassland distribution map of Sampurnanagar range



Map.10. Grassland distribution map of Haripur range

2. Grassland Vegetation

2.1. Grassland Vegetation

A total of 188 species of plants were found from 165 vegetation plots put in lowland and upland regions of the study area; of these, 166 were identified up to species level and 13 to genus level. Other 9 species could not be identified given the absence of flowers and poor vegetative growth and structure. Flowering plants were represented with 184 species while other 4 were pteridophytes, majority (3) being ferns. All plants assorted to 48 families represented by 6 of monocots, 30 of dicots and 4 of pteridophytes. Among angiosperms, 44 species were monocots and rest 140 were dicots. Family Poaceae, with 36 species was the dominant family, followed by Fabaceae (23 species), Asteraceae (15) and Malvaceae (8). Non-grass monocots were few in number with just 8 species, prominent being Orchidaceae (3 species) and Cyperaceae (2 species). Polygonum, with 3 species, was the genus with largest number of species.

On the basis of growth form, trees were 22 species in number, shrubs 28, grasses 36, herbs 95 and climbers 7. Climbers were also poorly represented, and two were woody and the other 5 were twiners. For the purpose of analysis, former was clubbed with shrubs and latter with herbs. Among the grasses 11 species were tall grasses (>2 m in height) and the rest 25 were short (<2m in height).

Trees- trees were represented with only 22 species. As majority of the plots were put in the open grasslands, only 81 individuals of tree of all species appeared in the samples. This shows average density of trees to 5/per hectare. *Acacia catechu* with 22 individuals and frequency of 9 was the most commonly met tree, followed by *Dalbergia sissoo* and *Syzygium cumini*.

Shrubs- twenty-eight species of shrubs assorting to 15 families were found in all the plots clubbed together. Malvaceae (8) and Moraceae (4) showed highest number of species. A total of 650 individuals of shrubs were counted within 5m quadrate of all the plots, giving out a density of 1575 individuals/ ha. *Ziziphus mauritiana* had the highest density (334/ha) as well as frequency (5.15%). Other important shrubs were *Tamarix dioca, Helectres isora* and *Grewig asiatica.* All the shrub species found in the sample plots registered very poor frequency and density. It appears that none are associated uniformly with grasslands except *Tamarix dioca*, *Ziziphus mauritiana, Grewia sapida* and *Pogostemon bengalensis*. *Ziziphus mauritiana* always appeared in association with *Saccharum bengalense* dominated plots. *Tamarix dioca* was sampled only from *Saccharum spontaneum* and *Cynodon* dominated grasslands where soil was always pure sandy. *Grewia sapida, Pogostemon bengalensis* and *Helectres isora* were also met majorly in *Saccharum bengalense* dominated plots as well as with *Vetiveria* and *Imperata*. *Ochina pumila* and *Careya herbacea* was the only shrub which grows purely in the grasslands burnt every year in the uplands (Kanjilal 1933, Singh 1997). However, this species is regarded rare and we found it only in one plot. *Erythrina resupinata* was another rare species which always grow from a thick root stock following burning of grasslands (Kanjilal 1933). Only one

plot sampled this rare species from the study area; the patch was dominated with *Saccharum bengalense* grass.

Table.9. List top ten most common shrubs found in the sample plots

Sr. No.	Species	Density/ha	% Frequency
1	*Ziziphus mauritiana*	334	12.72
2	*Helectres isora*	193	4.84
3	*Cassia tora*	169	1.21
4	*Grewia sapida*	155	7.27
5	*Tamarix dioica*	130	8.48
6	*Flemingia congesta*	96	1.81
7	*Xanthium strumarium*	84	0.62
8	*Pogostemon bengalensis*	84	7.27
9	*Triumfetta rhomboidea*	80	6.66
10	*Fluggea virosa*	41	2.42

Herbs- non-grass herbaceous flora dominated the diversity and altogether 95 species of these plants were found. Non-grass herbaceous plants belonged to 35 different families; Fabaceae (14) and Asteraceae (12) had the highest representation. *Medicago lupulina, Cyperus* sp. and *Diplazium esculentum* were the most common associates of grasslands in the study area. These three species had the highest frequency and average percentage cover; *Taraxacum* sp., *Cirsium arvensis* and *Alternanthera sessilis* were the other important associates showing wide distribution. None of the other species had frequency more than 8% and 54 species showed frequency below 2%. Sixteen of the species, in fact, were sampled only in any one plot. The total average % of the ground covered by all herbs combined was 9.27%.

Some rare species which are only found in grasslands were also found during sampling. These include three species of terrestrial orchids, *Zeuxine strateumatica, Spirenthe*s sp. and *Pachystoma pubescens*, latter two species were not reported from

the area before and possibly could be the first record from this part of terai. Other important but less common species met was *Aeginetia pedunculata* of family Orobanchaceae. It is a root parasite and find hosts in species of some specific families (O'Neill & Rana, 2017). Apart from these few specialized herbs, none other appears to be exclusively found in the grasslands (Singh 1997, Duthei, 1903).

Table.10. List of top 14 most common herbs species in overall grasslands

No.	Species	frequency	Average % cover
1	*Medicago lupulina*	30.75	1.37
2	*Cyperus sp. 1*	29.5	2.1
3	*Diplazium esculentum*	19.52	0.63
4	*Taraxacum sp.*	14.91	0.45
5	*Cirsium arvense*	12.52	0.43
6	*Alternanthera sessilis*	9.03	0.25
7	*Hemigraphis hirta*	7.55	0.25
8	*Equisetum debile*	6.99	0.21
9	*Rungia pectinata*	6.81	0.28
10	*Polygonum glabrum*	6.44	0.15
11	*Oxalis corniculata*	6.26	0.19
12	*Pouzolzia zeylanica*	6.07	0.19
13	*Volvulopsis nummularia*	5.34	0.18
14	*Mazus pumilis*	5.15	0.13

Grasses- thirty-six species of grasses were found from the grasslands of Pilibhit habitat block showing a rich diversity of family Poaceae in this part of tarai. *Imperata cylindrica* was by far the most common grass species, followed by *Vetiveria zizanioides, Saccharum spontaneum* and *Cynodon dactylon*. The total average % coverage of grasses from all the plots were 45.93%. This is almost 5 times higher than the non-grass herbaceous plants. Together grass as well as non-grass herbaceous plants covered 55.20% of the sampling ground and rest was bare. High percentage under bare ground mainly comes due to the season in which this sampling

was done (March-April). Grasslands are fired just before this and in springs are still growing. Moreover, majority of annual grasses and herbs grow post monsoon and were not represented in this study. Fourty percent of the total ground covered with grasses was shared by top ten grass species, while rest was contributed by remaining 26 species. Fourteen species had frequency of less than 1%, and ten species appeared in <2 plots. All grasses sampled were native species except *Sorghum halepense*, an exotic which has naturalised widely in India. Moreover, all Species of grasses were either exclusive to grasslands or both grassland and forest, and only one species, *Oplismenus compositus*, was the forest grass sampled in the grass lands.

Erianthus ravennae, a huge grass was also sampled from the study area. It is probably the first record of this grass from the terai conservation area of UP, as it was not reported by the earlier studies (Singh, 1997; Kumar et al 2002, Mathur & Midha 2008). *Capillipedium parviflorum* is another grass probably new to Pilibhit and neighbouring areas.

Table.11. List of 14 grasses with highest frequency and average cover			
No.	**Species**	**Frequency**	**Average % cover**
1	*Imperata cylindrica*	50.82	6.93
2	*Vetiveria zizainoides*	38.67	4.15
3	*Saccharum spontaneum*	34.80	2.45
4	*Cynodon dactylon*	31.12	3.11
5	*Paspalum scrubiculatum*	30.93	1.45
6	*Phragmites karka*	23.02	1.42
7	*Desmostachya bipinnata*	19.33	1.01
8	*Sclerostachya fusca*	16.57	1.54
9	*Apluda mutica*	12.89	0.61
10	*Saccharum bengalense*	8.10	0.78
11	*Narenga porphyrocoma*	4.60	0.36
12	*Cymbopogon flexuosus*	4.60	0.41
13	*Eleusine indica*	4.60	0.18
14	*Chrysopogon aciculatus*	3.31	0.48

2.2. NMDS Ordination Results

Data collected from all the samples in study area were assorted to various dominate classes. This dominate class was always based on a grass species having highest % coverage among all other grass species. Likewise, all 543 quadrates were assorted to 11 different dominate species. All those species which dominated in <5 plots were removed from analysis as they make little ecological sense and interpretation of results become complex.

These different dominance classes were used as clusters with their own species composition. This was subjected to Non-Metric Multidimensional Scaling ordination to look if these clusters had some difference in species composition. The analysis was performed in R. Necessary libraries were installed in R for running NMDS and the distance used for this analysis was 'bray-curtis'. Further, the number of dimensions were set at 2 (k=2). The analysis was run and R produced NMDS

ordinations at a stress value of 0.27. The stress value signifies the fit of data and varies from 0 to 1. Stress values higher than 0.3 cannot be interpreted reliably; less stress values shows that the data is a better fit.

Table.12. List of dominant classes and numbers of plots they dominated

No.	Dominant class	No. of Plots	No. of species in the group	Species Evenness (Pielou's evenness index)
1	*Imperata cylindrica*	145	80	0.4253
2	*Vetiveria zizanioides*	59	60	0.50815
3	*Cynodon dactylon*	59	49	0.5091
4	*Sclerostachya fusca*	47	43	0.56852
5	*Saccharum spontaneum*	40	41	0.59264
6	*Phragmites karka*	30	28	0.4137
7	*Saccharum bengalense*	28	34	0.4881
8	*Paspalum scrobiculatum*	25	37	0.6094
9	*Cymbopogon flexuosus*	19	19	0.5751
10	*Chrysopogon aciculatus*	16	20	0.6213
11	*Desmostachya bipinnata*	8	17	0.6140

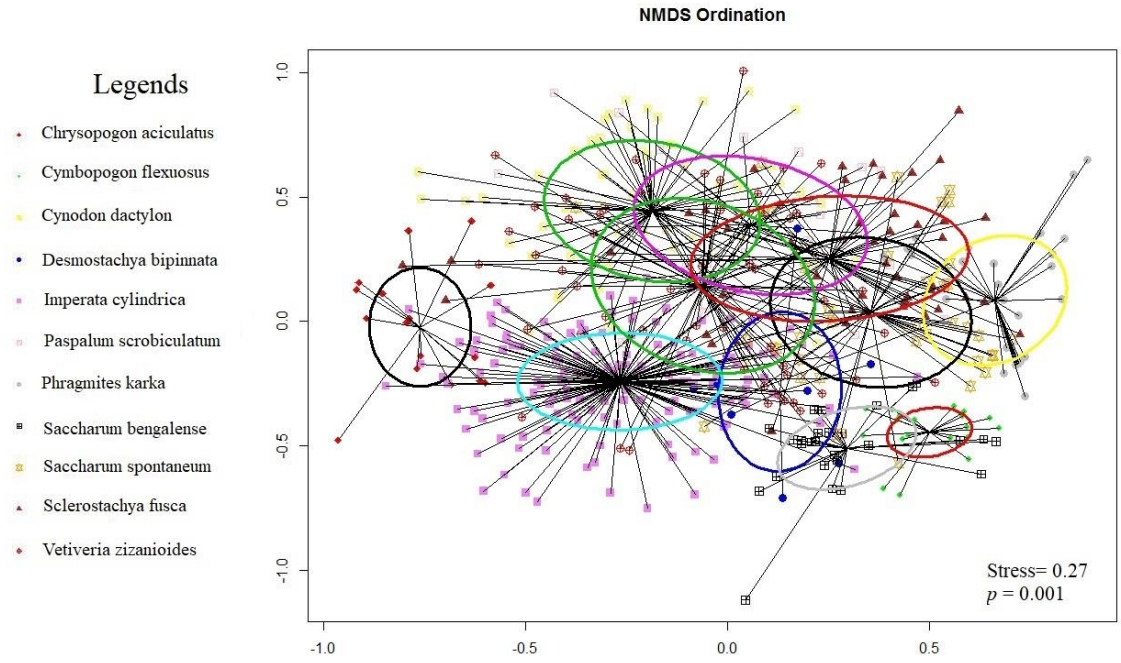


Fig.3. NMDS Ordination of the 11 dominant groups

The ordination plot produced from the above-mentioned dominance classes data was interpreted as follows:

1. ***Imperata cylindrica*** **dominated class-**Imperata dominated in largest number of plots (145). Due to its wide distribution it had a presence of 80 species of herbaceous plants, of these 19 were grasses and rest non-grass herbs. *Imperata*, given its larger distribution and high species richness overlapped with many other classes. It could not be completely separated from *Vetiveria* dominated class, as well as clubbed

partly with *Saccharum spontaneum, Sclerostachya,* and lightly with *Saccharum bengalense. Medicago lupulina, Vetiveria zizanioides, Taraxacum* sp., *Saccharum spontaneum* etc were the most common species of *Imperata* class. *Imperata cylindrica* had the highest % coverage on an average, ten folds higher than next prominent species. *Imperata* is known to occur in three forms and can grow in a large range of moisture gradient; moreover, it also withstands grazing pressure more prominently than many other grasses (Bor 1941, Lehmkuhl 1989 & 1991, Peet et al 1999). This explains a wide distribution and overlap of species compositions with other dominant classes, particularly *Cynodon* and *Vetiveria* which have similar growing conditions and occupy similar areas.

Table.13. Comparison of frequency and average % cover of first 14 species of Vetiveria, Imperata and Cynodon class

No.	Vetiveria class	F	% C	Imperata class	F	% C	Cynodon class	F	% C
1	*Vetiveria zizanioides*	100	21.32	*Imperata cylindrica*	100	20.57	*Cynodon dactylon*	100	16.15
2	*Paspalum scrubiculatum*	44.06	1.83	*Medicago lupulina*	57.24	2.26	*Cyperus sp. 1*	45.76	3.52
3	*Cyperus sp. 1*	44.06	3.33	*Vetiveria zizanioides*	55.17	3.34	*Paspalum scrubiculatum*	38.98	1.64
4	*Imperata cylindrica*	42.37	1.90	*Taraxacum sp.*	36.55	1.03	*Medicago lupulina*	38.98	1.93
5	*Cynodon dactylon*	35.59	1.35	*Saccharum spontaneum*	33.79	1.32	*Saccharum spontaneum*	27.11	1.59
6	*Desmostachya bipinnata*	30.50	1.16	*Cynodon dactylon*	32.41	2.30	*Alternanthera sessilis*	25.42	0.83
7	*Medicago lupulina*	30.50	1.11	*Paspalum scrubiculatum*	31.72	0.88	*Vetiveria zizanioides*	23.72	1.10
8	*Saccharum spontaneum*	25.42	0.74	*Phragmites karka*	28.96	0.57	*Diplazium esculentum*	22.0	0.77
9	*Alternanthera sessilis*	20.33	0.61	*Desmostachya bipinnata*	22.06	1.12	*Imperata cylindrica*	20.33	1.33
10	*Hemigraphis hirta*	16.94	0.86	*Cyperus sp. 1*	21.37	0.89	*Parthinium hysterophorus*	20.33	0.54
11	*Phragmites karka*	15.25	0.32	*Diplazium esculentum*	21.37	0.69	*Phyla nudiflora*	18.64	0.57
12	*Taraxacum sp.*	13.55	0.28	*Cirsium arvensis*	15.86	0.63	*Frageria indica*	16.94	0.35
13	*Diplazium esculentum*	10.16	0.45	*Sclerostachya fusca*	13.72	0.66	*Hydrocotyle sibthorpiodes*	15.25	0.32
14	*Oxalis corniculata*	10.16	0.35	*Equisetum debile*	11.03	0.40	*Eleusine indica*	13.55	0.47

F- Frequency **% C**-average percentage cover

2. *Vetiveria zizanioides*- *Vetiveria* dominated all other grasses in 59 plots and had 60 species in its class. Seventeen of them were grasses and 43 assorted to non-grass herbs. In the ordination it overlapped with *Cynodon, Paspalum* and *Imperata* classes to a considerable degree, and moderately with *Saccharum spontaneum* and *Sclerostachya. Paspalum scrobiculatum*, *Cyperus* sp. l, *Imperata cylindrica*, *Cynodon dactylon* and *Medicago lupulina* were the most common species in this class; these species are also shared by *Cynodon* and *Imperata* classes as well.

3. ***Cynodon dactylon***- *Cynodon* class had 59 plots with species diversity of 49, of these 12 were grasses and 37 non-grass herbs. Cynodon class overlapped with *Vetiveria, Paspalum* and *Imperata* classes, and moderately with *Sclerostachya*. The table 2 Shows 14 most common species of *Imperata, Vetiveria* and *Cynodon* classes with highest frequencies and % cover. It could be deduced that the top prominent species are nearly similar in all three groups.

4. *Paspalum* -*Paspalum* group was represented with 25 plots, and had 37 species. Ten grasses and 27 non-grass herb species constituted the plant diversity in this group. On the ordination *Paspalum* overlapped with *Vetiveria* and *Cynodon* classes, and slightly with *Imperata* and *Sclerostachya. Cyperus* sp. 1, *Diplazium esculentum, Cynodon dactylon, Vetiveria zizanioides* and *Cirsium arvense* were the most common species in this group. Very little is known of the ecology of this dwarf species.

Table.14. Comparison of frequency and average % cover of first 14 species of Paspalum, Sclerostachya and Saccharum spontaneum class									
No.	**Paspalum**	**F.**	**% C**	**Sclerostachya**	**F**	**% C**	**Saccharum spontaneum**	**F**	**% C**
1	*Paspalum scrubiculatum*	100	9.56	*Sclerostachya fusca*	100	12.36	*Saccharum spontneum*	100	14
2	*Cyperus sp. 1*	52	3.12	*Cyperus sp. 1*	63.82	5.61	*Cyperus sp. 1*	42.5	5.1
3	*Diplazium esculentum*	48	1.6	*Diplazium esculentum*	44.68	1.42	*Imperata cylindrica*	37.5	1.7
4	*Cynodon dactylon*	40	4.16	*Cirsium arvensis*	34.04	1.27	*Phragmites karka*	35	1.125
5	*Vetiveria zizainoides*	28	2.04	*Apluda mutica*	29.78	1.17	*Cynodon dactylon*	25	1.65
6	*Cirsium arvensis*	28	0.64	*Pouzolzia zeylanica*	29.78	1.27	*Apluda mutica*	20	0.775
7	*Saccharum spontneum*	24	2.68	*Imperata cylindrica*	25.5	1.38	*Paspalum scrubiculatum*	20	1.025
8	*Alternanthera sessilis*	24	0.64	*Phragmites karka*	25.5	0.72	*Diplazium esculentum*	20	0.55
9	*Frageria indica*	20	0.68	*Paspalum scrubiculatum*	25.5	0.63	*Cirsium arvensis*	20	0.75
10	*Mazus pumilis*	20	0.72	*Vetiveria zizainoides*	21.2	1.17	*Vetiveria zizainoides*	17.5	0.925
11	*Medicago lupulina*	20	1.04	*Medicago lupulina*	21.2	0.76	*Typha angustifolia*	17.5	0.8
12	*Apluda mutica*	16	0.48	*Saccharum spontneum*	19.1	0.63	*Taraxacum sp.*	17.5	0.45
13	*Imperata cylindrica*	16	0.16	*Equisetum debile*	17.0	0.44	*Pouzolzia zeylanica*	15	0.45
14	*Desmostachya bipinnata*	16	0.32	*Polygonum glabrum*	14.8	0.34	*Sclerostachya fusca*	12.5	0.95
F- Frequency **% C**-average percentage cover									

5. *Sclerostachya fusca*- fourty seven plots were dominated by this class. It had 43 plant species, comprising of 13 grass and 30 non-grass plants. The cluster of this group merged with *Saccharum spontaneum* and lightly with Phragmites karka. It stood completely dissimilar from all other groups. *Cyperus* sp. l, *Diplazium esculentum, Crissum arvense, Apluda mutica* and *Pouzolzia zeylanica* were the most common species in this group. *Sclerostachya* grows prominently in the depressions where moister is higher than the level lands but where ground is not inundated for a long time (Kanjilal 1933, Bor 1941). Its closeness with *Phragmites* group appears

mainly due to preference of moist ground and association of herbaceous vegetation growing on similar habitats.

6. *Saccharum spontaneum*-*Saccharum spontaneum*** dominated 40 plots overall, it had richness of 41 species, consisting of 12 grass and 29 non-grass herb species. *Saccharum spontaneum* mixed with wide variety of other classes, particularly *Paspalum, Sclerostachya, Phragmites* and to some extent with *Imperata* and *Vetiveria*. *Cyperus* sp. 1, *Imperata cylindrica, Phragmites karka, Cynodon dactylon* and *Paspalum scrubiculatum* were the principle species in its composition. Table 3 compares the 14 species which were most frequent and had a higher average cover in *Paspalum, Sclerostachya* and *Saccharum spontaneum* classes. *Saccharum spontaneum* grows in two varieties, one preferring dry sandy area and the other moisture loving variety (Kanjilal 1933, Bor 1941). This wide range of habitat produce *Saccharum spontaneum* dominant grasslands not only in the riverine areas as well as in damp patches. In the former habitat *Saccharum spontaneum* stands mostly pure (Lehmkuhl 1989), however, in the latter it mixes with *Phragmites and Sclerostachya*.

7. *Phragmites karka*-*Phragmites* had 30 plots under its dominance. Eleven species of grasses and 17 of non-grass herbs made a diversity of 20 species in this group. It was separated from all the groups very well except overlapping lightly with *Sclerostachya* and *Saccharum spontaneum* group. *Diplazium esculentum, Polygonum glabrum, Cyperus* sp. I, *Saccharum spontaneum*, *Apluda mutica* etc were the most

common species. *Phragmites* mostly grows on very hydric soils unsuitable for most other grass species (Bor 1941). This special habitat accounted to a unique composition of species separating it from all other groups. Interestingly, many species of grasses, *Sorghum halepense, Capillipedium parviflorum, Brachiaria mutica* and *Arundo donax* appeared only in this group.

8. *Saccharum bengalense*- this group held dominance over 28 plots in the study area. Thirty-four species, consisting of 12 grasses and 16 non-grass herbs represented it in the samples. On the ordination graph, this group stood apart from all the groups except *Cymbopogon flexuosus,* and mixed very lightly with *Saccharum spontaneum. Imperata cylindrica, Desmostachya bipinnata, Cyperus* sp. 2, *Medicago lupilina, Vetiveria zizanioides* and *Arnebia hispidissima* were the most common species. *Saccharum bengalense* was always sampled on the drier uplands and never ventured into depressed and damp areas. This condition made it stand aloof from the other classes in the study area.

9. *Desmostachya bipinnata-* *Desmostachya* represented dominance over only 8 plots. Altogether, 17 species, 6 of grasses and 11 of non-grass herbs were found in this group. On the ordination plot its pattern overlaps with *Imperata, Vetiveria* and lightly with *Saccharum bengalense*. Table 15 compares the 14 species which were most frequent and had a higher average cover in *Phragmites, Saccharum bengalense* and *Desmostachya* classes.

Table.15. Comparison of frequency and average % cover of first 14 species of Phragmites, Saccharum bengalense and Desmostachya class									
No.	**Phragmites**	**F**	**%C**	**Saccharum bengalense**	**F**	**%C**	**Desmostachya**	**F**	**%C**
1	*Phragmites karka*	100	17.3	*Saccharum bengalense*	100	12.32	*Desmostachya bipinnata*	100	20.37
2	*Diplazium esculentum*	43.33	1.1	*Imperata cylindrica*	53.57	2.46	*Medicago lupulina*	75	3.12
3	*Polygonum glabrum*	30	0.8	*Desmostachya bipinnata*	28.57	1.03	*Vetiveria zizanioides*	62.5	2.7
4	*Cyperus sp. 1*	26.66	1.5	*Cyperus sp. 2*	28.57	1.32	*Imperata cylindrica*	37.5	0.87
5	*Saccharum spontneum*	23.3	1.1	*Medicago lupulina*	21.42	0.89	*Arnebia hispidissima*	25	1.7
6	*Apluda mutica*	20	1.03	*Vetiveria zizanioides*	17.85	0.92	*Saccharum spontneum*	25	0.87
7	*Alternanthera sessilis*	13.33	0.2	*Arnebia hispidissima*	17.85	0.5	*Cyperus sp. 2*	25	0.75
8	*Equisetum debile*	13.33	0.26	*Cirsium arvensis*	14.28	0.17	*Paspalum s crubiculatum*	25	0.62
9	*Pouzolzia zeylanica*	13.33	0.36	*Sphaeranthus indicus*	14.28	0.25	*Flemingia procumbens*	25	0.37
10	*Alopecurus geniculatus*	10	0.3	*Saccharum spontneum*	10.71	0.32	*Polygala erioptera*	25	0.37
11	*Arundo donax*	10	0.3	*Phragmites karka*	10.71	0.17	*Cyperus sp. 1*	12.5	1
12	*Oryza sp.*	6.66	0.13	*Cymbopogon flexuousus*	10.71	0.21	*Cynodon dactylon*	12.5	0.25
13	*Commelina paludosa*	6.66	0.66	*Oxalis corniculata*	10.71	0.32	*Oxalis corniculata*	12.5	0.25
14	*Oenanthe javanica*	6.66	0.3	*Desmodium sp.*	10.71	0.21	*Hemigraphis hirta*	12.5	0.12
F- Frequency **% C**-average percentage cover									

10. *Cymbopogon flexuosus*- *Cymbopogon* held dominance over 19 plots. All these plots were from a single grassland; nowhere else, except in one plot, did this species appeared in a plot. It had 16 species of plants in its ambit, of this only three being grass, rest 16 were non-grass herbs. It stood perfectly aloof from all other groups expect *Saccharum bengalense*, which overlapped it lightly. *Cymbopogon jwarancus* was a unique grass of this group. Other non-grass associates were also unique in this group explaining its dissimilarity from the other groups. Like *Saccharum bengalense*, all these plots were from raised upland ground, representing driest conditions among any other group found in the study area.

Table.16. Comparison of frequency and average % cover of first 14 species of Cymbopogon and Chrysopogon class						
No.	**Cymbopogon**	**F**	**% C**	**Chrysopogon**	**F**	**% C**
1	*Cymbopogon flexuousus*	100	11	*Chrysopogon aciculatus*	100	15.62
2	*Saccharum spontneum*	84.21	3.15	*Rungia pectinata*	93.75	5.37
3	*Uraria sp.*	63.15	3.10	*Medicago lupulina*	87.5	7.25
4	*Desmostachya bipinnata*	94.73	2.94	*Volvulopsis nummularia*	81.25	3.25
5	*Trichodesma indicum*	31.57	1.31	*Hemigraphis hirta*	81.25	2.5
6	*U.I. Sp. 2*	31.57	1.10	*Dicanthium annulatum*	43.75	1.81
7	*Imperata cylindrica*	52.63	1.05	*Imperata cylindrica*	37.5	2.3
8	*Evolvulus alsinioides*	10.52	0.52	*Cynodon dactylon*	37.5	0.87
9	*Euphorbia prolifera*	5.26	0.42	*Indigofera linifolia*	25	2
10	*Sphaeranthus indicus*	26.31	0.26	*Cyperus sp. 1*	25	0.37
11	*Saccharum bengalense*	15.78	0.15	*Vetiveria zizanioides*	18.75	0.31
12	*Crotalaria medicaginea*	5.26	0.15	*Oxalis corniculata*	12.5	0.12
13	*Crotolaria alata*	5.26	0.10	*Taraxacum sp.*	12.5	0.12
14	*Cyperus sp. 2*	5.26	0.10	*Bothriocloa pertusa*	6.25	0.93
F- Frequency **% C**- average percentage cover						

11. *Chrysopogon aciculatus*-only sixteen plots showed dominance of this grass in the entire study area. It had diversity of 20 plants, consisting of 7 grass and 13 non-grass species. On the ordination plot it stood perfectly separate from all the other groups, only one plot from *Imperata* group mingled with it. *Rungia pectinata, Medicago lupilina, Volvulopsis nummularia* and *Hemigraphis hirta* were the most common plants. Grasses *Dicanthium annulatum* and *Bothriocloa pertusa* were unique to this group. This grass is known to dominate excessively grazed areas (Bor

1941), and in the study it was found only on forest margins where grazing incidence was very high. Table 5 compares the top 14 species which were most frequent and had a higher average cover in *Cymbopogon flexuousus* and *Chrysopogon aciculatus* classes.

The ordinance plot shows that among 11 dominant classes three, *Cymbopogon flexuosus Chrysopogon aciculatus* and *Phragmites karka* stands away from other groups due to dissimilarity of species composition. The other 8 groups did not show a very clear pattern. Very similar diversity and composition of major species, which is the combined effect of climatic, biogeographic and anthropogenic characters, held other classes in a tight group.

Swamp deer status in the Pilibhit Habitat Block

Grasslands occupy a fair proportion of Pilibhit habitat block nurtured with numerous small to moderate sized waterbodies skirting them along with mosaic of other habitats. Many larger grasslands have shown presence of Swamp deer, some of them being in good numbers. Majority of this habitat lies in buffer zone prone to high anthropogenic activities; nonetheless, its geographical location between Shuklaphanta WLR and Kishanpur WLS, as well as connectivity with these protected areas having large population ensures barasinga survival in buffer zones of this habitat block. Moreover, a mosaic of grasslands (inaccessible thickets of *Phragmites* reeds, *Erianthus ravannae* and other tall tarai grasses) and invincible morasses along with miscellaneous forests provide good hide in the diurnal hours to escape interaction with humans. This is further supplemented by large coverage of sugarcane fields providing extraordinary asylum during a part of the year (July-February). Contrarily, in the core zone the protection is sufficient and barasinga population is healthy and appears to flourish.

The original idea of this study was to understand population density of swampdeer in the lowlands and Mahof-Mala region of uplands using line transect based distance method. However, the covid pandemic did not allow work during the field tenure of this study. Meanwhile, we present tabular statement of our findings we had during our field work. We sampled almost all larger grasslands of the study area, as well as many smaller ones during field work for mapping and then vegetation component,

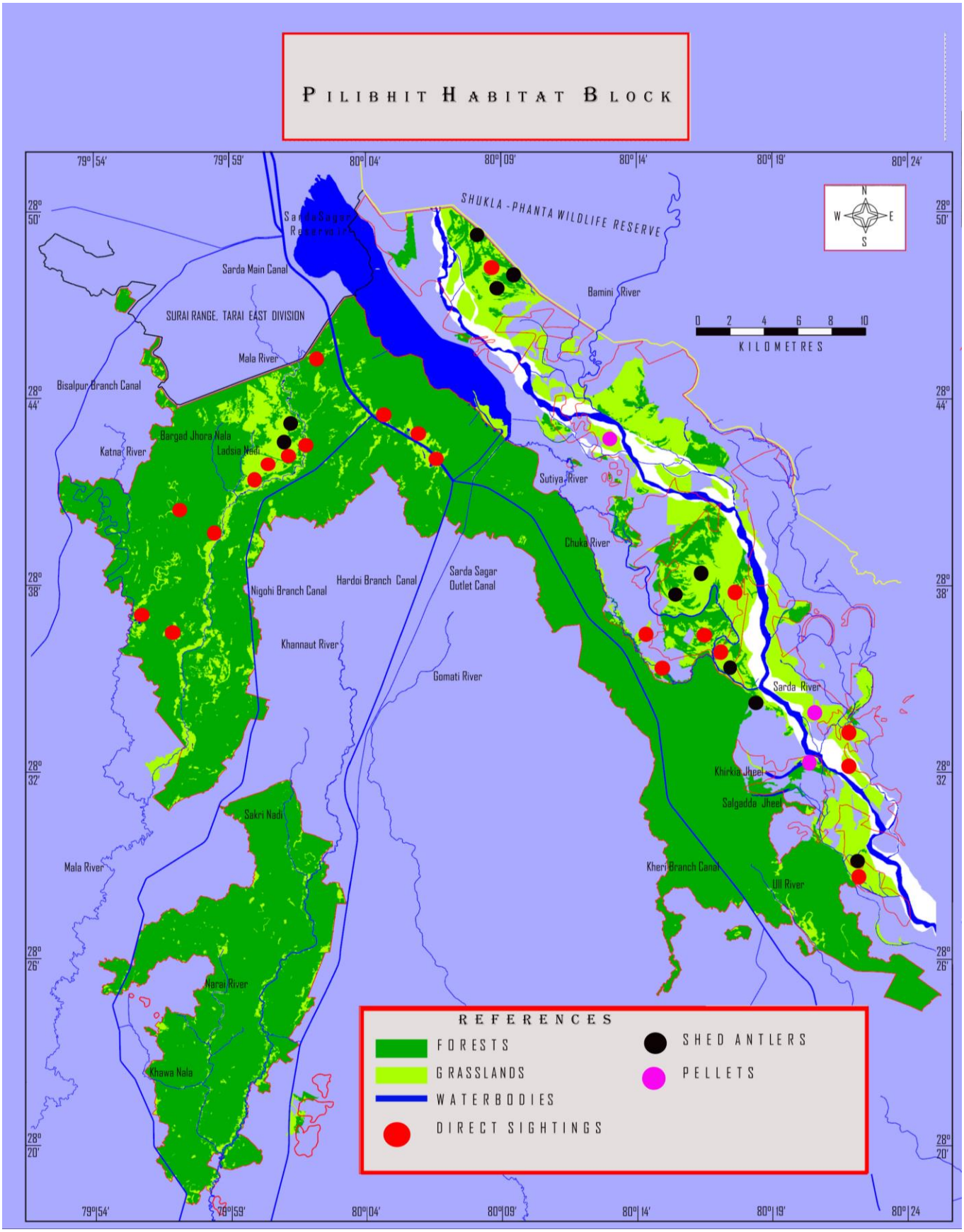
and during this time we carefully observed all signs and records of Swamp deer. This included pellets, shed antlers and direct sightings of the animal. GPS points and detailed observations on herd composition, habitat and important other variables were noted down. Some of the prominent barasinga groups in uplands, where protection is high and threats absent- owing to which they were less cryptic and allowed close approach- were observed multiple times.

Chaugebi grassland in Mahof range is the most important barasinga habitat in Pilibhit habitat block. A population of 120-150 animals was observed regularly in the compartment 105 and a different herd of 25-35 animals in compartment 106. It is a compact block of 17sq.km, consisting of dry upland chandar and marshes of the Mala River and is free from all human interventions. Other important blocks for swampdeer numbers in the study area are Lagga-bagga and Binaura phantas. Both have good population of the deer, and in Binaura we observed same herds regularly during our field work. We did not have good number of sightings in the Lagga Bagga block but collected a large number of antlers. Frontline staff testified of a healthy population of barasinga in this block (100-150 animals) which could be understood by its location adjacent to Shukla Phanta sanctuary and good density of pellet groups we observed.

Table 17- Swamp deer status in various important grassland patches in Pilibhit habitat block							
Sr. No.	**Name of the block**	**Grass land habitat Area (in ha)**	**Range**	**Survey effort (in Km)**	**Swamp deer evidence**	**Habitat characteristics**	**Disturbance**
1	Chaugebi chandar	1725	Mahof	18	Direct sightings (two groups of 140 and 25 individuals); fallen antlers (8) and pellets	Open grassland with sparse *Eucalyptus* and teak plantation in patches. *Saccharum bengalense* and *Cymbopogon flexuosus* dominates the grasslands.	None, except presence of wild cattle (80-100). Falls completely in the core zone.
2	Jhandtal and nearby chandar	112	Mahof	6.13	Direct sighting (one group of 25 animals)	*Phragmites* and *Sclerostachya* dominated grassland running parallel to the Sarda Canal. Three lakes are situated in this grassland.	None. Comes under core zone and is located quite in the interiors of Pilibhit TR
3	Barasingha tal and nearby chandar	156	Mahof	7	Direct sighting (one group of 18 animals)	Runs parallel to Sarda main canal. *Phragmites karka* along the canal and *Saccharum bengalense* on the other edge abutting into sal forest.	None. Comes in core zone. Located in the interiors of Pilibhit TR.
4	Lalkunwa chandar	156	Mahof	1.78	Direct sighting (one group of 14 individuals)	Part of the above grassland. Habitat is similar.	None. Comes under core zone.
5	Semalkunwa chandar	4	Mahof	3	Direct sighting (group of 4 animals)	This area in Malasi block has many fragmented grasslands along with teak plantations, dominated on the ground by *Saccharum bengalense*.	None. Comes under core zone
6	Mahof Block	88	Mahof	5.19	Direct sighting (5 individuals)	Numerous small scattered grasslands dominated with *Sclerostachya fusca* abounds the Mahof compartment 117. It is sparsely planted with *Eucalyptus* on the edges	None. Comes under core zone
7	Mala marshlands in Dhamela Block	209	Mala	6	Direct sighting (group of 2 females)	Mala marshland dominated with thick *Phragmites* reed travels through this block.	None. Comes under core zone
8	Anjania chandar	40	Mala	3.1	Direct sighting (4 individuals)	It is an upland grassland mainly covered with *Saccharum bengalense* and *Desmostachya* grasses	None. Comes under core zone
9	Badhaila tal and	29	Mala	2.78	Direct sightings (group of 9	A conglomeration of numerous small sized	None. Comes under core zone

	grasslands				animals)	*Sclerostachya fusca* grasslands. Katna river flows on one edge and Badhaila group of 2 tals are in the centre.	
10	Lagga Bagga phanta	852	Barahi	10.5	Direct sighting (6 individuals). Antlers were collected in large number from this phanta (18)	A large grassland dominated mainly with *Imperata, Phragmites* and *Sclerostachya* grasses. Numerous small taals find home in this great phanta	Moderate to high grazing pressure; a population of 100-150 wild cattle flourishes in this block. Two cattle stations are situated on the edge of this phanta
11	Lagga-Bagga savannah	55	Barahi	3.40	Collected (6) antlers from this savannah. A herd of 800+ barasinga was spotted just under half KM from the international boundary in Shukla Phanta	This savannah is located on the Nepal boundary and continuous with the great Shukla Phanta in north. Open miscellaneous forests with *Saccharum bengalense* and *Imperata* grasslands characterize the habitat	Low grazing pressure from wild cattle and livestock from the cattle stations
12	Simra phanta	2176	Partly in Barahi, Sampurnanagar and NRA	32	Direct sighting (groups of 25, 15, 2 and 4 individuals at different places). Also collected 5 antlers from this phanta	Largest grassland of the region. Mainly dominated with *Imperata, Vetiveria, Sclerostachya* and *Phragmites* grasslands.	Comes under buffer zone. Very high grazing pressure from the wild cattle and 4 large cattle stations located inside the patch.
13	Musapur phanta	78	Barahi	4	Direct sighting (group of 5 individuals). Barasinga pellets were very common in this patch	*Saccharum bengalense* and *Vetiveria zizanioides* grass dominate this phanta with scarce *Bombax* and *Acacia catechu* trees	Comes under the buffer zone. High grazing and cutting pressure from the nearby small village of Musapur
14	Hagniya marsh (part of Chuka marsh)	56	NRA	1.5	Direct sighting (group of 5 individuals)	Dominated with Phragmites reeds and rich inclusion of hydrophytic non-grass herbs. It is a perennial swamp and two large lakes are located inside it	Non-reserved area. Highly used for cutting narkul reeds and for fishing
15	Nawadia Kundri (part of Chuka marsh)	25	NRA	1.10	Direct sighting (group of 3 individuals)	*Phragmites karka* dominated swamp with *Sclerostachya fusca*, and dotted with *Salix tetrasperma* trees	Non-reserved area.
16	Hazara phanta	230	NRA	3	Direct sighting (group of 3 individuals)	Pure *Saccharum spontaneum* grassland recently abandoned by the Sarda River	Non-reserved area. Very high pressure for grazing and cutting grass for thatching.
17	Hazara phanta (norther	811	NRA	6	Direct sighting (group of 5 individuals).	Pure *Saccharum spontaneum* grassland recently abandoned by	Non-reserved area. Very high pressure for

	n)					the Sarda River	grazing and cutting grass for thatching.
18	Binaura	1227	Bhira	27	Direct sighting (group of 27, 5 and 3 individuals). twelve shed antlers were also met in this grassland	*Saccharum spontaneum* dominated grasslands mixed with Typha and dotted uniformly with *Tamarix dioca*.	Comes under buffer zone of the Dudhwa TR. Grazing and cutting pressure is considerable.
19	Chandpur Phanta	180	Barahi	6	Relatively fresh pellet groups were observed at 7 different places	Pure riverine *Saccharum spontaneum* grassland	Comes under buffer zone. High pressure of cutting and grazing. Encroachment for agriculture is a serious dilemma here.
20	Khirkia grasslands	60	Haripur	1.5	Relatively fresh pellet groups were seen at 4 locations in this grassland	*Phragmites karka* dominated grasslands, with *Typha* and *Saccharum spontaneum* on the edges	Comes under buffer zone. Human use in this patch is very light



Map.11. showing key barasingha sighting, shed antler and pellets signs in the study area

DISCUSSION AND CONSERVATION IMPLICATIONS

Tarai grasslands, savannahs and woodlands are the only natural forest in the upper Gangetic plains biogeographic zone of India having any considerable coverage of natural areas (Rodgers & Panwar 1988). Proliferation of civilization saw extermination of large areas of wilderness, and worldwide pattern shows how discriminately fertile areas were selected for colonization. Only those areas escaped axe which were either inaccessible due to hostile environment or tough geography or areas which were infertile and in consequence less useful for cultivation (Mathur & Midha, 2008). Contrarily, terai was the only region where highly fertile plains were still completely under wilderness till recent times (Webber, 1902; Wilmot 1910; Hewett 1938), thanks to dampness and severe dread of malaria. Cultivation was nearly non-existent or very patchy until 1850s when a large area of sal forests and grasslands were auctioned to clear way for cultivation under wasteland rules (Keshavanand, 1896). A big loss was done post-independence and local peasants as well as settlers from western Punjab, eastern Bengal and eastern Uttar Pradesh were settled in the terai region in a large number (Singh & Prashad, 2013). This had the impact of cleaning all the grasslands for cultivation, encroachment on the reserve forests, river catchment areas as well as leveling of small jheels and ponds (Mathur & Midha, 2008). It would not be wrong to claim that this led UP terai to lose its

original character and what has left behind is merely an iota of once impenetrable wilderness.

Presently the total extent of Tarai forests and grasslands combined is less than 10000sq.km in India, and covers five states of the country, Uttarakhand, Uttar Pradesh, Bihar, Bengal and Assam (Semwal 2006). Conclusively, terai itself is an endangered habitat due to its puny extent much of which is fragmented, and these fragments themselves are of poor quality given the large-scale monoculture plantations responsible to destroy natural vegetation, particularly grasslands. What is even more threatening is the insignificant amount of grasslands which has now left behind, once being the identity of tarai. Unfortunately, data is deficient on total coverage of grasslands in this zone, and roughly less than 1800 sq.km survives. These tall grasslands, until quite recently considered sheer waste, are home to country's unique fauna, particularly large mammals including many endemics.

This study filled one small gap among many by understanding grasslands in Pilibhit tiger reserve and neighbouring reserve forests and non-reserve areas. Notably, Pilibhit wildlife sanctuary is the largest protected area after Manas national park in tarai proper of Indian side; and is also the western most part of tarai still having a considerable area under grasslands.

The study area recorded 17.56% of its portion under grasslands signifying its great importance for barasinga conservation and as well as a rich component of tarai

wilderness. Lowlands were more important and had larger area as well as percentage of grasslands. Upland tracts are old alluvial deposits and free from any disturbance of floods and erosion, thus staying stable than the lowlands (Keshvanand 1896). Vegetation succession has progressed to near climax stage here and dense sal forests characterize this tract (Gaur, 1971). Apparently, the lowlands being new alluvial deposits are scored with blatant floods and episodes of incisive erosions by great rivers. Succession is retained to progress to a higher seral level and regression often ensues in communities which have ascended a higher ladder during some time of its development (Troup 1921). This render lowland tarai excessively unstable and consequently a large part of it remains under grassland-savannah system dotted with small patches of miscellaneous forests (Bhatt 1992). Secondly, human intervention has also played big role in producing quite a less area under grasslands in upland tract. Sal was always the most favoured species for the Forest Department since its inception given its valuable mechanical properties. Evidently grasslands were treated as wasteland and best idea to put them to use was artificially encouraging nature to transcend over them. Consequently, Assisted Natural Regeneration schemes corroborated with improvement fellings, fire protection as well as inception of large plantations was employed to stock grasslands on a large scale (Gupta, 1971). Lowlands, on the other hand didn't respond to plantations according to the aspirations and much less grasslands were lost. This explains a great disparity in grassland distribution among uplands and lowlands of terai.

Not only grassland coverage in the uplands is less than lowlands, moreover mean patch size is also 10 times smaller in the uplands. Interestingly, except the Chaugebi chandar of Mahof and Mala not a single patch was larger than 3 sq.km in this belt. This pattern is shown by Dudhwa and other parts of terai as well (Kumar et al 2002). Pilibhit habitat block had almost equivalent % area of grasslands as Dudhwa, less than Kishanpur and slightly more than Katerniaghat. For comparison with Kumar et al (2002) and Mathur & Midha (2008) see table no. 18.

Table.18. Comparison of grassland distribution in western terai of UP (all areas in sq.km)

No.	PA	Upland grasslands	Lowland grasslands	Total area of grassland	% area under grassland
1	Dudhwa	43	82	125	18.3
2	Kishanpur	13	33	46	22.9
3	Katerniaghat	14	33	47	11.8
4	Pilibhit Habitat Block	49	105	154	17.56

There is a great difference in number of patches and mean patch size between PHB and Dudhwa national Park. The total patches were 174 in Dudhwa producing mean size of patch at 71.89 ha; this was only 14.26 ha with 1080 patches in PHB. Patch density was just 0.27/sq.km in Dudhwa, much less than 1.23 in Pilibhit HB. The methodology employed by both studies were different. Satellite image classification with less intensive ground truthing was used by Kumar et al (2002) to understand distribution of various vegetation classes including grasslands. This study only focused on grassland distribution and digitised them using google earth imageries

and almost visiting every grass patch in the study area to collect GPS references and other attributes.

Digital classification of the satellite imagery probably left out all smaller patches within the sal forest in Dudhwa. Interestingly, smallest patch in Dudhwa, both in lowlands and uplands, was 0.09 ha, being 0.012 ha in Pilibhit HB. Apparently, our study included multitude of smaller patch sizes as well. Largest grassland patch, both in upland and lowland was larger in Pilibhit habitat block than Dudhwa. In upland, Dudhwa had largest grassland measuring 16 sq.km which was 17.20 sq.km in PHB; similarly, lowland patch in PHB (21.76 sq.km) was also much larger than Dudhwa's 14.4 sq.km.

A big concern that this study flags is the preponderance of grasslands in the buffer zone. Out of the total 154 sq.km of grasslands, 97 sq.km, or 63%, falls in buffer and the remnant 57 sq.km in core zone. This situation exacerbates in Lowlands, here 90% of the grassland area comes in buffer zone. All large phantas in this region viz. Binaura, Taturgunj, Simra, Hazara, Hazara north etc comes under the buffer zone. Despite of a handful area left under coverage of this unique habitat, tall wet lowland grasslands have received very little protection outside the ambit of protected area network (Mathur & Midha 2008). However, the case of Pilibhit habitat block shows faulty preparation of protected area boundaries inadvertently assigning prime zones in buffer without strong scientific background. In fact, core zone of Pilibhit tiger reserve overwhelmingly includes all the sal blocks showing persistence of forestry

policy giving importance to well stocked areas with high and dense coverage of trees.

Meanwhile, the lowlands are subjected to very high usage by neighbouring villages. Grazing is the largest threat in the study area followed by harvesting grasses for thatching. Ten cattle stations with estimated population of 1200 (pers. comm. forest frontline staff) buffaloes and cows live within the reserve forest and depend on the grasslands for all their requirements. Moreover, a large number of wild cattle are also flourishing in Lagga-Bagga, Faizullagunj, Bamanpur and Taturgunj forest blocks (their exact population is unknown, but large herds of these animals are commonly seen). In the surroundings of these cattle stations grasslands are degraded to such an extent that obnoxious species like *Solanum incanum, Solanum surratense, Calotropis procera, Calotropis gigantea, Parthenium* sp. etc have formed dense bushlands.

This study explored the vegetation diversity and pattern of their distribution in prime swamp deer habitat of Pilibhit habitat block. By virtue of a large number of plots put to cover a wide area of the study region, we found 188 species of plants. This was perhaps one of the most detailed recent work on grassland vegetation which has been very poorly studied in tarai region of western UP. The study recorded 36 species of grasses which stands higher than all the units in Tarai Conservation Area of UP viz. Dudhwa NP, Kishanpur WLS, Katerniaghat WLS and neighbouring reserve forests. We also found 11 dominant grass species and their associated vegetation of the Pilibhit region which are nearly same to the results of Kumar et al (2002). Among

several of these dominant classes *Imperata cyclindrica* followed by *Vetiveria zizanioides* were the most common. This appears to be a good sign for herbivores as *Imperata cylindrica* is known to be the most favoured grass by wild ungulates, including barasinga (Peet et al 1999). Other palatable species viz. *Cynodon dactylon* also showed high coverage and wide distribution. *Saccharum spontaneum*, *Apluda mutica* and *Sclerostachya fusca* grasses, identified as major forage constituent of barasinga (Moe 1977, Ahmad 2007) was also found in high abundance in the study area.

Cymbopogon flexuosus dominated grasslands were also found in prominence in one large grassland (Chaugebi), here it held ranks along with *Saccharum bengalense*. Interestingly, nowhere else did it dominate a patch and except one plot in a sparse teak and eucalyptus plantation, not a single vegetation plot recorded its presence. *Cymbopogon jwarancus* was another species of this genus growing on the edges of Mala River (raised ground). *C. flexuosus* and *C. jwarancus* were absent altogether in lowlands. Both of these species are highly aromatic and very poor source of fodder (Bor 1941), and their dominance over a best barasinga habitat patch is a real concern. Artificial origin of Chaugebi could be a plausible explanation of dominance by *Cymbopogon flexuosus* grass. More detailed studies on the importance value of *Cymbopogon* as fodder and its consumption by barasinga as well as other herbivores is demanded.

On the margins of Deoria Range and southern part of Mala, which is the only upland region subjected to tremendous grazing pressure in Pilibhit by cattle from neighbouring villages, we found *Chrysopogon aciculatus* dominant grasslands. This grass did not appear in any other plot throughout the study area. *Dichanthium annulatum*, *Cynodon dactylon* and *Imperata cylindrica* were other important grasses growing with *C. aciculatus*. *D. annulatum* was almost non-existent anywhere else. *C. aciculatus* is one of the few grasses known to withstand heavy grazing, and its dominance over other grasses could be a definite sign of overgrazing and compaction of the soil (Bor 1941).

Among the 36 species of grasses found in vegetation plots in Pilibhit habitat block, few were not reported from other areas of terai conservation unit in UP. The most interesting among them was *Erianthus ravennae*, a giant grass locally called hathi ghas. It is perhaps the tallest grass of the study area, some culms of which measured 19.4 feet in height including the inflorescence. *Erianthus ravennae* is distributed widely in the plains from Uttarakhand to Assam (Bor 1961) but absent in Dudhwa, Katerniaghat, Kishanpur and neighboring forest divisions (Singh 1997, Kumar et al 2002). In the study area it was reported from Lagga Bagga block (where it dominated some plots), Faizullagunj (near Sutiya River) and Tatargung blocks in the lowlands and along the banks of Sarda main canal in uplands (Mahof Range).

Narenga porphyrocoma and *Themeda arundinacea*, both well-known common tall species of terai were poorly represented in the Pilibhit habitat block. Percentage

frequency of *Narenga* was just 4.60. This was quite lower than Dudhwa and other tarai areas under Kumar's (2002) study. This grass grows on soils best suitable for Sal forests and in fact is a valuable indicator species for selecting compartments for proliferation of Sal (Hole 1911, Troup 1921). Pilibhit has a long history of silvicultural interventions for improvement and expansion of sal which appears a possible explanation of poor representation of this species. *Themeda arundinacea,* other common terai species elsewhere was equally poor in representation; it had a frequency of only 2.02% and dominated over just 5 plots. Possibly, Pilibhit contains the western most distribution of this grass in tarai proper (for it is found both in bhabar and dun valleys in Uttarakhand) and has a patchy distribution. Notably, *Themeda arundinacea* appears to dominate slightly low-lying chandars in Kishanpur and South Kheri just from the point Ull River starts its journey on Pilibhit-Kheri boundary.

The study found negligible presence of young classes of tree species in the grassland. Regenerating individuals were (seedling stage) completely absent except *Barringtonia acutangula* and *Syzygium cumini* (found only in 3 and 2 plots respectively). Moreover, sapling stage trees were equally missing, and only *Acacia catechu*, *Dalbergia sissoo* and *Cassia fistula* showed them up in this stage in a very nominal number. This is a welcoming result and principle reason of their poverty could be traced to high grazing pressure, high fire incidences, harrowing by forest department (few areas only) and absence of seed sources. Absence of obnoxious weed, *Lantana camara* in the grasslands of Pilibhit is another important finding.

Lantana appeared only in one plot throughout the study area. However, other obnoxious unpalatable plants recorded a concerning frequency and coverage and we believe the management interventions current in the area would only burgeon this threat. *Parthenium hysterophorus* and *Cirsium arvense* are two major species of these weeds.

In future management of grasslands on scientific lines as suggested by some seminal studies is crucially needed. Lowland grasslands are completely influenced by floods of Sarda River, which plays a significant role in their sustenance, particularly those near the river. Fires, grazing and artificial management are also agents of halting succession of these phantas into miscellaneous forests (Lehmkuhl 1989); management has just been started in Pilibhit with very insignificant vigour and former two are the chief agencies to this direction, meanwhile. In the upland tract as shown by this study, majority of chandars are located as small hollow blanks within the sal forest and sustain themselves on properties of depression, seasonal inundations and probably due to edaphic characteristics as well (Troup 1921). It is apparent that growing conditions in these hollow blanks are unconducive for shrubs and trees to colonise otherwise which transcend open spaces quickly; this has helped sustenance of grasslands here in the small blanks. Apart from these blanks, grasslands growing on land level with the neighbouring forests are but few. Majority of them are situated on the boundaries where they are subject to very high grazing pressure. Chaugebi, the largest upland chandar in the whole area, is another interesting level ground grassland. This chandar is mostly of an artificial origin

carved out of the Sal and miscellaneous forest by clear felling. Meanwhile, fires are the principal agency to wipe out trees and shrubs colonising Chaugebi from nearby forests. However, of recent sal and other miscellaneous trees have started encroaching Chaugebi chandar. This pattern is evident on the edges where grassland meets the forest; mention may be made of compartment 105 near Mala River (adjacent to Mahof-Mustafabad first road), where miscellaneous species of young age classes have encroached a small area.

Chaugebi is the most important grassland patch for Swamp deer conservation in upland Pilibhit and requires best management practices instantly. All the three compartments of Chaugebi (104, 105 and 106) are sparsely planted with *Eucalyptus* sp., *Albizia chinensis* and *Tectona grandis* which needs to be harvested for further active management of this chandar. From last two years forest department has also started two management interventions. Firstly, harrowing some patches of grasslands in the first year and taking equivalent area adjacently in the next year. Second intervention is by JCB machines. Broad, 30-40 m wide strips are completely uprooted from the ground for 150-200 m length; this strip is followed by uncut grass strips alternating with the dragged strip. Harrowing has been shown inimical by studies done in Dudhwa, recommending to stop it immediately (Kumar et al 2002). It found unpalatable grasses gaining higher coverage and biomass over other important grasses after harrowing was done consecutively for 2-3 years. Moreover, uprooting broad strips of grasslands completely from the ground level and exposing soil to the environment equally appears to be a disastrous idea. The grass stubble and earth

which collects from the strip is dumped on the sides of the strip adjacent to intact strips. This would impede drainage and effect micro-climatic and edaphic changes. During the last week of our field work we observed *Cymbopogon flexuosus* coming up almost purely on these cleared strips. The neighbouring parts of Chaugebi, those never exposed to any management intervention of recent are also dominated with *Cymbopogon flexuosus* grass, however, long term studies are needed to understand effects of cleaning these strips (as well as harrowing) before they should be employed on such a large scale as is apparent in uplands of Pilibhit.

Binaura grasslands, partly coming under Sampurnanagar, Bhira and non-reserved areas is a compact block of 12 Sq.km and connected with Kishanpur's Jhadi tal grasslands through Lagadhan block of Paliya range in the east as well as by non-reserved Kanp grassland from the western side. This block has a good population of swampdeer despite heavy grazing and needs to be protected on a priority basis. This patch is also important to maintain connectivity between lowland tracts located further north to it and right upto Lagga Bagga adjacent to Shukla Phanta wildlife Reserve in Nepal. The non-reserved areas of Binaura have been under influence of floods since long and thick pile of sand deposited by Sarda River has rendered it infertile for agriculture. However, now villagers from Nehrosa and neighbourhood has contracted a big amount of land for vegetable farming in the interiors. This is a pensive threat and would keep on growing in the future.

This study has found a considerable and an important area under grasslands assigning to non-reserved areas class (25sq.km). Notably, this category has larger area under grasslands than Bhira, Haripur and Deoria ranges combined (grasslands). These grasslands can be discussed in four major categories. The most important one is those located around the Sarda River and belongs to private ownership. As mentioned elsewhere, 11.77sq.km of grasslands in the lowland festoons around the Sarda. Distribution on the map clearly shows continuity of grasslands right from Lagga-bagga to Binaura along Sarda River in this landscape. In fact, all the major blocks of the reserve forests are connected with each other through these non-reserved areas only. Hence, these patches are crucial for connectivity between blocks right from Lagga-Bagga to Kishanpur. Unfortunately, many of these patches would not survive any longer for they are continuously converted into agricultural lands by their real owners. Much cannot be done to protect these lands, and all hopes lies on Sarda River which would take new areas under erosion before seceding the older ones. This is a continuous process of producing new grasslands while older abandoned ones are converted into agriculture. Meanwhile, the pace of converting seceded areas back to agriculture has increased manifold. Farming sector has developed with leaps and bounds in the Pilibhit region and heavy investment in mechanization has made it easy to convert tough areas like grasslands with great ease. This change has shortened the fallow period of flooded areas which were turned into grasslands by the river. Initiatives, however, should be taken to demarcate reserved forests actively following monsoon, so that they are not encroached inadvertently.

A second category is a government land dominated with *Phragmites* reeds (Puraina grassland) dotted with short grass lawns developed in the Sarda reservoir. Gradual siltation in the reservoir has elevated a mound bordering compartments 60 and 61 of Barahi Range (Bifurcation block) and *Narkul* took possession of this escape from deep inundation. Meanwhile this patch is slowly increasing towards north along the boundary of Mahof range. Currently, this patch is under jurisdiction of irrigation department and there was proposal in 2013-14 to desilt the Sarda Reservoir by UP government. Puraina lies on the junction of sal forest and the main water column of the reservoir, undeniably producing prime habitat for barasinga, as well as tigers, hog deer, and various water birds among others. Nothing is known of barasinga presence or numbers in this patch, but it is important as it lies close to Barasinga *tal* in Mahof range and neighbouring grasslands where barasinga are flourishing.

The third category includes marshy areas rendered unproductive for agriculture by virtue of perennial inundation and morasses. Chaka marsh, Nawadia Banki grasslands and Kanp marsh are the examples of this type. Nawadia Banki patch is the result of continuous seepage from the Hardoi Branch canal, while the other two areas remain waterlogged owing to their location just on the junction of lowlands with highlands. Here upland tract is 30-40 feet higher than the lowland and all the water during monsoon drains down to this belt through deep gullies spread palmately all along the length of the high bank; secondly, hydraulic pressure, naturally causes seepage below the high bank and many springs sprout up in the lowland. Chuka marshes are likewise formed; here dense *Phragmites karka* reeds juxtaposed with

Sclerostachya fusca, *Saccharum spontaneum* and *Typha angustifolia* patches towards less hydric soils makes a favourable barasinga habitat. Presently, barasinga is reported from the Nawadia Kundri and Hagniya patches of this marsh and is an important unit for their conservation. Moreover, its importance lies in running all the way parallel to the narrowest part of Pilibhit Tiger Reserve (1.5-4km). This thin dry sal belt does not have any grassland patch inside it and chuka marshes are the only grazing grounds for wild herbivores. It is also a resort of tigers during summers. These impenetrable morasses are also an infallible shield to the forest barring direct interaction of the cultivation and habitations with the tiger reserve. All the lands in Chuka marshes, those out of the reserve forest boundary, belongs to the *gram samaj* of neighbouring villages. Cultivating it is a tough work and manually paddy is transplanted in a 50-acre patch below Nawadia forest rest house. Double cropping is an impossibility, meanwhile. However, village panchayats under Land Development and Revenue Department have started excavation of drainage *nalas* to dry this marsh further at some places. This entails need of some quick action by the forest department as land under *gram samaj* (and not individual proprietors) could be transferred given its disposition of a wilderness and importance to wildlife conservation.

Kanp grasslands under the non-reserved category probably does not have barasinga presence but could be important for their movement directly from Binaura to Kishanpur. Protection of all these important patches is of an utmost necessity and

various legal instruments available should be explored to alienate these areas to forest department.

Mention should be made of benevolence of Sarda canal and its numerous branches straddling the whole length and breadth of the upland tract. Importance as a source of water for wildlife throughout the year could not be over emphasized. Moreover, large tract of marshes the main canal has created in Mahof range, and infested with thick invincible cover of *Phragmites karka*, is a unique creation. Seepage from the channel caused sal trees to die, which they are incapable to cope (Gupta, 1971), and were gradually replaced by the reeds. Prominent among these marshlands are Jhand chandar; and grasslands located in Mainakot, Chuka and Bifurcation blocks of Pilibhit. These grasslands were absent before the construction of Sarda canal or were completely dry as shown in the divisional maps of that era. Additionally, it had the effect of producing many small jheels along its bank on both sides which are extremely favourable for swamp deer, as well as tigers and waterbirds. Best barasinga habitat where they live in considerable numbers are created by Sarda canal only, examples worth mentioning are Jhand tal, Barasinga tal and Lalkunwa tal regions of Mahof range.

References

Ahmad, K. (2007). Ecology and conservation of Swamp Deer in Terai Grasslands of Uttar Pradesh, India. Dissertation submitted for the award of the degree of Masters in Philosophy, Department of Wildlife Sciences, Aligarh Muslim University, Aligarh, India.

Ahmad, K. & Nigam, P. (2014). Kashmir Red deer or Hangul *Cervus elaphus hanglu* at the Brink of Extinction. Conservation Action, the need of an Hour. DGS newsletter. ISSN 2312-4644.

Asthana, M.S. (1962). Working Plan of the Pilibhit Forest Division, 1961-62 to 1971-72. Superintendent, Printing and Stationary, Allahabad, Uttar Pradesh, India.

Attri, S.D. & Tyagi, A. (2010). Climate profile of India. Indian Meteorological Department. Met Monograph No. Environment Meteorology-01/2010.

Baldwin, J.H. (1877). The large and small game of Bengal and North-west provinces of India. Henry S. King & CO. London.

Beehler, B. M., Raju, K. S. R., & Ali, S. (1987). Avian use of mandisturbedforest habitats in the Eastern Ghats, India. *Ibis*, *129*,197–211.

Bhatta, B. (2008). Daily Activities, Distribution, and Food Preference of Swamp Deer (*Cervus duvauceliiduvaucelii*). BSc Thesis. Department of Forestry, Tribhuvan University, Kathmandu, Nepal.

Bhatt, D.N. (1992). Working Plan of the South Pilibhit Forest Division, 1991-92 to 2000-01. Working Plan Circle (First), Nainital, Uttar Pradesh, India.

Bhatterai, B. (2015). Habitat Preference and Evaluation of Swamp Deer (*Cervus duvauceliiduvaucelii*) in Bardia National Park. BSc Thesis. Department of Forestry, Tribhuvan University, Kathmandu, Nepal.

Blanford, W.T. (1891). The Fauna of British India, including Ceylon and Burma. Mammalia. Francis & Taylor, London.

Bor, N.L. (1940). Flora of Assam. Vol 5, Graminae. Government of Assam.

Bor, N.L. (1941). Common grasses of United Provinces. Bishen Singh Mahendra Pal Singh, 23-A, Connaught Place, Dehra Dun. Rep. 1993. Pp. 222, plts lxiv.

Bor, N.L. (1960). The Grasses of Burma, Ceylon, India and Pakistan (Excluding Bambuseae)**.** Pergamon, New York. xviii + 767 pp. Illus.

Boyd, C.E. (1969). “Production, mineral accumulation, and pigmentation concentrations in *Typha latifolia* and *Scirpus americanus*,” *Ecology*, vol. 51, no. 2, pp. 285–290, 1969.

Brander, A. 1927. Wild animal in Central India, London. Edward Arnold & Co.

Census of India 2011. New Delhi: Registrar General & Census Commissioner of India. 2011. http://censusindia.gov.in.

Champion, F.W. (1933a). The Jungle in sunlight and shadow. Chatto & Windus. London.

Champion, F.W. (1933b). Working Plan for the North Kheri Forest Division for period 1933-34 to 1947-48. Superintendent, Printing and Stationary, Allahabad.

Joshi, K.D. (1922). Working Plan for the South Kheri Forest Division for period 1922-23 to 1932-33. Superintendent, Printing and Stationary, Allahabad.

Champion, H.G. & Seth, S.K. (1968). A revised survey of forest types of India, Government of India Press, New Delhi.

Chandrasekar-Rao, A., & Sunquist, M. E. (1996). Ecology of smallmammals in tropical forest habitats of southern India. *Journalof Tropical Ecology*, *12*, 561–571.

Chaturvedi, B.N. (1954). Working Plan of the Pilibhit Forest Division, 1952-53 to 1961-62. Superintendent, Printing and Stationary, Allahabad, Uttar Pradesh, India.

Das, A.; Basu, D.; Converse, L. & Chaudhary, S.C. (2012). Herpetofauna of Katerniaghat Wildlife Sanctuary, Uttar Pradesh, India. Journal of Threatened Taxa 4(5): 2553-2568.

De, J.K.; Mahato, A.K.R. & Ghosh, M.K. (2013). Some observation on the status and conservation of Swamp deer*Cervus duvauceliiduvaucelii* (Cuvier, 1823) in Dudhwa National Park, India. *Rec. Zool. Surv.India*: 113 (Part-4):93-101, 2013.

Duckworth, J.W.; Kumar, N.S.; Pokharel, C.P.; Baral, S.H.; & Timmins, R. (2015). *Rucervus duvauceliii*. In: The IUCN Red List of Threatened Species: e.T4257A22167675. https:// doi.org/10.2305/IUCN.UK.2015-4.RLTS.T4257A22167675.en.

Duthie, J.F. (1888). The fodder grasses of Northern India. Printed at the Thomas Civil Engineering College Press, Roorkee.

Eisenberg, J.F. & Lockhart, M. (972). An ecological reconnaissance of Wilpattu National Park. Ceylon. Smithsonian contrib. to Zool. 100, 1-110.

Ellerman, J & Morrison- Scott. (1951). Checklist of Palearctic and Indian mammals, British Museum. London.

Forsyth, J. (1889). The Highlands of central India: notes on their forests and wild tribes, natural history and sports. London: Chapman and Hall, Limited.

Garg, I.P. (1959). Working Plan of erstwhile Private forests of Pilibhit Forest Division, 1957-58 to 1966-67. Superintendent, Printing and Stationary, Allahabad, Uttar Pradesh, India.

Gaur, V. (1982). Working Plan of the North Kheri Forest Division for the period 1982-91. Working Plans Branch, Nainital (U.P.).

Ghimire, S.K., Dhamala, M.K.; Lamichhane, B.R.; Ranabhat, K.B. & Poudel, S. (2019). Identification of suitable habitat for Swamp Deer *Rucervus duvauceliii duvauceliii* (Mammalia: Artiodactyla: Cervidae) in Chitwan National Park, Nepal. *Journal of Threatened Taxa* 11(6): 13644–13653. https://doi.org/10.11609/jott.4129.11.6.13644-13653.

Groves, C. 1982. Geographic variation in the barasingha or swamp deer *(Cervus duvauceliii). ,. Bomb. Nat. Hist. Soc* ... 79 (3): 620-629.

Gupta, A.C. (1971). Working Plan for the Pilibhit Forest Division, Central Circle, UP. 1971-72 to 1980-81. Nainital, Working Plans Circle, Uttar Pradesh.

Harikrishnan, S.; Vasudevan, K; Udhayan, A. & Mathur, P.K. (2012). Biodiversity values of abandoned teak, *Tectona grandis* plantations insouthern Western Ghats: Is there a need for management intervention. Basic and Applied Ecology 13 (2012) 139–148.

Hall, W.T. (1924). Working Plan for the Pilibhit Forest Division for the period 1923-24 to 1932-33. Allahabad; Printed by the Superintendent, Government Press, United Provinces.

Hewett, J. (1938) Jungle trails in northern India. Methuen and company Limited, 36 Essex Street, W.C.2, London.

Hole, R.S. (1911). The Indian Forest Memoirs- On some Indian forest grasses and their oecology. Forest Botany Series, Vol 1. Superintendent Government Printing, Calcutta.

Holloway, C.W. (1973). Swamp deer in Uttar Pradesh. *Oryx*. 41-48.

Hooker, J.D. (1872-1897). The Flora of British India. 1-7 Vols. L. Reeve & Co., 5, Henrietta Street, Covent Garden, London.

Hutton, J.T. (1958). The chemistry of rainwater with particular reference to conditions in south eastern Australia. In climatology and microclimatology. Proceedings of the Canberra Symposium. UNESCO, Paris, pp. 285-90.

Jerdon, T.C. (1867). The Mammals of India; A natural history of all the animals known to inhabit continental India. Thomason College Press, Roorkee.

Jhala, Y.V., Qureshi, Q. and Nayak, A.K. (2020). Status of tigers, copredators and prey in India, 2018. National Tiger Conservation Authority, Government of India, New Delhi, and Wildlife Instituteof India, Dehradun.

Kanjilal, U.N., Kanjilal, P.C., De, R.N., Das, A. (1938-40). Flora of Assam. In four volumes. Government of Assam.

Keshavanand (1896). Working Plan for the forest of Pilibhit Division. Superintendent, Government Printing, Allahabad.

Khan, A. & Khan, J.A. (1999) Conservation of swamp deer (*Cervus duvaucelii duvaucelii*) in Hastinapur Wildlife Sanctuary. Proceedings of the 4th International Deer Biology Congress, Hungary,194-199.

Khan, J.A.; Khan, A. & Khan, A.A. (2003). Structure and composition of barasingha habitat in Hastinapur Wildlife Sanctuary. Technical Report No. 14, Wildlife Society of India, AMU, Aligarh. 57 Pp.

Krebs, C. J. (1999). *Ecological methodology* (second edition). New York, N.Y.: Addison Wesley Longman.

Kumar, H., Mathur, P.K., Lehmkuhl, J.F., Khati, D.V.S., De, R., Longwah W. (2002). Management of Forests in India for Biological Diversity and Forest Productivity, A New Perspective - Volume VI: Terai Conservation Area (TCA). WII-USDA Forest Service Collaborative Project Report, Wildlife Institute of India, Dehradun.

Kumar, P. & Chandra, S. (2000). Working Plan for the Pilibhit Forest Division for the period 2001-02 to 2011-12. Working Plans Circle, Nainital, Uttar Pradesh.

Kunte, K., Joglekar, A., Utkarsh, G., & Pramod, P. (1999). Patterns of butterfly, bird and tree diversity in the Western Ghats. *Current Science*, *77*, 577–586.

Kushwaha, S.P.S. & Roy, P.S. (2002) Geospatial technology for wildlife habitat evaluation. Tropical Ecology 43(1):137–150.

Laurie, A. (1982). Behavioural ecology of the Greater One-horned Rhinoceros *Rhinoceros unicornis*. J. Zool., Lond., 196, 307-41.

Lehmkuhl, J.F. 1989. The Ecology of a South-AsianTall-Grass Community. Ph.D. Dissertation.
University of Washington, Seattle, USA. 195pp.

Lehmkuhl, J.F. (1994). A classification of subtropical riverine grassland and forest in Chitwan National Park, Nepal. *Vegetation* 111, 29–43.

Magurran, A.E. 1988. Why diversity? In Magurran: Ecological Diversity and its Measurement. Springer publication.

Martin, C. (1977). Status and ecology of barasingha *(Cervus duvaucelii branderi)* in Kanha National Park (India). *J. Bombay Nat. Hist. Soc.* 74(1): 60-132.

Mathur, P.K. & Midha, N. (2008). Mapping of National Parks and WildlifeSanctuaries, Dudhwa Tiger Reserve, WII-NNRMS-MoEF Project, Final TechnicalReport, Wildlife Institute of India, Dehradun, India. 216 pp.

Mathur, R.B. (1960). Working Plan of the South Kheri Forest Division for the period 1960-61 to 1969-70. Uttar Pradesh Forest Department.

Moe, S.R. (1994). The importance of aquatic vegetation for the management of the Barasingha *Cervus duvauceli*in Nepal. *Biological Conservation* 70(1): 33–37. https://doi.org/10.1016/0006-3207(94)90296- 8

Mukherjee, A.K. (1974). Some examples of recent faunal impoverishment and regression. In ecology and biogeography in India, ed. M.S. Mani. Dr. W. Junk Publishers, The Hague, pp. 330-68.

Nathani, S.; Bedi, P. & Areendran, G. (2018). Habitat Suitability Analysis for Swamp Deer (*Rucervus Duvauceliii*) Using Geo-Spatial Tools in Dudhwa National Park. American Journal of Remote Sensing. 6(1): 52-58.

O'Neill, A. & Rana, S. (2017). An ethnobotanical analysis of parasitic plants (Parijibi) in the Nepal Himalayas. Journal of Ethnobotany and Ethnomedicine. Vol. 12 (14).

Paul, S., Pandav, B., Mohan, D., Habib, B., Nigam, P., Mondol, S., 2018. Current distribution and status of swamp deer Rucervus duvaucelii duvaucelii in theupper Gangetic plains of north India. Oryx 52, 646e653.

Paul, S.; Sarkar, D.; Patil, A.; Ghosh, T.; Talukdar, G.; Kumar, M.; Habib, B.; Nigam, P.; Mohan, D.; Pandav, B.; Mondol, S. (2020). Assessment of endemic northern swamp deer (*Rucervus duvauceliii duvauceliii*) distribution and identification of priority conservation areas through modeling and field surveys across north India. Global Ecology and Conservation 24 (2020).

Pocock, R.I. (1943). The largest deer of British India. Part II. *J. Bombay Nat. Hist. Soc.* 43:553-572.

Pokheral, C.P. (1996). Food Habit and Habitat Utilization of Swamp Deer (*Cervus duvauceliiduvaucelii*) in Royal Bardia National Park, Nepal. MSc Thesis. Department of Zoology, Tribhuvan University, Kathmandu, Nepal, 62pp.

Poore, M.E.D. & Fries, C. (1985) - *The ecological effects of eucalyptus*. FAO Forestry Paper 59. Rome.

Poudel, B.S. (2007). Thirty years of managing Suklaphanta the Swamp Deer and the tiger: issues and strategies. *The Initiation* 1: 72–76

Poudyal, S. (2000) Impact of management practices on species composition ingrasslands of Royal Suklaphanta Wildlife Reserve, Nepal. Central Departmentof Botany, Tribhuwan University. A report submitted to Parks and Peopleprogramme/UNDP

Qureshi, Q.; Sawarkar, V.B & Mathur, P.K. (1991). Swamp Deer Population Structure, Patterns of Habitat Utilization and Some Management Needs in Dudwa National Park. Wildlife Institute of India, Dehradun.

Qureshi, Q., Singh, V.P.; Sankaran, R.; Seal, U.S.; Walker, S & Molur, S. (1995). Population and habitat viability assessment workshop (P.H.V.A.) for Barasingha *(Cervus duvauceliiduvaucelii).* Wildlife Institute of India, Dehradun, 31 pp.

Qureshi, Q., Sawarkar, V.B., Rahmani, A.R. & Mathur, P.K. (2004). Swamp deer or barasingha (*Cervus duvauceli*Cuvier, 1823) In Ungulates of India (Eds.: K. Sankar and S.P. Goyal) Envis Bulletin: Wildlife and Protected Areas, Vol.07, No. 1, Wildlife Institute of India, Dehradun, India, 181-192.

Rodgers, W.A. & Panwar, S.H. (1988). Biogeographical classification of India. New Forest, Dehradun, India.

Ripple, W.J., Newsome, T.M., Wolf, C., Dirzo, R., Everatt, K.T., Galetti, M., Hayward, M.W., Kerley, G.I.H., Levi, T., Lindsey, P.A., Macdonald, D.W., Malhi, Y., Painter, L.E., Sandom, C.J., Terborgh, J., Van Valkenburgh, B., 2015. Collapse of the world's largest herbivores. Sci. Adv. 1, e1400103 https://doi.org/10. 1126/sciadv.1400103.

Sankaran, R. (1990). Status of the swamp deer in Dudhwa National Park. *J. Bombay Nat. Hist. Soc.* 87: 250-259.

Saravanakumar, S. U. (1995). Impacts of habitat conversion on theleaf litter anuran community of Varagaliar, Western Ghats. Dissertationreport submitted to Saurashtra University, Rajkot fromWildlife Institute of India.

Sarma, P.K.; Lahkar, B.P; Ghosh, S.; Rabha, A.; Das, J.P., Nath, N.K.; Dey, S. and Brahma, N. (2008). Land-use and land-cover change and future implication analysis in Manas National Park, India, using multi-temporal satellite data. Current Science; vol. 95, No.2, pp. 223-227.

Semwal, R.L. (2005). The Terai Arc Landscape in India: Securing Protected Areas in the Face of Global Change. WWF-India, New Delhi. Vii+47pp.

Schaaf, D. & Singh, A. (1977). Barasingha in the Dudhwa Sanctuary. *Oryx* 13: 495-498.

Schaff, D. 1978. Population size and structure and habitat relations of the Barasingha (*Cervus d. duvaucelii*) in Suklaphanta wildlife reserve, Nepal. Ph.D. Dissertation, Michigan State University, USA.

Schaller, G.B. (1967). The Deer and the Tiger. A Study of Wildlife in India. The University of Chicago Press.

Sharma, G.; Kamalakannan, M. & Venkataraman, K. 2013. A Checklist of Mammals of India with their distribution and conservation status. Zoological Survey of India, M Block, New Alipore, Kolkata-700 053..

Sidensticker, J. (1976). Ungulate populations in Chitawan Valley. Nepal. *Biol . Conser.*10.,183, 210.

Singh, R.L. (1982). Management Plan for Dudwa National Park. Forest Department, Uttar Pradesh. Pp 203.

Singh, K.K. (1997). Flora of Dudhwa National Park (Kheri Distt., U.P.). Publisher Bishen Singh Mahendra Pal Singh, Dehra Dun: 516 pp.

Sinha, S.P. & Chandola, S.S. (2006) Swamp deer sighting in Uttaranchal State, India. Oryx, 40, 14-40.

Singh, S. & Prashad, S. (2013). Tiger conservation plan of Dudhwa Tiger Reserve for the period of 2013-14 to 2022-23. Uttar Pradesh Forest Department.

Smith, R.L. (1974). Ecology and field biology. Harper and Row, New York.

Staaland, H. (1992). The supply of Sodium to large northern wild herbivores. In chemical climatology and geomedical problems, international symposium in Oslo, 21-22 May 1992, ed. J. Lag. The Norwegian Academy of Science and Letters, Oslo, pp. 125-30..

Symonds, T.J. (1886). Indian Grasses. Higginbotham and Co. Madras. Pp.252.

Tewari, R. (1992). Working Plan of the North Pilibhit Forest Division, 1991-92 to 2000-01. Working Plan Branch, Nainital (Uttar Pradesh).

Tewari, R. & Rawat, G.S. (2013). Studies on the Food and Feeding Habits of Swamp Deer (*Rucervus duvauceliii duvauceliii*) in Jhilmil Jheel Conservation Reserve, Haridwar, Uttarakhand, India. Hindawi. Volume 2013.

Thomas, L.; Buckland,S.T.; Rexstad, E.A.; Laake, J.L.; Strindberg; S., Hedley, S.L.& Burnham, K.P. 2010.Distance software: design and analysis of distance

sampling surveys for estimating populationsize. Journal of Applied Ecology, 47(1), 5-14.

Troup, R.S. (1911). “Chandars” or Frosty Blanks in Pilibhit and Kheri Divisions, United Provinces. Office of the Silviculturist, Forest Research Institute, Dehradun.

Troup, R.S. (1921). The silviculture of Indian Trees. Three Volumes. Clarendon Press, Oxford.

Webber, W.T. (1902). The forests of upper India and their inhabitants. Edward Arnold, London.

Wilmot, S.E. (1910). Forest Life and Sports in India. Edward Arnold, London.

Annexure.1. List of Tree Species		
No.	**Species**	**Family**
1	*Terminalia arjuna*	Combretaceae
2	*Ficus glomerata*	Moraceae
3	*Ficus hispida*	Moraceae
4	*Trewia nudiflora*	Euphorbiaceae
5	*Acacia catechu*	Fabaceae
6	*Dalbergia sissoo*	Fabaceae
7	*Pongamia pinnata*	Fabaceae
8	*Cassia fistula*	Fabaceae
9	*Bauhinia malabarica*	Fabaceae
10	*Catunaregam spinosa*	Rubiaceae
11	*Adina cordifolia*	Rubiaceae
12	*Syzygium cumini*	Myrtaceae
13	*Syzygium operculata*	Myrtaceae
14	*Eucalyptus sp.*	Myrtaceae
15	*Bombax ceiba*	Malvaceae
16	*Oroxylum indicum*	Bignoniaceae
17	*Ehretia acuminata*	Bignoniaceae
18	*Salix tetrasperma*	Salicaceae
19	*Tectona grandis*	Lamiaceae
20	*Barringtonia acutangula*	Lecythidaceae
21	*Miliusa velutina*	Annonaceae
22	*Holarrhena antidysentrica*	Apocynaceae

Annexure.2. List of non-tree woody species found in the vegetation plots (shrubs and woody climbers)		
S. No.	**Species**	**Family**
1	*Calotropis gigantea*	Apocynaceae
2	*Ichnocarpus frutescens*	Apocynaceae
3	*Vallaris solanacea*	Apocynaceae
4	*Artemisia nilagirica*	Asteraceae
5	*Eupatorium adenophorum*	Asteraceae
6	*Xanthium strumarium*	Asteraceae
7	*Ipomoea carnea*	Convolvulaceae
8	*Acacia concinna*	Fabaceae
9	*Cassia tora*	Fabaceae
10	*Erythrina resupinata*	Fabaceae
11	*Flemingia congesta*	Fabaceae
12	*Callicarpa macrophylla*	Lamiaceae
13	*Pogostemon benghalensis*	Lamiaceae
14	*Desmodium polycarpum*	Malvaceae
15	*Grewia hirsuta*	Malvaceae
16	*Grewia sapida*	Malvaceae
17	*Helectres isora*	Malvaceae
18	*Sida cordifolia*	Malvaceae
19	*Triumfetta rhomboidea*	Malvaceae
20	*Ficus heterophylla*	Moraceae
21	*Ochna pumila*	Ochnaceae
22	*Flueggea virosa*	Phyllanthaceae
23	*Ziziphus mauritiana*	Rhamnaceae
24	*Ziziphus oenoplia*	Rhamnaceae
25	*Clausena pentaphylla*	Rutaceae
26	*Murraya koenigii*	Rutaceae
27	*Solanum incanum*	Solanaceae
28	*Careya herbacea*	Lecythidaceae
29	*Tamarix dioica*	Tamaricaceae
30	*Clerodendron viscosum*	Verbenaceae
31	*Lantana camara*	Verbenaceae

Annexure.3. List of dicot herbs		
S. No.	**Species**	**Family**
1	*Hemigraphis hirta*	Acanthaceae
2	*Lepidagathis incurva*	Acanthaceae
3	*Nelsonia canescens*	Acanthaceae
4	*Rungia pectinate*	Acanthaceae
5	*Aerva sanguinolenta*	Amaranthaceae
6	*Alternanthera sessilis*	Amaranthaceae
7	*Chenopodium album*	Amaranthaceae
8	*Centella asiatica*	Apiaceae
9	*Oenanthe javanica*	Apiaceae
10	*Peucedanum dhana*	Apiaceae
11	*Oxystelma esculentum*	Apocynaceae
12	*Hydrocotyle sibthorpioides*	Araliaceae
13	*Ageratum conyzoides*	Asteraceae
14	*Blumea sp.*	Asteraceae
15	*Blumea sp. 2*	Asteraceae
16	*Blumeopsis flava*	Asteraceae
17	*Cirsium arvense*	Asteraceae
18	*Gnaphalium peregrinum*	Asteraceae
19	*Ixeris polycephala*	Asteraceae
20	*Parthenium hysterophorus*	Asteraceae
21	*Pentanema indicum*	Asteraceae
22	*Pentanema vestitum*	Asteraceae
23	*Sphaeranthus indicus*	Asteraceae
24	*Taraxacum sp.*	Asteraceae
25	*Arnebia hispidissima*	Boraginaceae
26	*Cynoglossum zeylanicum*	Boraginaceae
27	*Trichodesma indicum*	Boraginaceae
28	*Cannabis sativa*	Cannabaceae
29	*Wahlenbergia marginata*	Companulaceae
30	*Evolvulus alsinoides*	Convolvulaceae
31	*Ipomoea aquatic*	Convolvulaceae
32	*Volvulopsis nummularia*	Convolvulaceae
33	*Coccinia grandis*	Cucurbitaceae
34	*Mukia maderasptana*	Cucurbitaceae
35	*Solena heterophylla*	Cucurbitaceae
36	*Euphorbia chamaesyce*	Euphorbiaceae
37	*Euphorbia prolifera*	Euphorbiaceae
38	*Atylosia scarabaeoides*	Fabaceae

39	*Crotalaria alata*	Fabaceae
40	*Crotalaria medicaginea*	Fabaceae
41	*Desmodium sp. 1*	Fabaceae
42	*Flemingia procumbens*	Fabaceae
43	*Indigofera linifolia*	Fabaceae
44	*Indigofera trifoliata*	Fabaceae
45	*Lotus sp.*	Fabaceae
46	*Medicago lupilina*	Fabaceae
47	*Medicago polymorpha*	Fabaceae
48	*Melilotus albus*	Fabaceae
49	*Rhynchosia minima*	Fabaceae
50	*Uraria neglecta*	Fabaceae
51	*Vicia sativa*	Fabaceae
52	*Swertia angustifolia*	Gentianaceae
53	*Ajuga bracteosa*	Lamiaceae
54	*Leucas nutans*	Lamiaceae
55	*Salvia plebeia*	Lamiaceae
56	*Sida rhombifolia*	Malvaceae
57	*Mazus pumilus*	Mazaceae
58	*Cissampelos pareira*	Menispermaceae
59	*Ludwigia adscendens*	Onagraceae
60	*Ludwigia octovalvis*	Onagraceae
61	*Aeginetia pedunculata*	Orobanchaceae
62	*Oxalis corniculata*	Oxalidaceae
63	*Bacopa procumbens*	Plantaginaceae
64	*Scoparia dulcis*	Plantaginaceae
65	*Veronica anagallis-aquatica*	Plantaginaceae
66	*Polygala erioptera*	Polygalaceae
67	*Persicaria strigosa*	Polygonaceae
68	*Polygonum barbatum*	Polygonaceae
69	*Polygonum glabrum*	Polygonaceae
70	*Polygonum plebeium*	Polygonaceae
71	*Primula umbellata*	Primulaceae
72	*Ranunculus sceleratus*	Ranunculaceae
73	*Fragaria indica*	Rosaceae
74	*Oldenlandia gracilis*	Rubiaceae
75	*Boehmeria scabrella*	Urticaceae
76	*Pouzolzia zeylanica*	Urticaceae
77	*Phyla nudiflora*	Verbenaceae
78	*Viola betonicifolia*	Violaceae

79	*Viola sp. 2*	Violaceae
Nine species of dicot herbs could not be identified and is not given in this list		

Annexure.4. List of monocot herbs found in the vegetation plots		
S. No.	**Species**	**Family**
1	*Commelina paludosa*	Commelinaceae
2	*Cyperus sp. 1*	Cyperaceae
3	*Cyperus sp. 2*	Cyperaceae
4	*Pachystoma pubescens*	Orchidaceae
5	*Spiranthes sp.*	Orchidaceae
6	*Zeuxine strateumatica*	Orchidaceae
7	*Typha angustifolia*	Typhaceae
8	*Alpinia nigra*	Zingiberaceae

Annexure.5. List of grasses found in the vegetation plots		
S. No.	**Species**	**Family**
1	*Alopecurus geniculatus*	Poaceae
2	*Apluda mutica*	Poaceae
3	*Arundo donax*	Poaceae
4	*Bothriocloa pertusa*	Poaceae
5	*Brachiaria mutica*	Poaceae
6	*Capillipedium parviflorum*	Poaceae
7	*Chrysopogon aciculatus*	Poaceae
8	*Cymbopogon flexuosus*	Poaceae
9	*Cymbopogon jwarancus*	Poaceae
10	*Cynodon dactylon*	Poaceae
11	*Desmostachya bipinnata*	Poaceae
12	*Dicanthium annulatum*	Poaceae
13	*Digitaria ciliaris*	Poaceae
14	*Eleusine indica*	Poaceae
15	*Eragrostris viscosa*	Poaceae
16	*Erianthus ravennae*	Poaceae
17	*Eulaliopsis binata*	Poaceae
18	*Hemarthria compressa*	Poaceae
19	*Hymenachne amplexicaulis*	Poaceae
20	*Imperata cylindrica*	Poaceae
21	*Narenga porphyrocoma*	Poaceae
22	*Oplismenus compositus*	Poaceae
23	*Oryza sp.*	Poaceae
24	*Panicum psilopodium*	Poaceae
25	*Paspalum scrubiculatum*	Poaceae
26	*Phalaris minor*	Poaceae
27	*Phragmites karka*	Poaceae
28	*Saccharum bengalense*	Poaceae
29	*Saccharum spontaneum*	Poaceae
30	*Setaria glauca*	Poaceae
31	*Sclerostachya fusca*	Poaceae
32	*Sorghum halepense*	Poaceae
33	*Themeda arundinacea*	Poaceae
34	*Vetiveria zizanioides*	Poaceae
Two species of grasses were unidentified		

Annexure.6. List of Pteridophytes found in the vegetation plots			
No.	**SPECIES**	**HABIT**	**FAMILY**
1	*Equisetum debile*	Herb	Equisetaceae
2	*Lygodium flexuosum*	Herb	Schizaeaceae
3	*Ophioglossum reticulatum*	Herb	Ophioglossaceae
4	*Diplazium esculentum*	Herb	Athyriaceae

Annexure.7. List of important waterbodies in the study area				
Waterboody	**Area (in ha)**	**Region**	**Category**	**Upland/ Lowland**
Khirkia Bagahar	48.6	Haripur Range	Natural	Lowland
Salgadda	23.1	Haripur Range	Natural	Lowland
Chaundhar Kunda	8.58	Sampurnanagar Range	Natural	Lowland
Hazara Kunda	7.65	Sampurnanagar Range	Natural	Lowland
Jhand Tal	7	Mahof Range	Natural	Upland
Khannaut Swamp	4.39	Deoria Range	Natural	Upland
Badhaila Tal (eastern)	3.7	Mala Range	Natural but deepened artificially	Upland
Barasinga Tal	3.57	Mahof Range	Natural	Upland
Nagin Kunda	3.49	Sampurnanagar Range	Natural	Lowland
Jhand Tal (northern)	2.63	Mahof Range	Natural	Upland
Baiju Tal	2.35	Barahi Range	Natural	Lowland
Badhaila Tal (western)	2.1	Mala Range	Natural but deepened artificially	Upland
Bharari Tal	1.95	Barahi Range	Natural	Lowland
Baiju Tal 2	1.77	Barahi Range	Natural	Lowland
Mala Lake 2	1.75	Mahof Range	Natural	Upland
Mala Lake 31	1.69	Mahof Range	Natural	Upland
Mala Lake 30	1.63	Mahof Range	Natural	Upland
Baiju Tal 3	1.34	Barahi Range	Natural	Lowland
Hazara Jheel	1.32	Non-reserved area	Natural	Lowland
Lalkunwa Tal	1.31	Mahof Range	Natural	Upland
Ladsia	1.15	Mahof Range	Artificial	Upland
Durraina Tal	0.68	Mala Range	Natural but deepened artificially	Upland
Bhimtal	0.13	Mahof Range	Natural but deepened artificially	Upland
Khirkia	48.6	Haripur Range	Natural	Lowland