

Studying movement pattern and dispersal of the  
Bengal Florican (*Houbaropsis bengalensis*):  
a Satellite Telemetry Pilot Project

Final Report  
2013-2017



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2017

BOMBAY NATURAL HISTORY SOCIETY

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2013-2017**

Funded by the  
Ministry of Environment and Forest,  
Government of India

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**2017**



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By

Asad Rahmani

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## Summary of findings of the Project titled

### Studying movement pattern and dispersal of the Bengal Florican (*Houbaropsis bengalensis*): A Satellite Telemetry Pilot Project

The Bengal Florican *Houbaropsis bengalensis* (Gmelin 1789) is a Critically Endangered species, according to the International Union for Conservation of Nature (IUCN). It is listed under Schedule I of the Indian Wildlife (Protection) Act, 1972, and has been a priority species for conservation in the Wildlife Action Plan (2002-2016) prepared by the Ministry of Environment and Forest (MoEF). A guideline document to frame state-specific Recovery Plans has also been developed by the MoEF for the Bengal Florican as well as for the other two resident bustard species (Great Indian Bustard *Ardeotis nigriceps* and Lesser Florican *Sypheotides indicus*) found in India.

Ecology, behaviour and distribution of the Bengal Florican have been studied by BNHS in India since 1980s, and by *Aaranyak* and other organizations in Assam since late 1990s. Bengal Florican is found mainly in the protected grasslands of Dudhwa, Kishanpur and Pilibhit reserves in Uttar Pradesh; Manas, Orang and Kaziranga reserves in Assam, and D'Ering Sanctuary in Arunachal Pradesh. Occasional birds are reported from Katerniaghat Sanctuary (old records) in Uttar Pradesh; reserved grasslands/plantations in Uttarakhand bordering Pilibhit Tiger Reserve; Burachapori-Laokhowa and Dibru-Saikhowa reserves in Assam; and on several river islands in the Brahmaputra River flowing through Assam and Arunachal Pradesh. It is possibly locally extinct from West Bengal, although unconfirmed reports of its sightings have been received through the last ten years. In our estimation, perhaps less than 500 adult Bengal Floricans survive in India and Nepal. A separate subspecies, *Houbaropsis bengalensis blandini*, occurs in Cambodia and Vietnam.

Owing to the Bengal Florican's rarity, secretive nature and tall grassland habitat where it lives, it is difficult to study its detailed ecology and behaviour. The species is largely seen in protected grasslands at few relatively well-known sites/Protected Areas (PAs) from February onward after grass is burnt as an annual management practice by local Forest Departments. February to June (varies with regions) also happen to be its breeding season, when the male becomes conspicuous and indulges in spectacular aerial displays above the grasses and bushes, in a dispersed lek mating system. Thus, counting territorial displaying male Bengal Floricans is one of the more reliable method to monitor its population trend, although we must move beyond such methods towards incorporating detection probabilities gradually.

While male Bengal Floricans are easier to detect during the breeding season, females are very shy and cryptic, and mostly keep themselves to tall grass patches where their plumage merges perfectly making them very difficult to detect and observe. Prior to this study, nothing was known about the species post-breeding movements from India. We knew that at the onset of the monsoon season, grass becomes tall and dense and birds probably moved away from their breeding areas to seek 'better' and more open habitat elsewhere. Yet, the dynamics of this movement with respect to where and how far do the birds venture was entirely unknown.

Putting satellite transmitters on birds at Pilibhit (three birds) and Dudhwa (one) has given us specific information about their post-breeding movement. The transmitter of one bird caught at Pilibhit stopped working after three months, but the transmitters on the other three birds has given us insightful information for almost three years.

We found that by July-August, the birds move out from their breeding sites (which happen to be inside Pilibhit and Dudhwa reserves) and move approximately 15-50 km into floodplain-agricapes, which are areas along rivers characterised by a mosaic of unmanaged grasslands and lower intensity agriculture with relatively low human population densities and minimum infrastructure, generally outside the territorial jurisdiction of the Forest Department. They spend about six to eight months in such areas, showing a wide breadth of local movements perhaps due to specific anthropogenic disturbance events (e.g. harvesting or sowing of crops, harrowing the field, burning crop stubble). Hence, for up to eight months in a year, they are not in protected grasslands of PAs, and may thus be potentially more prone to the dangers of hunting and trapping. Therefore, for the protection of Bengal Florican we must look at the larger landscape beyond officially protected areas and reserved forests (RFs). The Species Recovery Plan for the Bengal Florican in Uttar Pradesh may keep this larger heterogeneous landscape in mind and devise appropriate strategies based on recommendations of this report.

We also conducted a pilot project to manipulate the vegetation structure at a grassland territory of a male bird at Dudhwa to assess whether it stayed back inside the Park if it were provided a mosaic of short and tall grass areas post the breeding season. Perhaps our experiment was done a little late and/or on a smaller scale, as the bird moved out of the Park eventually, although it tended to use open patches created by vegetation trimming more than usual. We suggest that such experiments be repeated at more than one site and on a larger scale to assess the efficacy of such an interventionist approach.

Since the results presented here are largely based on only three tagged birds, we recommend that more birds of both sexes be tagged in Uttar Pradesh, Assam and Arunachal Pradesh to fully understand the landscape-level ecological requirements of the Bengal Florican.

At present, most of the grassland management is done keeping in mind the requirements of large mega-vertebrates such as Rhino, Swamp Deer, Asian Elephant, Tiger and Wild Buffalo. Sometimes the grassland is burnt during the breeding season of the Bengal Florican and other grassland avian species. We strongly recommend long-term studies on the impact of annual grassland burning at Dudhwa, Manas, Kaziranga, D'Ering, Orang and other reserves/areas in order to help devise scientific grassland management protocols.

Limited livestock grazing is beneficial to keep the grass sparse and short– the habitat that Bengal Florican seem to prefer. In most areas, natural grazing regime has been disrupted either due to absence of wild herbivores and/or due to their reduced numbers and diversity. Therefore, annual and repeated grassland burning is resorted to in order to remove dense and rank unpalatable grass. For example, limited livestock grazing was allowed in Pilibhit Tiger Reserve till the recent past which presumably kept the growth of grass under control. But ever since it was declared as a Tiger Reserve in 2014, livestock grazing has now ceased. Without the presence of strong wild herbivore populations (Cheetal is common in forest edge but also graze in grassland, Hog Deer population is very low, Sambar is mainly found in forest, Swamp Deer numbers are extremely low, and Elephant, Wild Buffalo and Rhino are extinct from the Reserve), it will not be advisable to suddenly stop livestock grazing from the Tiger Reserve as the grasslands are likely to become unsuitable for the small numbers of Bengal Florican that survive there. We suggest that livestock grazing be gradually phased out, while the wild herbivore population gradually recovers.

## INTRODUCTION

The Bengal Florican *Houbaropsis bengalensis* is one of the most threatened bustard species of the world (Packman 2011) with a peculiarly disjunct population. While one centre of population (subspecies *blandini*) inhabits the Tonle Sap area of Cambodia (and possibly some areas in Vietnam), the other (subspecies *bengalensis*) occurs in a more widely spread area along the Himalayan foothills in north and north-eastern India and southern Nepal (Ali and Ripley 1987, del Hoyo et al. 1996, Grimmett et al. 1998).

Early reports suggest that it was once common and widely distributed in many parts of north India, southern Nepal and the Brahmaputra valley of Assam (Ali and Ripley 1987, BirdLife International 2001, Rahmani 2001). The loss and degradation of habitat, land-use intensification and hunting may have resulted in the species' observed demographic decline (Baral et al. 2003, BirdLife International 2001, Narayan and Rosalind 1990, Packman 2011, Rahmani 2001), due to which BirdLife International and IUCN uplisted it as 'Critically Endangered' since 2008. It is included under Schedule I of Indian Wildlife (Protection) Act 1972 according the highest level of legal protection on par with the tiger.

The Bengal Florican inhabits remaining patches of alluvial grasslands (*terai*) from Uttar Pradesh to the foothills and plains of Assam and Arunachal Pradesh in India, and is known to breed only at a handful of relatively well-known sites such as Dudhwa, Kishanpur and Pilibhit reserves in Uttar Pradesh; Kaziranga, Manas, and Orang reserves in Assam; D'Ering Sanctuary in Arunachal Pradesh; and Suklaphanta, Bardia, Chitwan and Koshi Tappu reserves in Nepal. Occasional birds are reported from Laokhowa-Burachapori and Dibru-Saikhowa reserves, and river islands in Assam, and some private grasslands in Arunachal Pradesh. Earlier it was found in grasslands of Meghalaya as well, but there is no recent record. There is no recent authentic record of the species from West Bengal either, and the species is perhaps locally extinct from the state.

A guideline document towards preparation of state-level Species Recovery Plans has been compiled by the MoEF in an important step towards the conservation of this species (Dutta et al. 2013).

The Bengal Florican shares its habitat with similarly other threatened fauna of the lowland floodplain-grassland such as Swamp Francolin *Francolinus gularis*, Manipur Bush-quail *Perdica manipurensis*, Slender-billed Babbler *Turdoides longirostris*, Jerdon's Babbler *Chrysomma altirostre*, Black-breasted Parrotbill *Paradoxornis flavirostris*, Hodgson's Bushchat *Saxicola insignis*, and Finn's Weaver *Ploceus megarhynchus*; and mammals like the Greater One-horned Rhinoceros *Rhinoceros unicornis*, Swamp Deer *Rucervus duvaucelii*, Hog Deer *Axis porcinus*, Hispid Hare *Caprolagus hispidus*, and Pygmy Hog *Porcula salvania*.

During the 1980s, detailed studies on its biology and behavior were conducted in Uttar Pradesh and Assam (Anonymous 1990, Narayan 1992, Narayan and Rosalind 1990, Sankaran and Rahmani 1990; Sankaran 1991, 1996) but its movement outside the breeding area was not known since the bird was largely seen only during its short breeding season (February-June). There was an urgent need of re-assessing its conservation status and understanding the ranging patterns of the species

for devising better conservation strategies. Under the current project, satellite telemetry approach was used along with field surveys to understand movement pattern for the better protection of the Bengal Florican.

### Species knowledge till now

#### Field Characters

The Bengal Florican is a large bird, the size of a domestic hen, of around 66-68 cm in height with longish legs. The male has mostly black head, neck, breast, and underparts, with a dark brown back which is heavily mottled and vermiculated, and with bold black arrowhead marks, and a glistening white on their wings. Elongated plumes overhang the breast, more visible before and during display. Its wings are largely white with black primaries. Female birds and juvenile males are an overall rufous-buff, sandy-buff in appearance with a brown back mottled with bold black arrowhead marks. No glistening white is seen on their wings, instead they have buffish-white wing coverts (Figure 1). Females also have two brown bars on the wings, which is visible in flight. Unlike in other bustard species but like the Lesser Florican, females are slightly larger in size but are more elusive and cryptic.

The subspecies *H. b. blandini* (found in Cambodia) has overall richer plumage tones and the male has shorter ornamental feathers on the head and neck (Johnsgard 1991).

#### Ecology and Behaviour

The Bengal Florican lives in short and tall wet lowland grasslands and is basically a cursorial bird, but it is capable of long flight (Ali and Ripley 1987, Rahmani *et al.* 1991). Its food consists of insects, grasshoppers, beetles, ants, occasionally lizards and small snakes, and grasses, flowers, shoots, berries and seeds, as per availability of food (Ali and Ripley 1987, del Hoyo *et al.* 1996, Sterling *et al.* 2006). In India, the ecology and behavior of the Bengal Florican have been studied at Manas in Assam (Narayan and Rosalind 1990, Narayan 1992) and Dudhwa in Uttar Pradesh (Sankaran and Rahmani 1990; Sankaran 1991, 1996).

The Bengal Florican is normally solitary in the breeding season, but up to six males may come together for a short period lasting several minutes, and often two females are seen in the same patch of grassland. Most of the adult males become territorial in the breeding season, while a few remain non-territorial, probably due to lack of suitable grasslands. It appears to favour relatively open short grasslands (0.5-1 m tall), sometimes with patches of tall grass and scattered bushes (Inskipp and Inskipp 1983, Narayan and Rosalind 1990), usually in lowlands within 300 m asl. The major grass species are *Imperata cylindrica*, *Saccharum bengalensis* (= munj), *Phragmites karka*, *Vetiveria zizanioides* and *Desmostachya bipinnata*, with or without scattered small trees and bushes. Short grassland appears to be favoured whilst foraging or displaying (Sankaran 1996). However, birds seek shelter in tall grass during the heat of the day, and females, which are difficult to see, probably spend much of their time in tall grass. The Bengal Florican generally avoids large, dense stands of tall grass and is seen in shorter grassland dominated by *Imperata cylindrica*, interspersed with patches of taller grassland (Narayan & Rosalind 1990). Similar behavior was noticed in Nepal by Peet (1997) and in Cambodia by Davidson (2004).



Figure 1: Female (left) and male (right) Bengal Florican *Houbaropsis bengalensis bengalensis*  
 (Photo credits: Smarajit Ojah- female, Dhritiman Mukherjee- male)

During the breeding season, males go back to their traditional display territories year after year. Some territories have been occupied over the last 30 years of monitoring (e.g. Sonaripur grassland in Dudhwa). 'Good' territories are probably at premium and adult males fight for them.

The characteristic aerial display flight of the male Bengal Florican was first properly described by Sankaran (1991) and Narayan (1992). The flight display usually takes place in an open patch within the male's territory. Once the male is aroused, it fluffs up the head, neck and breast feathers. Just before committing to the jump, it inflates the breast pouch even further, draws the head further back, and lowers the body by bending the legs partly. The bird then springs forward at an angle of about 45°. A loud and rapid wing-flapping sound is made while ascending and on reaching a peak of 3-4 m high, where the flapping stops and the wings are opened, displaying the glistening white wing feathers vividly against the jet black body. It is then that it delivers its sharp, whistle-like *chip-chip* call. It glides down a meter or two, moving forward on open wings, with the pouch drooping under the breast and the head thrown back. Just when it is 1-2 m from the ground, it begins to flap its wings again and moves forward, gaining most of the lost height. On reaching the apogee, it stops flapping its wings and floats down more or less vertically with partly open wings, drooping pouch, dangling and even paddling legs. During the display flight, it covers anything between 20-40 m ground and takes about 6-8.5 seconds from the take-off to landing. During each such display, it utters its call four to seven times while in the air (Narayan 1992, Sankaran 1991).

Female Bengal Floricans are far more shy and secretive, and are known to visit a male territory only briefly to mate and forage. Females usually lay one to two eggs directly on the ground, situated amongst thick grass. The eggs are glossy, olive-green, flecked with purple-brown, and are incubated for 25 to 28 days by the female. The males provide no care for the chicks (Narayan 1992). Chicks become capable of walking, running, and feeding themselves within a short period after hatching and leave their nesting place within two days with their mother (Sterling *et al.* 2006).

### **OBJECTIVES OF THE PROJECT**

With a view to further our knowledge of the bird's ecology, the objectives of the current project were as following:

1. To conduct field and questionnaire surveys for re-assessing the status of Bengal Florican, particularly in Uttar Pradesh, Assam and Arunachal Pradesh.
2. To study movement pattern and dispersal of Bengal Florican through satellite telemetry
3. Monitor the extent and quality of habitat at key breeding sites
4. Based on the results obtained, suggest suitable recommendations for better protection of the Bengal Florican

## Study Areas

Surveys and research activities were conducted in five states namely Uttarakhand, Uttar Pradesh, Bihar, Assam and Arunachal Pradesh (Map 1). Comprehensive work was done in Pilibhit Reserved Forest (now known as Pilibhit Tiger Reserve), Dudhwa Tiger Reserve (Dudhwa National Park, Kishanpur Sanctuary and Katerniaghat Sanctuary), North Kheri Reserved Forest, Sohildev and Sohagibarwa sanctuaries in Uttar Pradesh; Kaziranga, Orang, Manas, and Laokhowa-Burachapori reserves, and Sadia plains in Assam; D'Ering Sanctuary and Nizamghat in Arunachal Pradesh. Besides these, reconnaissance surveys were carried out in Valmiki Tiger Reserve, Bihar, and Terai Central and Eastern Forest Divisions of Uttarakhand, and Dibru-Saikhowa and Brahmaputra floodplains in Assam. Almost all areas known to harbour Bengal Floricans in India were covered.

### Brief Description of Surveyed Areas

#### **Pilibhit Reserved Forest/Tiger Reserve, Uttar Pradesh**

The Pilibhit Forest Division is situated between 28° 52' - 28°46' N and 79° 55' - 82° 15' E in the foothills of Himalaya. It covers an area of 712.88 km<sup>2</sup> (Map 2). Pilibhit Forest Division is under the management of five forest ranges namely Barahi, Haripur, Deoria, Mala and Mahof. Pilibhit Reserved Forest connects with the Terai-Bhabar forests of the Surai Range of Terai East Forest Division in the northwest and with the Kishanpur Wildlife Sanctuary in the southeast. This division also provides connectivity to the Suklaphanta Wildlife Reserve in Nepal through the Lagga-Bagga forest block (Chanchani *et al.* 2014).

The vegetation in Pilibhit Reserve Forest is a mosaic of dry and moist deciduous forests, scrub savannah and alluvial grasslands. Small ditches, ponds and perennial rivers such as Sharda, Mala, Khannot, and Chuka are the major sources of water. The Kheri branch of the Sharda canal and other canal channels pass through different forest areas of the division, thus providing water for wildlife even during peak summer season (Chanchani *et al.* 2014).

#### **Dudhwa Tiger Reserve, Uttar Pradesh**

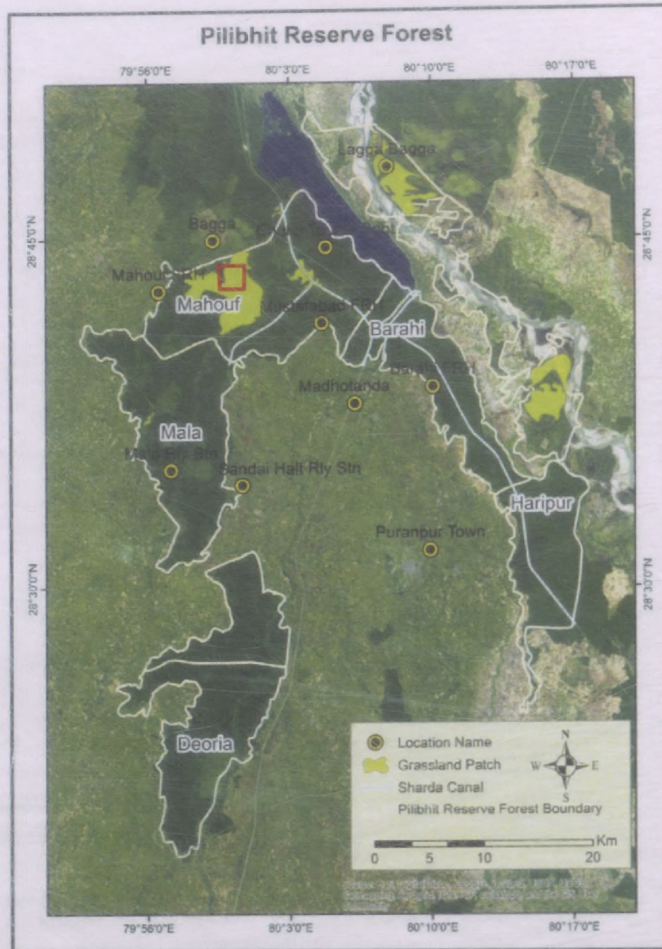
The Dudhwa Tiger Reserve comprise of three Protected Areas i.e., Dudhwa National Park (Map 3), Kishanpur Wildlife Sanctuary (Map 4) and Katerniaghat Wildlife Sanctuary (Map 5). Dudhwa National Park is situated on the Indo-Nepal border in the Palia and Nighasan tehsil of district Lakhimpur-Kheri and lies between 28° 18' N and 28° 42' N latitudes and 80° 28' E and 80° 57' E longitudes. The total area of the park is 429.90 km<sup>2</sup>. Reserved Forest areas of 124.01 km<sup>2</sup> is present as its northern buffer and an area of 66.02 km<sup>2</sup> serves as its southern buffer.

#### **Sohagibarwa Wildlife Sanctuary, Uttar Pradesh**

The Sohagibarwa Wildlife Sanctuary lies in Maharajganj and Deoria districts of Uttar Pradesh (Map 6). It is spread over an area of 428.20 km<sup>2</sup>. The Sanctuary provides connectivity with Chitwan National Park in Nepal and Valmiki Tiger Reserve in Bihar. It lies in the bio-geographic zone of Gangetic Plain and comprises of vegetation types such as Tropical Moist Deciduous Forest and Freshwater Swamp. While three-fourths of the Sanctuary is under forest cover, the rest consists of grasslands and patches



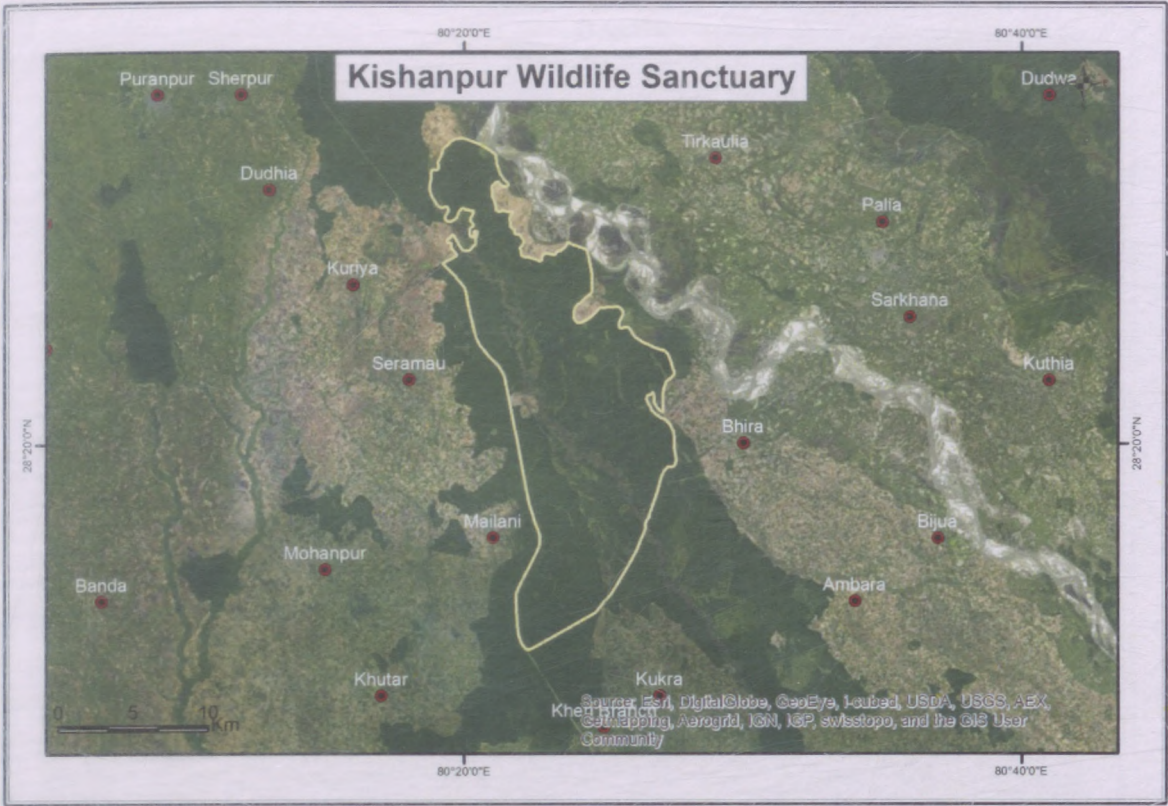
Map 1: Survey areas and study sites



Map 2: Pilibhit Tiger Reserve; Bengal Floricans were detected only in the area within the red box



Map 3: Dudhwa National Park (part of Dudhwa Tiger Reserve)



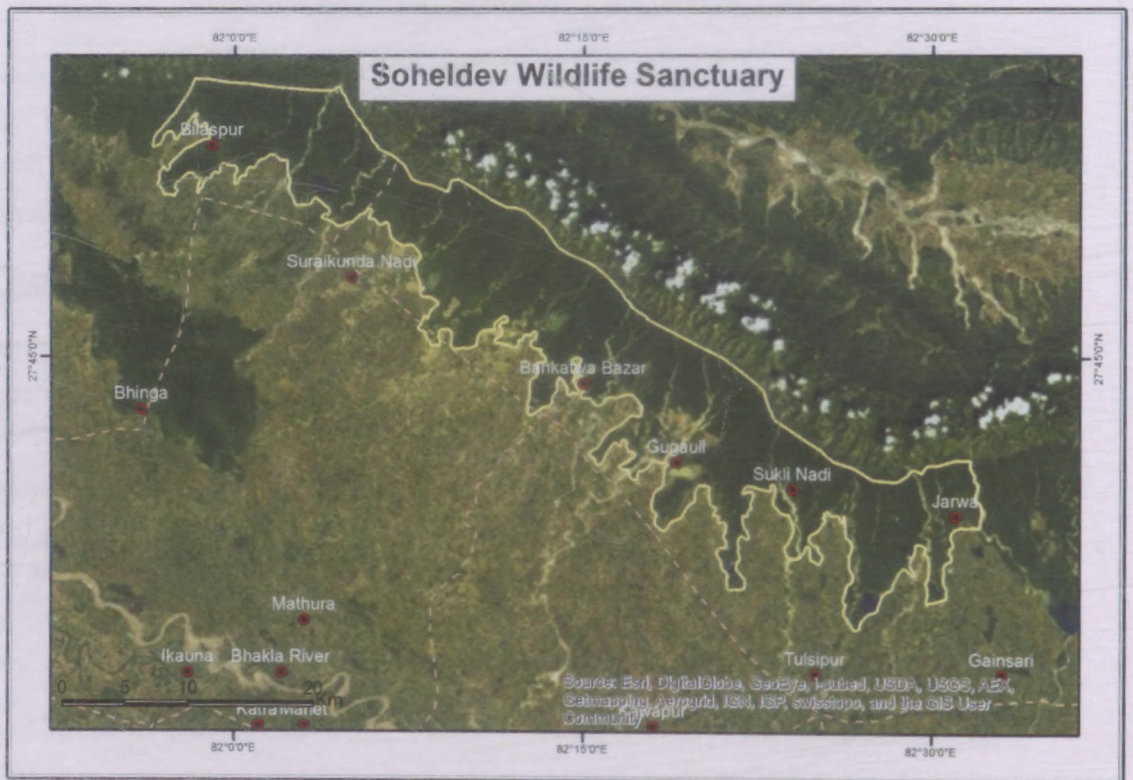
Map 4: Kishanpur Wildlife Sanctuary (part of Dudhwa Tiger Reserve)



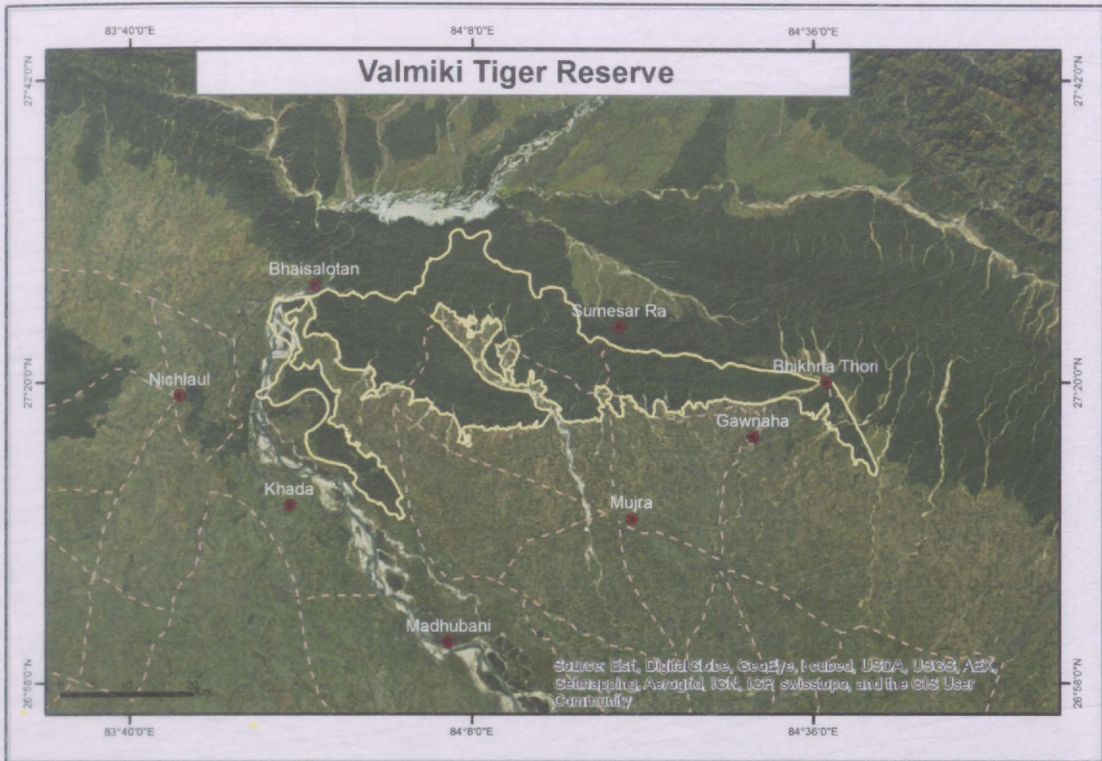
Map 5: Katerniaghat Wildlife Sanctuary (part of Dudhwa Tiger Reserve)



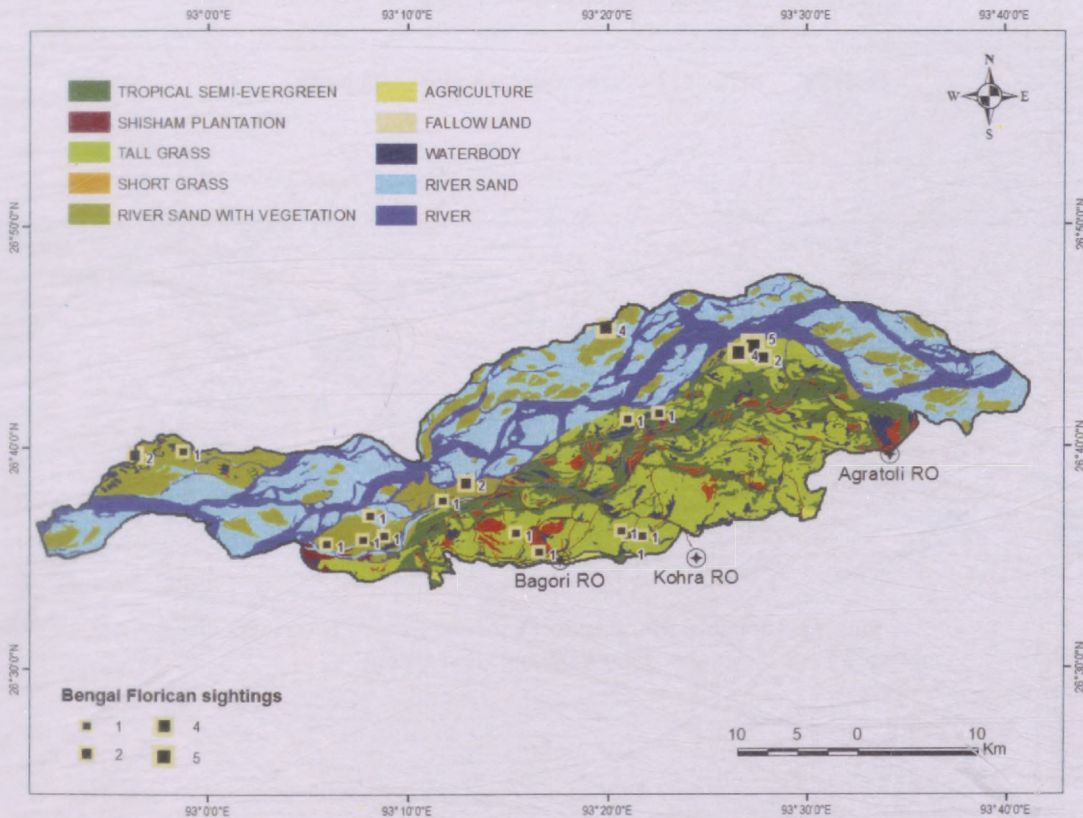
Map 6: Sohagibarwa Wildlife Sanctuary



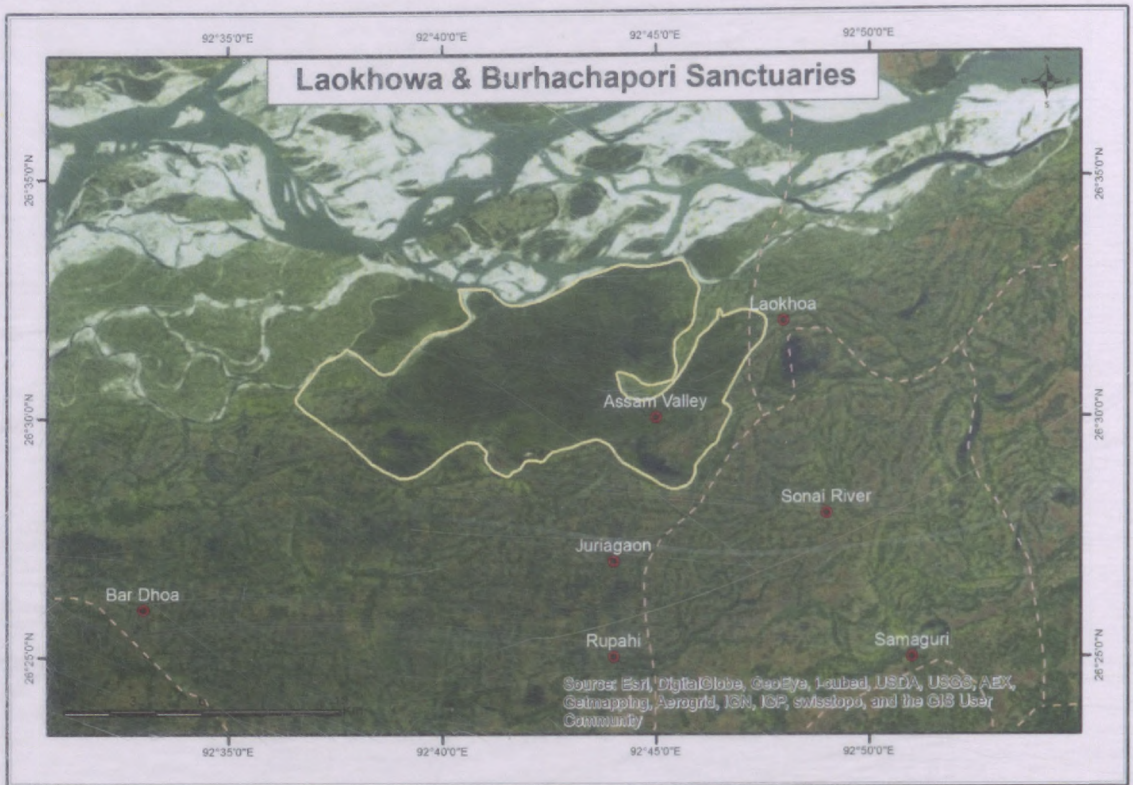
Map 7: Soheldev (also called Suhelwa) Wildlife Sanctuary



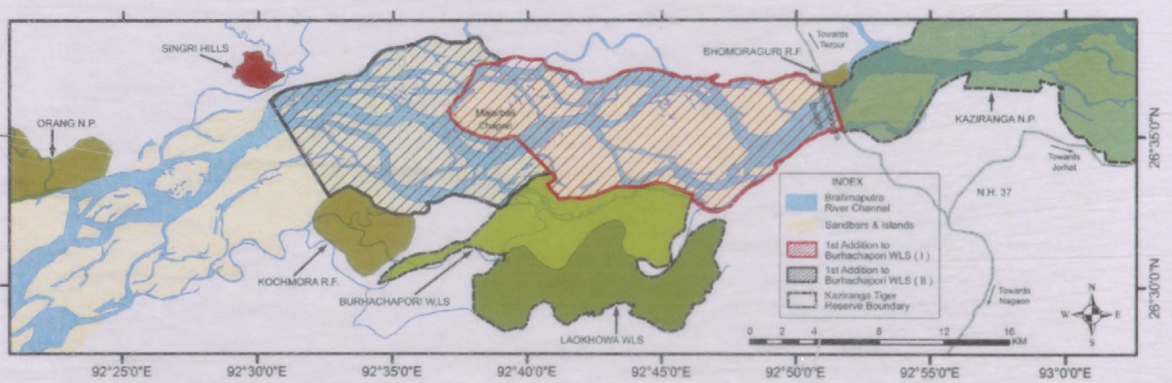
Map 8: Valmiki Tiger Reserve



Map 9: Kaziranga National Park showing Bengal Florican sightings



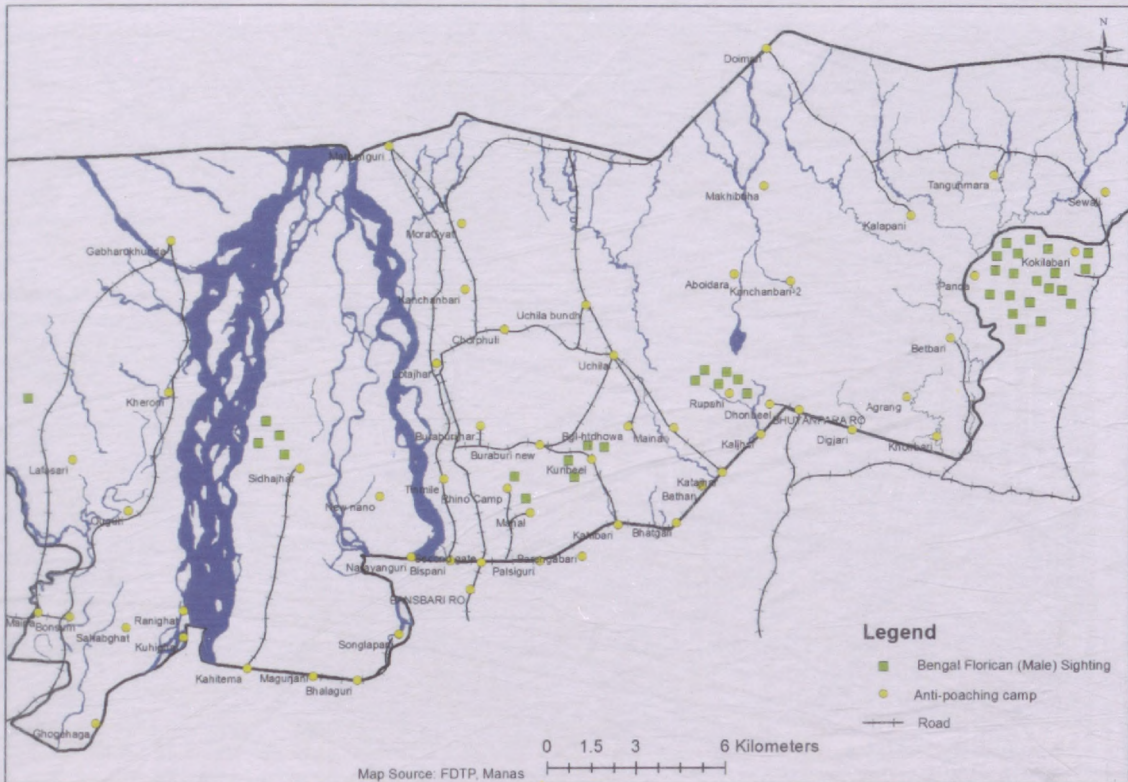
Map 10: Laokhoa-Burachapori Sanctuary



Map 11: Laokhoa-Burachapori Sanctuary showing connectivity between Kaziranga and Orang



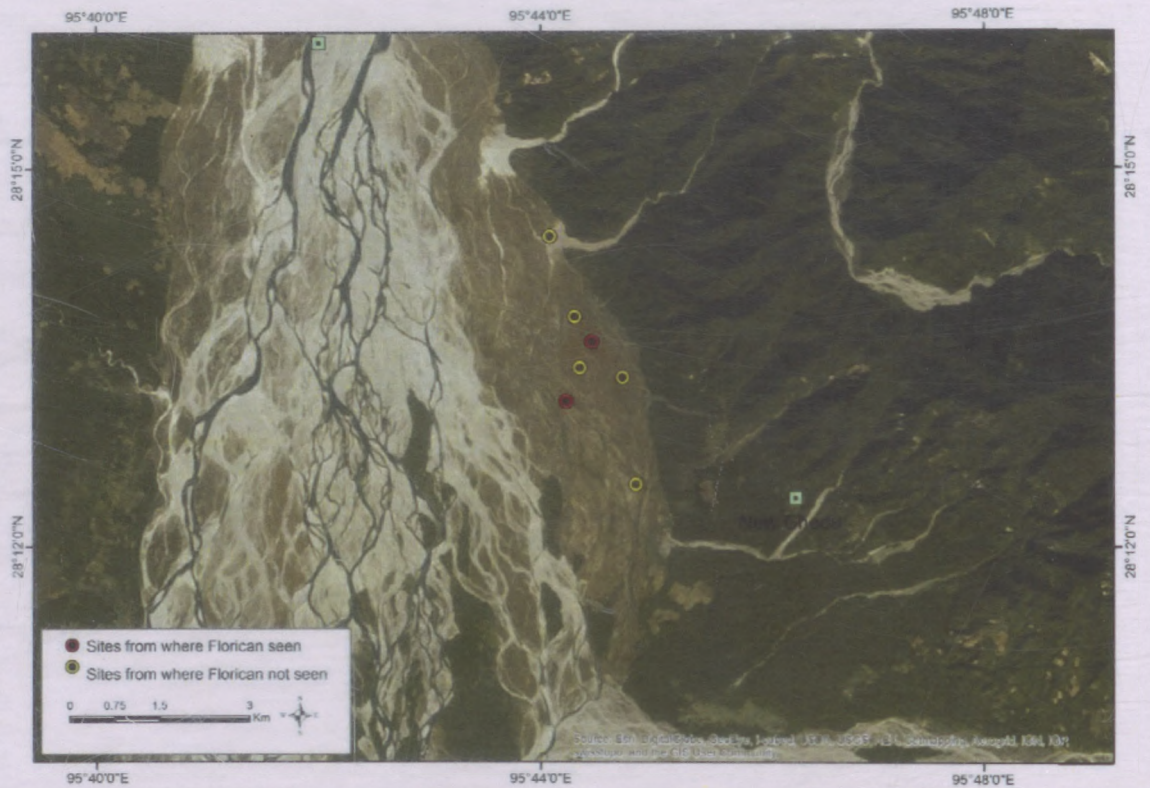
Map 12: Orang National Park showing Bengal Florican sightings



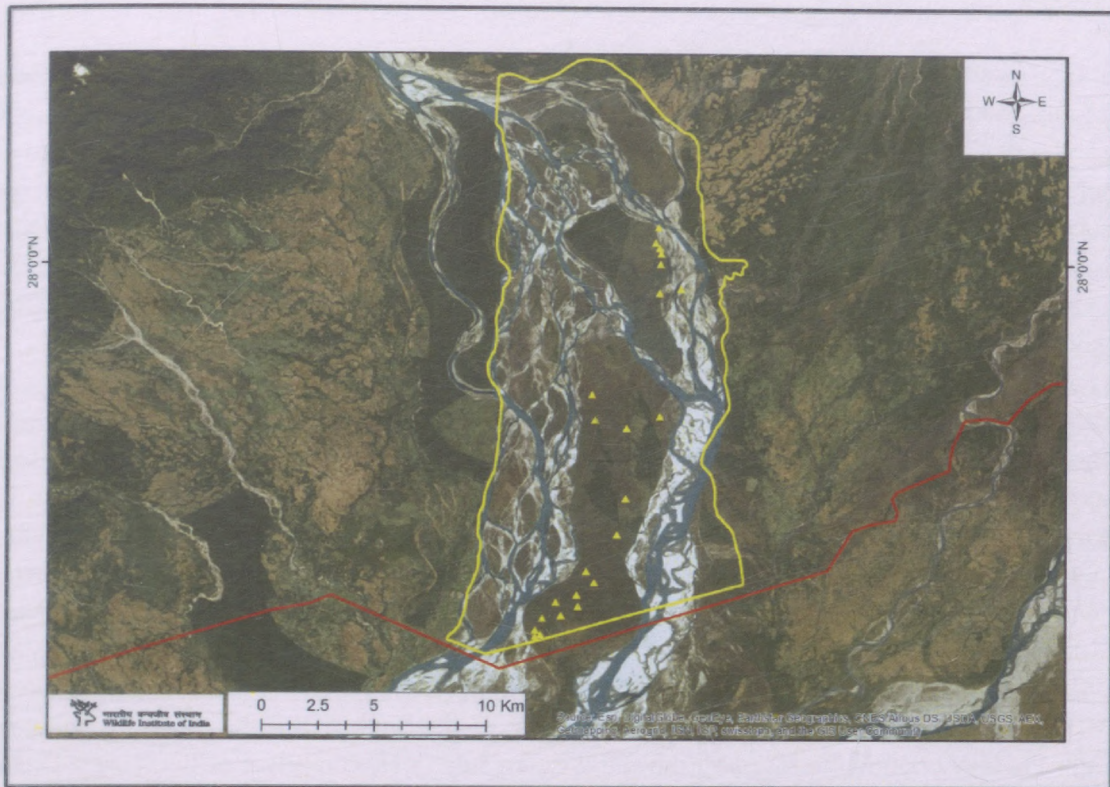
Map 13: Bengal Florican sightings at Manas National Park by Sonali Ghosh, Dr. Namita Brahma, Rustam Basumatary and Forest Department staff in 2014 (Map provided by Sonali Ghosh)



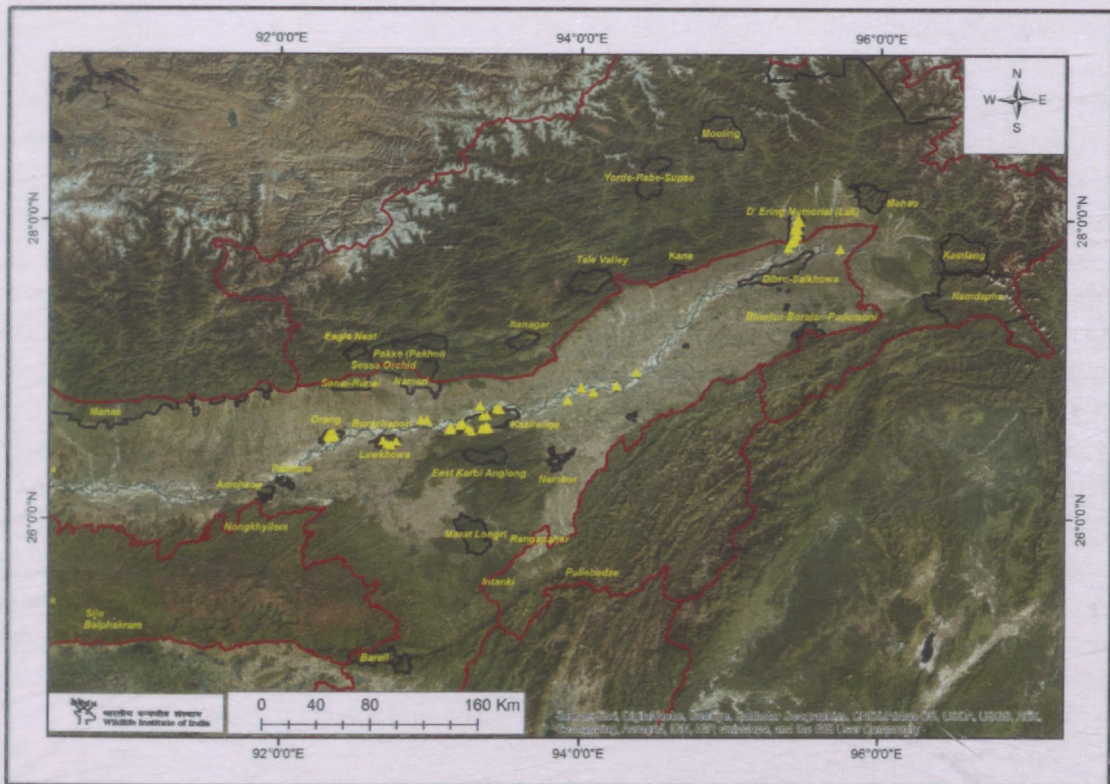
Map 14: Dibru-Saikhowa National Park



Map 15: Bengal Florican sightings at Nizamghat, Arunachal Pradesh



Map 16: Bengal Florican sighting locations in D'Ering Wildlife Sanctuary in 2016



Map 17: Locations of Bengal Florican in the Brahmaputra floodplains (yellow triangle); Manas is not included here although the Bengal Florican is found there

of cane forests. The Sanctuary is divided under seven administrative ranges namely Madhaulia, North Chauk, South Chauk, Lachhmipur, Pakri, Nichloul and Sheopur (Islam and Rahmani 2004).

#### **Soheldev Wildlife Sanctuary, Uttar Pradesh**

Soheldev Wildlife sanctuary lies in the Tulsipur tehsil of Balrampur district and Bhingra tehsil of Shravasti district (Map 7). The Sanctuary is approximately 120 km long and 6-8 km broad and covers an area of 452.77 km<sup>2</sup>. It lies in the Gangetic Plains biogeographic zone and vegetation is Tropical Moist Deciduous Forest (Islam and Rahmani 2004).

#### **Valmiki Tiger Reserve, Bihar**

The Valmiki Tiger Reserve (VTR) covers an area of 899.38 km<sup>2</sup> and comprises Valmiki National Park and Valmiki Wildlife Sanctuary (Map 8). The Valmiki forest got the status of Protected Forest in 1953. A part of the forest recognized as significant wildlife habitat was notified as Valmiki Wildlife Sanctuary in 1976 covering an area of 462 km<sup>2</sup>. Later in the year 1990, an area of 419 km<sup>2</sup> was declared as a part of Valmiki Wildlife Sanctuary, covering an aggregate area of 880.78 km<sup>2</sup>. Thereafter, Valmiki National Park was notified in the year 1990 covering an area of 355.64 km<sup>2</sup>. In 1994, Valmiki Wildlife Sanctuary and Valmiki National Park were together constituted as Valmiki Tiger Reserve (VTR), India's 18th such reserve under Project Tiger. In the north, VTR is bordered by Nepal while Uttar Pradesh bounds the reserve from the western side. VTR comprises of two Forest Divisions viz. Valmiki Tiger Reserve Division-I and Division- II, that are under the control of two Divisional Forest Officers. VTR is divided into eight ranges, out of which three ranges fall in Division-I while five ranges in Division-II.

We conducted our surveys at Gobardhana, Manguraha, Naurangia, Valmikinagar and Madanpur grassland but we did not detect Bengal Floricans at any site. It may be stated that Manguraha, Madanpur, Naurangia ranges have good and suitable grassland areas but we could not confirm the Bengal Florican's presence.

#### **Kaziranga National Park, Assam**

Kaziranga National Park is situated at 26°30'-26°45' N, 93°00'-93°45' E. It is one of the most important protected areas of India situated in the floodplains of Brahmaputra River. It includes parts of Brahmaputra River, parts of Nagaon, Golaghat and Sonitpur districts, and Panbari and Kukrakata Reserved Forests (Map 9). The Park is world famous for harbouring a significant global population of the Great Indian One-horned Rhinoceros, and large populations of the Asian Elephant and Wild Buffalo.

Few people are aware though that Kaziranga is also one of the most important bird areas for many globally threatened species. Besides Manas, it is the most important area for the Bengal Florican in Assam. It has also been declared as one of the outstanding IBAs (Important Bird Area), especially for birds of the tall, wet grasslands of the Assam Plains (Islam and Rahmani 2004).

### **Laokhowa-Burachapori Wildlife Sanctuary, Assam**

Laokhowa-Burachapori Wildlife Sanctuary is located in Nagoan and Sonitpur districts with a total area of 114.17 km<sup>2</sup> on the floodplain of the Brahmaputra River and under the administration of Kaziranga Tiger Reserve (Map 10). Laokhowa-Burachapori is very close to two well-known Bengal Florican sites i.e., Orang National Park (20 km approx) and Kaziranga National Park (10 km approx) (Map 11). During summer, Burachapori virtually becomes an island. The sanctuary is a breeding place for hundreds of Blue-tailed Bee-Eaters which we observed during our visit in April 2014.

Chapori (river island) surveys with a boat was very challenging as the conventional method of observation for three hours cannot be applied in those field conditions. For better understanding of the chapories, a survey was conducted on June 8, 2014 with Mr. Smarajit Ojah, Mr. Rajeev Basumatary and a local forest staff. The chapories of Jahaj Tapu, Majabil Tapu and Bawleswar Tapu appear as good habitats for the Bengal Florican. These grasslands though are subjected to heavy grazing while annual burning as a management practice has not been observed. These chaporis are not under formal protection at present.

Other grasslands inside the sanctuary seem to have suitable Bengal Florican habitats like Baghmari grassland, Chiali grassland and Jawani grassland.

### **Orang National Park, Assam**

Orang National Park is well known as an important habitat for the Indian One-horned Rhinoceros *Rhinoceros unicornis*. The Park lies 18 km off the national highway from Orang town and 15 km off the highway from Dhansirimukh town. The distance from Guwahati to Orang is 140 km (Map 12). The Park is situated on the northern bank of the Brahmaputra River. Pachnoi and Dhansiri rivers flow along its eastern and western boundaries respectively. Both these rivers are tributaries of the Brahmaputra. The terrain is flat, being the floodplain of these rivers. Two distinct alluvial terraces are found: the lower Orang of more recent origin along the river Brahmaputra and the older upper Orang to its north, separated by a high bank traversing the National Park from east to west. Orang National Park is one of the most important areas for Bengal Florican and other grassland bird species.

From our field surveys in 2015-16, we estimate a minimum of ten adult territorial males in the reserve. Due to the reintroduction of the Pygmy Hog in 2014, intensive monitoring of grasslands was being carried out during 2014-15 by researchers Biswajit Chakdar and Manabendra Ray Choudhury, and the Forest Department. During the course of their study, they also located about eight to ten adult male Bengal Floricans. Some grasslands could not be surveyed intensively by us due to logistic reasons, particularly in and around rhino inhabited areas in front of Satsamuli where Bengal Florican is frequently seen. Many river islands too, which have potentially suitable grasslands, could not be visited. Therefore, we suspect that there could be more than ten adult male Bengal Floricans in Orang.

### **Manas Tiger Reserve, Assam**

The Manas National Park, a world heritage site, is located in western Assam on the international border with Bhutan (Map 13). One of the most well known of the wildlife reserves of northeast India,

second only to Kaziranga, it was earlier called the North Kamrup Wildlife Sanctuary. The river Manas with its distributaries, the Beki and Hakua, flows through the Park. Other smaller streams include Jongrong, Gyati and Garuchara. Known for its scenic beauty, Manas is also home to a number of globally threatened birds and mammals. The Park has now the only viable population of the Critically Endangered Pygmy Hog. An added advantage to Manas is the presence of the 1,057 km<sup>2</sup> Royal Manas National Park across the border in Bhutan. For many species, it is a large contiguous wilderness area.

The terrain in Manas is mostly flat, gently sloping plain typical of *bhabar* and *terai*. Towards the north, small hilly promontories of the Bhutan Himalaya can be seen. Approximately half of Manas is savanna grassland, while the rest is Moist Deciduous and Semi-evergreen Forest. There are no large *beels* (waterbody), but small *beels* and pools occur in the southern areas. Manas has perhaps the largest known population of the Bengal Florican where Narayan (1992) estimated about 80 birds in 1989-90.

Due to various reasons, we could not conduct detailed surveys at Manas in 2013. In 2014 though, a detailed survey was conducted by Ms. Sonali Ghosh, IFS, Dy. Director, along with Drs. Bibhuti Lahkar and Namita Brahma during which 32 adult territorial male Bengal Floricans were sighted by them (Ghosh et al. 2014)

#### **Dibru -Saikhowa National Park, Assam**

Dibru-Saikhowa National Park lies in eastern Assam, falling partly in the districts of Tinsukia and Dibrugarh (Map 14). It is about 500 km by road from Guwahati. The original area of the sanctuary was 640 km<sup>2</sup>. However at the time of the Park's final notification in 1995, it was reduced to 340 km<sup>2</sup> in the process excluding large riverine stretches of the Brahmaputra and the Lohit rivers. Dibru-Saikhowa National Park has two ranges namely Guijan Range and Sadiya Range.

Dibru-Saikhowa is on the flat floodplains of the Brahmaputra, Lohit and Dibru rivers. The original vegetation was of the Tropical Rainforest type, but during the great earthquake of 1950, a large part of the area sank by a few meters resulting in the succession of vegetation. Deciduous forest with *Salix* swamps now dominate the forest. *Salix tetrasperma*, *Bischofia javanica*, *Dillenia indica* and *Terminalia myriocarpa* are the major tree species found in the reserve. Grasslands, reedbeds and wetlands (*beels* or oxbow lakes and depressions, marshes and sluggish channels) comprise other major habitat types. The forest village of Laika and Dadhai are situated inside the reserve, also there are more than 110 *khuttis* (cattle and buffalo camps) with more than 9,000 cattle heads grazed in the grassland causing disturbance to several grassland species.

#### **Brahmaputra Floodplain**

The Brahmaputra originates in Tibet from Angsi glacier and is known as Yarlung Tsangpo in the Tibetan language. In its long journey of 3,848 km, many rivers join it. Once it enters northern Arunachal Pradesh near a village called Gelling in Upper Siang District, it is known as Dihang or Siang. After rapidly descending in Arunachal Pradesh for about 200 km, the Siang is joined

by Lohit and Dibang rivers at Kobo chapori, about 25 km from Sadiya. The confluence of Siang, Dibang and Lohit creates a 'delta in reverse.' After entering Assam, it is known as Brahmaputra. Once it reaches Assam plains, it becomes very wide: in some places as wide as 9 km. In Sonitpur district, it is joined by the Kameng River (or Jai Bhoreli). It flows westward in Assam for about 700 km. It is in the plains of Assam that the Brahmaputra assumes its leisurely and regal flow in an east to west direction, bringing as many as 52 major and 121 minor tributaries in to her voluminous folds (Dwevidi 2016).

During the summer of 2015, a month-long survey of chaporis (river islands) of the Brahmaputra was conducted with the help of *Aaranyak*, a well-known NGO working in India's northeast region. Although no Bengal Florican was detected by us, we got confirmed reports from nine sites.

### **Amarpur chapori, Assam**

It is near Dibru-Saikhowa National Park and is well-known for Bengal Florican and other grassland birds. It is inhabited by large human and cattle populations, thereby putting grasslands near villages under severe pressure. Another issue is the spread of the exotic invasive weed *Lantana camara* particularly around villages. Nonetheless, remote grasslands still have *Imperata* and *Saccharum* grasses. We saw a displaying male and a female in one such grassland. The villagers recognise the Bengal Florican and some even described a nest to us. Considering the extent of grasslands, we estimate that 4-5 adult territorial males could be present in Amarpur chapori. More extensive survey is required in future, preferably by staying on the chapori so that time spent travelling is conserved.

### **Sadia area, Assam**

There are several chaporis (or river islands), both temporary and permanent, in Sadia area that have suitable grassland areas for Bengal Florican. During February-March 2016, we conducted extensive surveys on some of the chaporis and saw two adult male birds. We also obtained secondary information of at least another 10-12 male Bengal Floricans. On Kol chapori, part of Sadia plains, we saw one adult bird in flight on 22 April 2016. Most of the people (graziers and fishermen) knew about the Bengal Florican. It is difficult to say how many birds survive in the larger Sadia area but our estimate is that about 15-20 adult territorial males could be present in the region.

### **Nizamghat, Roing, Arunachal Pradesh**

In Nizamghat we surveyed a private grassland located near Lohit River (Map 15). This grassland is being held by many stakeholders chiefly for grazing cattle. There are four permanent cattle camps in the area. The grassland has a number of wild animals, for example one male wild water buffalo grazes quite close to the settlement and there are reports of elephants too in the area.

On May 6, 2011, Monsoon Jyoti Gogoi (*pers. comm.* 2015) detected seven adult male Bengal Floricans in flight, four flying from west to east on one side of the grassland, while three were flying east to west on another side. During our surveys in 2014-2015, we enumerated four adult male and one female Bengal Florican.

### **Daying Ering Memorial (or D'Ering) Wildlife Sanctuary, Arunachal Pradesh**

Located on the floodplain of the Siang River, the D'Ering Wildlife Sanctuary is spread over a cluster of river islands. The sanctuary covers an area of around 190 km<sup>2</sup>, the majority of which is alluvial grasslands while the rest is wooded areas. The Sanctuary is located in the East Siang district, close to the district headquarter town of Pasighat.

During our one-day survey in 2015, we saw one displaying male Bengal Florican and found the habitat as very suitable for the species. In 2016, we spent a total of six days and located 29 territorial males. We could not survey all parts of the grassland due to unfavourable weather conditions and logistical reasons. We suspect that there may be about 50-60 adult male birds in the sanctuary, thereby making D'Ering perhaps the finest Bengal Florican sanctuary in India (Map 16).

### **West Bengal**

In West Bengal, till late 1980s, Bengal Florican was seen in the private grassland of Sahabad-Sayedabad Tea Estate, and Chapra Tea Estate (Rahmani *et al.* 1990), and till late 1990s in the grasslands of Jaldapara Sanctuary, but there is no recent record (G. Maheswaran, *pers. comm.* 2011). According to Sumit Sen (*pers. comm.* 2010), a pair was observed by Bhaskar Das in the Buxa area in 2005, although this remains unconfirmed.

## **METHODOLOGY**

### **Bengal Florican detection surveys**

As the Bengal Florican lives in short and tall grasslands inhabited by potentially dangerous animals such as the elephant, tiger, rhino and wild buffalo, conventional transect methods cannot be applied. In fact, permission for the line transect method was not given at most PAs in the first place. The vehicle count method had limited scope as many parts of large grassland areas could not be surveyed.

Therefore, we designed a survey method of sitting quietly on any available prominent and safe vantage point (such as observation towers, vehicle rooftops, treetops) from where the grassland could be easily seen. Due to Bengal Florican's secretive nature, survey timings were limited to early morning and late evening when the bird forages and displays in more open grassland patches within its territory. Each grassland patch was surveyed for Bengal Florican detection one to four times. Each survey session lasted for one to three hours during the birds' peak activity periods. During each such survey, teams of one to four observers trained in florican identification continuously scanned for the presence of Bengal Floricans.

Upon each sighting of the bird, its initial activity as well as the suite of activities it performed during a given time period it was visible were recorded. We visually estimated the bird's distance from the observer and recorded the animal angle with a magnetic compass. From the observers' vantage/survey locations, visibility along eight directions too was recorded, along with information such as visible signs of recent burning, flooding and grazing. Other ancillary information such as duration of surveys, general notes on the habitat, and anthropogenic activities in and around grasslands was also noted (Appendix II).



Figure 2: Placing a dummy of male Bengal Florican as a decoy to attract the wild birds



Figure 3: Male Bengal Florican decoy as placed in the field



Figure 4: Deploying satellite tracking instrument (PTT) on a male Bengal Florican in Pilibhit Reserved Forest



Figure 5: Releasing the male Bengal Florican after fitting it with the satellite tracking instrument



Figures 6 & 7: Putting PTT on the back of a male Bengal Florican (above and below)





Figures 8 & 9: The Bengal Florican flying away upon the successful deployment of PTT (above and below)



### **Satellite telemetry**

After obtaining permission from relevant national authorities and subsequently from the U.P. Chief Wildlife Warden, we began the process to capture three or four Bengal Floricans for deploying satellite transmitters on them to study their movement. In order to know their daily movement and preferred display grounds, the floricans were observed daily for a month in Pilibhit Reserved Forest. Once the team was satisfied that they could safely catch the birds, BNHS' professional trappers, with 45 years experience, were tasked with trapping the birds. In order to attract the territorial male Bengal Florican to a particular area where traps were laid, we used male and female decoys (Figures 2, 3). Use of decoys has been reported as an effective method to capture partridges and francolins (Ramesh 2007). Within ten days, we were able to catch three male Bengal Floricans (Figures 4-7).

### **Field surveys (brief) 2012-13**

In Uttar Pradesh field surveys were carried out at Dudhwa National Park, Pilibhit Reserved Forest, Kishanpur Wildlife Sanctuary, Soheldev Wildlife Sanctuary and Sohagibarwa Wildlife Sanctuary (Table 1). A total of 15 male Bengal Floricans were recorded during the field work (Tables 2-4).

In Arunachal Pradesh, Bengal Floricans were recorded from the Nizamghat area on September 14, 2013 where three male birds were seen in a private grassland.

In Assam, the Brahmaputra valley has been a stronghold of the Bengal Florican. It includes large grasslands in Manas, Kaziranga, Orang, Dibru-Saikhowa, and Laokhowa-Burachapori reserves. As monsoon had already begun, the Kaziranga reserve was closed. Thus, we could not conduct proper and detailed surveys there. We visited only the extended part of the reserve and recorded three birds (one at each site) on May 17, 2013. These sites are- Gajraj view point, Raptor point and Borgula grassland.

In Orang National Park, four males were recorded from four different sites. These sites are- Nishlamari grassland, Ramkang camp, Bontapu grassland and Roumari Beel. Besides these four sites, five other sites, viz. Magurmari machan 1 & 2, Simul grassland, Satsimul Rest House, Shoulmari grassland and Bezimari grassland were also surveyed.

Grasslands inside Manas National Park could not be surveyed due to certain reasons. Therefore the Kokilabari Seed Farm area was surveyed thoroughly, which is located at the periphery of the reserve. The first survey was done on May 22 while another survey was conducted on May 26. A total of six males and one female Bengal Florican were recorded in this area.

On May 13, while crossing the Brahmaputra river on board a ferry, a male Bengal Florican was seen on an island (27° 46' 39.1" N and 95° 36' 57.1" E) across the river. We tried to survey the area but could not reach the grassland due to inundation of streams.

Table 1: List of grasslands surveyed in 2013 in Uttar Pradesh

Sr. No.	Date (DD/MM/YY)	Grassland/Place	Geographic coordinates	Bengal Florican detection
1	03-05-2013	Sonaripur Road No.74 GS*, DNP	N 28.27.255 E 80.44.634	YES
2	25-05-2013	Sonaripur Railway Phatak GS, DNP	N 28 28.027 E 80 44.139	YES
3	21-04-2013	Chandan chowki PWD Road GS, DNP	N 28.30.054 E 80.41.951	YES
4	21-05-2013	Compartment 105 (Chougebi), Mahof GS	N 28.41.838' E 80.00.940'	YES/ 2 Male Floricans
5	28-05-2013	Sarota GS, Masankhamb, DNP	N 28.30'32.2" E80.29'19.3"	YES
6	30-05-2013	Barwa Gul GS, Salukapur, DNP	N 28.25.326 E 80.41.539	YES
7	31-05-2013	Chapra GS, Sathiana, DNP	N 28.32.077 E80.33.178	YES
8	24-05-2013	Maduraiya GS, DNP	N 28.29'30.2"E 80.35'19.4"	YES
9	25-05-2013	Sonaripur Road No.64 GS, DNP	N 28.29.470 E 80.43.565	YES
10	05-06-2013	Nagra GS, Belrayan, DNP	N 28 22.878 E 80 47.353	YES
11	06-06-2013	Rehta Railway Station GS, Belrayan, DNP	N 28 25 695 E 80 48.115	YES
12	07-06-2013	Bargadchowki GS, Kishanpur WLS	N 28 18.827 E 80 25.472	YES/ 2 Male Floricans
13	20-05-2013	Bhimaal, Mahof GS, Pilibhit Reserved Forest	N 28.41'49.8"E 80.00'56.3"	YES/ WII Sighting 2013
14	31-05-2013	Sonaripur-Kila FRH GS, DNP	N 28.26.432 E 80.45.418	NO
15	01-06-2013	Satimath GS, Sathiana, DNP	N 28 32 794 E 80 32 734	NO
16	30-04-2013	Surmagaon, Chandan chowki, DNP	N 28.30.374 E 80.43.088	NO
17	05-06-2013	Naan taal GS, Belrayan, DNP	N 28.22.033 E 80 48.142	NO
18	09-06-2013	Jhaadi taal GS, Kishanpur WLS	N 28 23.725 E 80 25.994	NO
19	10-06-2013	Kishanpur-Pilibhit range boundary GS, Kishanpur WLS	N 28 26.105 E 80 20.130	NO
20	12-06-2013	Madha GS, Kishanpur WLS	N 28 16.905 E 80 24.802	NO
21	13-06-2013	Madha chowki GS, Kishanpur WLS	N 28 16.429 E 80 24.957	NO
22	05-12-2013	Madholiya GS, Sohagibarwa WLS	N 27.21.996 E 83.37.174	NO
23	05-12-2013	Deibhar FRH Road GS, Sohagibarwa WLS	N 27.22.437 E 83.35.812	NO
24	13/5/2013	Laxmipur GS, Sohagibarwa WLS	N 27.16.930 E 83.29.747	NO

\* GS = grassland

Table 2: Bengal Florican detections in Dudhwa National Park in 2013

Sr. No.	Date	Grassland Location	Geographic coordinates	Bengal Florican detection	Activity	Display
1	20/4/2013	Sonaripur Railway Phatak, Sonaripur Range	N 28.28.062' E 80.44.089'	Single Territorial Male	Flight (flushed during road transect)	No
2	21/4/2013	Chandan chowki railway phatak, Dudhwa Range	N 28.30.054' E 80.41.951'	Single Territorial Male	Flight	Aerial display
3	23/4/2013	Maduraiya, Sathiana Range	N 28.29'30.2" E 80.35'19.4"	Single Territorial Male	Flight	Aerial display
4	03/5/2013	Sonaripur Road No.74 (S.D. Singh Road), Sonaripur Range	N 28.27.255' E 80.44.634'	Single Territorial Male	Standing, Foraging, Flight	Aerial display
5	25/5/2013	Sonaripur Road No.64, Sonaripur Range	N 28.29.470' E 80.43.565'	Single Territorial Male	Flight	Aerial display
6	30/5/2013	Barwa gul, Salukhapur Range	N 28 25.326 E 80 41.539	Single Territorial Male	Flight	Aerial display
7	31/5/2013	Chapra, Sathiana Range	N 28.32.077' E 80.33.178'	Single Territorial Male	Flight	Aerial display
8	05/6/2013	Nagra, Belrayan Range	N 28 22.878' E 80 47.353'	Single Male	Walking	No
9	06/6/2013	Rehta railway station, Belrayan Range	N 28 25 695' E 80 48.115'	Single Territorial Male	Flight	Aerial display
10	08/6/2013	Sarota, Masankhamb Range	N28.30'32.2" E80.29'19.3"	Single Territorial Male	Flight	Aerial display

Table 3: Bengal Florican detections in Kishanpur Wildlife Sanctuary in 2013

Sr. No.	Date	Grassland Location	Geographic coordinates	Bengal Florican detection	Activity	Display
1	19/4/2013	Bargad Chowki, Kishanpur WLS, DTR	N 28 18'52.50" E 80 25'28.39"	Single Territorial Male	Flight	Aerial display
2	07/6/2013	Bargad Chowki, Kishanpur WLS, DTR	N 28.18.830' E 80.25.468'	Single Territorial Male	Flight	Aerial display

Table 4: Bengal Florican detections in Pilibhit Reserved Forest in 2013

Sr. No.	Date	Grassland Location	Geographic coordinates	Bengal Florican detection	Activity	Display
1	21/5/2013	Compartment No.105, Mahof Range	N 28.41.838' E 80.00.940'	Two territorial males	Flight & chase away	No

Table 5: Bengal Florican detections in Dudhwa National Park in 2014

Date	Place	GPS Co-ordinates	Activity	Display	Male
23/3/2014	Sonaripur Road No.74 GS, Dudhwa NP	N 28° 27' 15.3", E 80° 44' 38.0"	Forage	No	1
15/3/2014	Sonaripur Railway Phatak GS, Dudhwa NP	N 28° 28' 8.4", E 80° 43' 59.8"	Forage	No	1
NA	Near Baankey Taal, Dudhwa NP	N 28° 28' 23.2", E 80° 43' 8.1"	Flight	No	1
12/3/2014	Chandan Chowki, Dudhwa NP	N 28° 30' 3.2", E 80° 41' 57.0"	Display	Aerial Display	1
NA	Sonaripur Road No.64, Dudhwa NP	N 28° 29' 28.2" E 80° 43' 33.9"	Display	Aerial Display	1
3/4/2014	Barwa Gul, Salukapur, Dudhwa NP	N 28° 25' 19.6", E 80° 41' 32.3"	Flight	No	1
25/3/2014	Kakraha, Salukapur, Dudhwa NP	200-300 meters west to Barwa Gul	Flight	No	1
NA	Chhapra grassland, Sathiana, Dudhwa NP	N 28° 32' 4.6", E 80° 33' 10.7"	Display	Aerial Display	1

Table 6. Bengal Florican detections in Pilibhit Reserved Forest in 2014

Date	Place	GPS Co-ordinates	Male	Female
12/4/2014	Compt. No. 105, Chougebi Grassland, Pilibhit RF	N 28° 42' 21.2", E 80° 00' 48.3"	1	0
12/4/2014	Compt. No. 105, Chougebi Grassland, Pilibhit RF	N 28° 42' 5.2", E 80° 00' 32.8"	2	0
1/5/2014	Compt. No. 105, Bhimtaal Grassland, Pilibhit RF	N 28° 42' 50.8", E 79° 59' 49.0"	1	0
1/5/2014	Compt. No. 108, Bhimtaal Grassland, Pilibhit RF	N 28° 43' 5.5", E 79° 59' 23.3"	1	0

### Field surveys 2013-14

In Uttar Pradesh, we commenced our study from the first week of November 2013 after obtaining required permission from the Chief Wildlife Warden. However, we did not succeed in locating Bengal Floricans until the onset of the breeding season in the summer of 2014. Apart from primary surveys, we also interviewed park officials, local naturalists, bird watchers, and villagers for sharing their knowledge about recent sightings, status and conservation of Bengal Florican.

We conducted about 300 observation/detection surveys at Pilibhit Reserved Forest, where each observation session lasted for two to three hours. Five male Bengal Floricans were sighted during April-May 2014 (Table 6). Besides this, presence of eight male Bengal Floricans was confirmed from Dudhwa National Park during the same period by a volunteer (Table 5).

In Assam and Arunachal Pradesh, extensive field surveys with the assistance of local people were carried out (Tables 7-10). We scanned various grasslands from vantage points for direct sightings with the aid of binoculars. Sighting records of species was maintained, including their location, habitat and activity. Secondary information of the species was also recorded (e.g. locations confirmed by local people and ornithologists). We recorded GPS locations across the landscape, and made notes on vegetation and habitat. This information was used together with available satellite data to develop initial maps. In Assam and Arunachal date wise survey details are as following:

- 06-11 Feb '14** : First preliminary survey was started at Nizamghat, Roing, Lower Dibang
- 23 Feb - 06 March '14** : Second survey was conducted at Nizamghat
- 13-15 Feb '14** : Survey was conducted near Borgoli Camp, Borgoli Range, D'Ering Sanctuary
- 24-29 March '14** : Survey was carried out at Burhapahar Range, Kaziranga National Park
- 01-09 April '14** : Survey was carried out at Bagori Range, Kaziranga National Park
- 12-23 April '14** : Survey in Kohora Range, Kaziranga National Park
- 25-26 April '14** : Visit to D.F.O, Laokhowa-Burachapori Wildlife Sanctuary
- 28 April - 07 May '14** : Survey in Agaratoli Range, Kaziranga National Park
- 12-28 May '14** : Survey in Northern Range, Kaziranga National Park
- 04-06 June '14** : Survey on a chapori close to Dibrugarh Town
- 08 June '14** : Survey in Laokhowa-Burachapori Sanctuary chapories with Smarajit Ojah, Rajiv Basumatary and Forest Department
- 10-12 June '14** : Survey in Laokhowa-Burachapori Sanctuary
- 17-20 June '14** : Survey in Dibru-Saikhowa National Park

A total of four males and one female Bengal Florican was sighted in Nizamghat, Roing, Arunachal Pradesh (Table 8). Besides this, occurrence of 25 males and three female Bengal Floricans were recorded from Kaziranga National Park during the same period (Table 7). In addition to this, occurrences of seven males and three females were also recorded through information provided by various sources (Table 9).

Table 7: Bengal Florican detections in Kaziranga National Park, Assam

Date	Camp/ Range	Sex		Geographic coordinates	Observation	
		M	F		Direct	Secondary
25/3/14	Maite Camp	1M		N26°35'41.1"E 093°05'56.3"		✓
25/3/14	Maqbool Camp	1M		N 26°36'57.9"E 093°08'03.7"		✓
25/3/14	Lohoroni No 2 Camp	1M		N26°35'52.4"E 093°07'43.5"		✓
1/4/14	Dunga Beel	1M		N26°35'19.4"E 093°16'31.0"		✓
9/4/14	Bhaisamari Camp	1M		N26°36'11.1" E 093°15'21.4"	✓	
27/1/14	Tekaliphuta Area	1M		N26°41'32.4" E093°22'30.3"		✓
8/3/14	Boloni Camp	1M		N 26°36'03.3"E093°21'40.4"		✓
14/3/14	Borbeel Camp	1M		N 26°36'05.7"E093°20'59.1"		✓
21/4/14	Arimora Camp	1M		N 26°41'17.3"E093°20'57.1"	✓	
22/4/14	Borbeel Camp	1M		N26°36'15.9" E093°20'37.2"	✓	
28/4/14	Debeswari Camp	5M	2F	N26°44'33.5" E093°27'16.5"	✓	
29/4/14	Debeswari Tongi	2M	1F	N 26°44'00.7"E 093°27'45.0"	✓	
30/4/14	Debeswari grassland	4M		N 26°44'15.0"E093°26'30.5"	✓	
12/5/14	Panpur Camp	2M		N26°39'41.0" E092°56'21.1"	✓	
14/5/14	Siladubi Camp	1M		N26°39'50.8" E92°58'46.5"	✓	
17/5/14	Bhawani Camp	2M		N26°38'25.5" E093°12'51.1"	✓	
19/5/14	Murkhowa Camp	1M		N 26°37'37.4"E093°11'43.1"	✓	
21/5/14	Lohoroni Camp	1M		N26°36'03.1"E093°08'46.1"	✓	
26/5/14	Kote Tapu	4M		N 26°45'23.7"E093°19'53.0"	✓	
11/5/14	Panpur Camp		1F	N26°39'41.0" E092°56'21.1"		✓

Direct sightings: 25 males, 3 females

Sighting reports from other sources: 7 males, 1 female

Total Bengal Florican reports: 32 males, 4 females

Table 8: Bengal Florican detections at Nizamghat, Roing, Arunachal Pradesh in 2014

Date	Camp/ Range	Sex		Geographic coordinates	Observation	
		M	F		Direct	Secondary
5/3/2014	Nizamghat 007	4		N 28°13'37.5" E95°44'27.6"	✓	
5/3/2014	Nizamghat 007		1	N 28°13'37.5" E 95°44'27.6"		✓

**Table 9: Bengal Florican sightings confirmed by sources in Assam and Arunachal Pradesh (2014)**

Sr. No.	Date	Place	Geographic coordinates	Male	Female
1	03/09/14	Nizamghat (Arunachal Pradesh)	N 28°13'37.5", E 95°44'27.6"	0	1
2	04/01/14	Dungabeel Camp, Bagori, Kaziranga NP	N 26°35'19.5", E 93°16'31.2"	1	0
3	01/27/14	Tekaliphuta Area, Kohora, Kaziranga NP	N 26°41'57.3", E 93°23'28.0"	1	0
4	03/24/14	Tekaliphuta Area, Kohora, Kaziranga NP	N 26°41'32.4", E 93°22'30.3"	1	0
5	03/25/14	Maite Camp. Burapahar, Kaziranga NP	N 26°35'41.1", E 93° 05'56.3"	1	0
6	03/01/14	Lohoroni no 2 Camp. Burapahar, Kaziranga NP	N 26°35'52.4", E 93°07'43.5"	1	0
7	03/01/14	Maqbool Camp. Burapahar, Kaziranga NP	N 26°36'57.9, E 93°08'03."	1	0
8	03/08/14	Boloni Camp, Kohora, Kaziranga NP	N 26°36'03.5", E 93°21'40.6"	1	0
9	03/14/14	Borbeel Camp, Kohora, Kaziranga NP	N 26°36'15.9", E 93°20'37.2"	1	0
10	05/11/14	Panpur Camp, Northern Range, Kaziranga NP	N 26°38'55.7", E 92°56'17.6"	1	0

**Table 10: Bengal Florican sighting reports from secondary sources in Laokhowa-Burachapori Wildlife Sanctuary (2014)**

Date	Place	Geographic coordinates	Florican	Observers
18/5/2014	Jawani Camp	N 26°32'36.2" E 092°43'08.2"	2 males	Mintu Borah
15/3/2014	Majabil Chapori	N 26°35'11.8" E 092°38'16.2"	1 Male	Tarabir Chettery
05/7/2013	Siali-Lathimari	N 26°32'4.319" E092°38'52.699"	1 Male	Local villager
8/6/2014	Jahaj Tapu	N 26°35'40.5" E 092°43'47.9"	1 Male	Smarajit Ojah
12/7/2014	Jahaj Tapu	N 26°35'52.314" E092°48'17.831"	2 Male	Smarajit Ojah

Our research team did not detect any Bengal Florican in Laokhowa-Burachapori Wildlife Sanctuary. However, we have compiled records from earlier reports and sighting records from our volunteers (Table 10).

#### Field surveys (2015-16)

In 2015 and 2016, all grasslands in and around Dudhwa and Pilibhit reserves were surveyed. In Assam, an extensive survey was conducted in the Brahmaputra river (see chapter IV). Between March and June 2016, protected and non-protected grasslands of Assam and Arunachal Pradesh were surveyed for Bengal Florican and other grassland birds (Rahmani et al. 2016).

#### Uttarakhand survey in 2014

Potential sites for Bengal Florican based on the results of a presence-only predictive distribution modelling (maximum entropy) exercise using survey data from 2013, were identified. The results highlighted forest regions in three Forest Divisions in the state of Uttarakhand with high probability of occurrence, namely Haldwani Forest Division, Terai East Forest Division and Terai Central Forest Division. These three Forest Divisions combinedly cover areas of three districts i.e. Haldwani, Uddhamsingh Nagar and Champawat. These Forest Divisions are situated in the Gangetic plains and comprises of forests with a combination of *bhabhar* and *terai* tracts.

Road transect method was used to survey predicted sites. Geographic co-ordinates and habitat information of sites were noted. Forest staffs of the respective ranges were interviewed to gather information on the presence of any potential grassland habitat for Bengal Florican in the proximity of their respective areas. Members of local wildlife NGOs too were interviewed in order to gather reliable information.

On February 25, 2014, we surveyed the Pipalpadav, Gadgadiya, Bhakda and Tanda ranges of Terai Central Forest Division and Gola Range of Terai East Forest Division. The predicted sites majorly comprised of mosaic of dry and moist deciduous forest along with forest plantation of teak and eucalyptus. Next day, we surveyed Kishanpur and Barakoli ranges of Terai East Forest Division, but no grassland habitat was found.

On the third day, Ransali and Jaulasal areas near Tanakpur Range were surveyed. These ranges comprise generally of Sal-dominated forest, along with dispersed bamboos and forest plantations. On February 28, we surveyed the southern most ranges of Terai East Forest Division i.e. Khatima Range and Surai Range. No natural grassland was found during this period of survey, except for a very small patch of grassland in Surai Range, which seemed unsuitable for Bengal Floricans on the face of it.

On May 28 and 30, 2014, during the second phase of our survey, three patches of grasslands were located in Surai Range of Terai East Forest Division with the assistance of Terai East Forest Department staff. The locations of the grasslands are N 28° 45' 08.1" E 80° 01' 38.2" (Patch 1), N 28° 46' 08.7" E 80° 02' 35.0" (Patch 2), and N 28° 46' 28.2" E 80° 02' 33.8" (Patch 3). Although all three patches seemed suitable for Bengal Florican, we did not see any bird on those days.

During interviews with forest staff of Surai Range, information about recent sightings of one male Bengal Florican in the month of March 2014 and one male Lesser Florican (deduced from the description by local staff) in the beginning of the monsoon season in year 2012 in Surai Range was revealed.

### Satellite Telemetry

Earlier research work related to bird migration was mainly based on ring recovery data. Satellite tracking offers more details about animal migration routes, wintering ground, home range, behavior, habitat use and habitat selection (Bobek *et al.* 2008, Seegar *et al.* 1996). In the past, many bird species such as cranes (Kanai *et al.* 2002), Bar-tailed Godwits (Gill Jr. *et al.* 2008), pelicans (Izhaki *et al.* 2002), raptors (Hake *et al.* 2001), White Storks (Berthold *et al.* 2001 and 2002) and Black Stork (Bobek *et al.* 2008) have been tracked successfully during and after migration.

In India, BNHS scientists have deployed Platform Terminal Transmitters (PTTs), a kind of satellite transmitter, on nearly 150 birds over the years (Gilbert *et al.* 2010, Hawkes *et al.* 2011, Iversen *et al.* 2011, Newman 2012). In UP, four Bar-headed Geese were trapped and deployed with PTTs at Sur Sarovar Bird Sanctuary near Agra (Kalra *et al.* 2011). More recently, two Bar-headed Geese and two Black-necked Cranes were studied through satellite tracking in Ladakh, Jammu and Kashmir (WII 2014).

Details of how Bengal Floricans were trapped for the present study in order to study their movements are in Chapter II.

Table 11: Bengal Forican tagging sites in Pilibhit and Dudhwa reserves

Date of capture	Date of first transmission	Site (PA)	Latitude	Longitude	Bird code (PTT-serial)	Ring-serial	Animal weight (kg)	Capture time	Release time
09-05-2014	09-05-2014	Bhimtal, Compartment 105 (Pilibhit TR)	28.7153	79.99741	Pilibhit1 (123078)	K-3231	-	1740	1754
14-05-2014	14-05-2014	Chougebi grassland, Compartment 105 (Pilibhit TR)	28.70775	80.01236	Pilibhit2 (123079)	K-3232	1.41	1710	1728
16-05-2014	16-05-2014	Chougebi grassland, Compartment 105 (Pilibhit TR)	28.70015	80.01091	Pilibhit3 (123080)	K-3233	1.42	1810	1823
27-06-2015	29-06-2015	Chandan chowki 2 <sup>nd</sup> rail crossing <i>phanta</i> (Dudhwa NP)	28.4985	80.70474	Dudhwa1 (136675)	K-3234	-	1905	1930

## Chapter II

### Bengal Florican- Pilot Satellite Telemetry Study

#### INTRODUCTION

##### Grassland ecosystem

Grasslands are dynamic ecosystems encompassing all natural and semi-natural pastures, woodlands, scrub, and steppe formations dominated by grasses and grass like plants (Blair *et al.* 2014). Grasslands not only provide vital ecosystem services such as water and climate regulation in support of agriculture, biogeochemical cycling, carbon storage, cultural and recreational services, but also form backbone of livelihoods for pastoral communities (White *et al.* 2000). In addition, they form critical habitat for a variety of wild herbivores and other faunal groups for their breeding, migration and wintering activities (Rahmani 2006, Verma and Prakash 2007). In spite of providing a wide variety of such crucial ecosystem services, grasslands continue to be one of the most threatened and relatively least protected biome on Earth (Jenkins and Joppa 2009).

In the last few centuries, grasslands have proved easy for conversion to agriculture, forest monoculture plantations, urbanization and other land uses such as energy and mining development (Sala *et al.* 2013). Grasslands across the world were once home to some of the greatest assemblages of wildlife, but the remaining few intact and largely fragmented indigenous grasslands now support only their remnant populations.

##### Satellite telemetry project to better understand Bengal Florican ecology

As an applied branch of ecology, conservation science is fundamentally concerned with understanding why species distribution and abundance patterns vary in time and space (Flather *et al.* 2009). Spatial patterns of movement are fundamental to the ecology of animal populations, pervasively influencing life activities such as their social organization, mating systems, demography, and the spatial distribution of prey and competitors. This is especially crucial when such knowledge is essential to address emergent biodiversity conservation challenges such as the effects of climate and land use change on species geographic ranges, spread of exotic invasive species and infectious diseases on native biota (Nathan *et al.* 2008).

Animal tracking data help biologists understand how individuals and populations move within local areas and/or migrate across large distances with changing seasons. This knowledge is important towards designing an effective Protected Area (PA) network and devising appropriate species and habitat management regimes in consonance with observed ranging patterns (Calabrese *et al.* 2016). Scientists have been systematically tracking individual animal movements since around 1900, when the first bird ringing (also known as bird banding) schemes were started in Germany (Fiedler 2009).

Since those initial studies, improved communication systems, shrinking battery sizes, and other technological developments through the twentieth century have led to a range of methods for

tracking animals. Conventional radio telemetry using very high-frequency (VHF) tags have been and are still being used in numerous studies in different regions. However, the use of VHF technology is generally restricted to a relatively smaller area or to species with restricted movements, further limited by topological constraints such as hilly terrain or dense vegetation, where getting signals and following animals is often difficult (Javed *et al.* 2003).

In 1978, the Argos satellite system was created by the French Space Agency (the Centre National d'Etudes Spatiales, or CNES), the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA), originally as a scientific tool for collecting and relaying meteorological and oceanographic data around the world. Argos is a unique worldwide location and data collection system dedicated to studying and protecting the environment. This provided a new method for tracking animals globally.

In 1986, CNES created a subsidiary, Collecte Localisation satellite (CLS), to operate, maintain and commercialize the system. Currently, several other international space agencies like the European Organization of the Exploitation of Meteorological Satellites (EUMETSAT), the Indian Space Research Organization (ISRO) and others also actively participate in the Argos system. Ultra-high frequency (UHF) Platform Transmitter Terminal (PTT) devices, kind of satellite radio-transmitters, can uplink different information like location or sensor data etc. to the Argos system and distribute it to end users (for more details see: <http://www.argos-system.org>).

Location by such PTT devices is calculated by the Doppler shift in the transmitted frequency as low (about 850 km above Earth) polar-orbiting satellites, operated by the Argos system and equipped with UHF receivers, approach and then move away from each PTT (Seegar *et al.* 1996). Transmission data are relayed to ground stations on Earth and are then electronically forwarded to processing centres in the US and France after which geographic coordinates are made available to researchers over the internet within two hours. Argos categorizes each location fix into one of seven location classes (LC): Z, B, A, 0, 1, 2, and 3, in ascending order of accuracy (Table 12).

Combining the current state-of-the-art technology of remote sensing and GIS (Geographic Information Systems) with satellite telemetry, it is now possible to quickly, efficiently and accurately compile critical habitat information for conservation of species, especially for vagile animal species (Olival and Higuchi 2006) which exhibit cryptic and shy behaviour.

In recognition of the myriad uses and benefits of this technology, there is an increase in interest among biologists, managers and various conservation organizations in such studies (Javed *et al.* 2003). While historically a lack of movement data limited progress, recent and continuing technological advances have fuelled an explosion of tracking studies in recent times (Gilbert *et al.* 2010, Hawkes *et al.* 2011, Iversen *et al.* 2011, Kalra *et al.* 2011, Kays *et al.* 2015, Newman 2012).

Table 12: Accuracy of various category Argos-PTT location fixes

Class	Estimated accuracy in latitude and longitude
3	≤ 150 metres
2	150 m < accuracy < 350 m
1	350 m < accuracy < 1000 m
0	> 1000 m
A	no estimate of location accuracy
B	no estimate of location accuracy
Z	(invalid locations)

BNHS, in collaboration and with the support of the state Forest Departments of Uttar Pradesh, Uttarakhand, Bihar, Assam and Arunachal Pradesh, and with grants from the Ministry of Environment and Forests (MoEF) along with some funds of BNHS from other sources, began a pilot satellite telemetry project on Bengal Floricans in India in 2013. A similar project was executed in Nepal as well by the non-profit Bird Conservation Nepal (BCN) and Darwin Initiative, UK where BNHS has given inputs with respect to designing appropriate survey techniques and trapping Bengal Floricans to deploy satellite-tracking devices.

The specific objectives of this part of the study were as follows:

1. Assemble a long-term multi-year dataset and enhance our understanding of Bengal Florican movements and habitat-use utilising tools in the remote sensing and GIS domain;
2. Quantify home range sizes; and
3. Determine seasonal home range patterns, especially hitherto unknown non-breeding locations, for adult birds.

## METHODOLOGY

### Deploying PTT-transmitters on Bengal Floricans in Uttar Pradesh

We used solar PTTs manufactured by Microwave Telemetry, Inc. (model PTT-100) weighing 35 g (Microwave Telemetry Inc., Columbia, Maryland, USA) for the present study. The charging of this PTT is microprocessor controlled, and needs about four hours of outdoor exposure to direct sunlight to power the device for 24 hours. The solar duty cycle timer regulates the battery charge control and commands the PTT to transmit during the "ON" time of its duty cycle, depending on the state of the charge of the battery. The 35 g solar PTT also transmits data from temperature, battery voltage and activity sensors.

The PTTs were programmed for a duty cycle of 10 hours "ON" and 24 hours "OFF" (see: <http://www.microwavetelemetry.com> for more information). Such an approach helps conserve the batteries and provide enough time for adequate recharging from the solar panel. The PTT cycles were offset from the 24-hour daily cycle to avoid transmission at the same time each day. "On" periods, therefore, occurred at different times of the day and alternated between nocturnal and diurnal transmissions.

Table 13: Number of locations obtained from www.movebank.org from May 2014 to December 2016

Bird	Tagging Date	LC 1	LC 2	LC 3
Pilibhit 1	09-May-14	557	948	2052
Pilibhit 2*	14-May-14	61	111	268
Pilibhit 3	16-May-14	535	909	2001
Dudhwa 1	27-Jun-15	245	492	1376

\* signals ceased coming from August 20, 2014

With all requisite permissions in place, a BNHS team comprising of researchers and expert animal-trappers reached Pilibhit Forest Division (now Pilibhit Tiger Reserve, or PTR) in April 2014. Initially, movements of five Bengal Florican males were studied systematically for several weeks during the birds' peak activity periods (early morning and late evening). During the short breeding period window of about three-and-half to four months (March-June), adult Bengal Florican males become extremely territorial. During this period, they also perform an elaborate 'aerial display' (Sankaran and Rahmani 1990) purportedly to attract the usually shy and secretive females (which do not perform any such 'display') and demonstrate its territorial hold. Many a time, locations within the territory from where the territorial males display are also more or less fixed. Overall, this makes the males more visible during this period with predictable movements.

Taking advantage of this breeding biology knowledge of Bengal Floricans, BNHS researchers selected places within the males' territories, usually at or near their display locations, where noose traps could be laid to capture the birds. Subsequently, these traps were laid in the second week of May 2014. Within a few days, three Bengal Florican individuals (all coincidentally males) were captured by the team in the grasslands of Mahof range and a PTT-tag each was strapped on them.

Transmitters were attached to the back of floricans with a Teflon tape harness using a standard backpack configuration. Taking body weight into account, the transmitter and harness weights were approximately 3 % of the body mass of the captured birds, well below the general rule-of-thumb of 4% (Bander and Cochran 1991).

A need was subsequently felt to investigate the movements of Bengal Floricans residing in Dudhwa National Park's (DNP) grassland *phantas*, whether they too exhibited similar movement and behaviour as the Pilibhit tagged birds, and whether they too chose similar habitats during the non-breeding season. Accordingly, with all prior permissions in place, a plan was made to attempt to capture and tag the often-sighted territorial male at the Chandan Chowki *phanta* (second railway crossing on the Dudhwa-Chandan Chowki road) in June 2015.

After systematically studying the territorial male bird's movements during its usual peak activity periods (early morning and late evening) for several days, traps were finally laid by a BNHS expert team comprising of experienced trappers and researchers from June 24 onward. After two unsuccessful days/attempts and near-misses, the bird was finally captured and PTT-tagged on the late evening of June 27, 2015. Details of birds captured and tagged with PTT devices for this research project is mentioned in Table 11.

Table 14: Details of tagged birds' movement during 2014-2016

Bird ID	Year	Breeding location	Site/PA	Breeding-arrival	Distance travelled (km)	Breeding location- duration	Post-breeding movements	Post-breeding movements- duration	Non-breeding-arrival	Non-breeding- locality	Transit	Distance travelled (km)	Non-breeding- departure	Stay duration
Pilibhit1	2014-15	BheemTaal, Mahof	Pilibhit TR	NA (May 09, 2014 *)	NA	NA	nil	0	August 29-31, 2014	Tattargani, District Pilibhit	0-4 days	~ 23.4	March 29-31, 2015	211-215 days
	2015-16	BheemTaal, Mahof	Pilibhit TR	March 31 - April 01, 2015	~ 22.3	110-112 days	July 19-20 to September 22-23, 2015	64-66 days	September 23-24, 2015	Tattargani, District Pilibhit	0-3 days	~ 22.9	March 12-14, 2016	172-175 days
	2016	BheemTaal, Mahof	Pilibhit TR	March 12-14, 2016	~ 22.0	123-126 days	July 15-16 to September 05, 2016	51-52 days	September 05, 2016	Tattargani, District Pilibhit	0	~ 20.6	NA #	NA #
Pilibhit2	2014	Comp.105 (Chougebi), Mahof	Pilibhit TR	NA (May 12, 2014 *)	NA	NA	July 02 to 22-23, 2014	21-22 days	July 25-26, 2014	Tattargani, District Pilibhit	3-5 days	~ 21.7	NA ^	NA ^
Pilibhit3	2014-15	Comp.105 (Chougebi), Mahof	PilibhitTR	NA (May 16, 2014 *)	NA	NA	July 11-13 to September 17-18, 2014	66-69 days	September 21, 2014	Tattargani, District Pilibhit	3-4 days	~ 26.4	March 30-31, 2015	191-192 days
	2015-16	Comp.105, Mahof	PilibhitTR	March 31 - April 02, 2015	~ 23.7	110-112 days	July 20 to September 13-14, 2015	56-57 days	September 14-15, 2015	Tattargani, District Pilibhit	1-3 days	~ 18.2	March 12-14, 2016	180-183 days
	2016	Comp.105, Mahof	PilibhitTR	March 12-14, 2016	~ 27.4	116-119 days	July 07-08 to September 05, 2016	50-51 days	September 05, 2016	Tattargani, District Pilibhit	0	~ 23.6	NA #	NA #
Dudhwa1	2015-16	Chandan chowki, 2nd rail crossing	Dudhwa NP	NA (June 29, 2015 *)	NA	NA	July 27-28 to August 02, 2015	6-7 days	August 03-05, 2015	Ramnagar, District Kheri	1-3 days	~ 22.0	March 22-23, 2016	231-234 days
	2016	Chandan chowki, 2nd rail crossing	Dudhwa NP	March 31 - April 01, 2016	~ 19.3	103-105 days	July 12-13 to 16-18, 2016	4-7 days	July 16-18, 2016	Ramnagar, District Kheri	0-3 days	~ 18.3	NA #	NA #

\* date of first transmission # satellite data still being received ^ location data ceased being received from August 20, 2014 onward

**Table 15: Breeding season home ranges (in hectares) of PTT-tagged Bengal Floricans in 2014, 2015 and 2016 (all home range figures are reported in hectares)**

Bird ID	Year	# points	MCP 50	MCP 95	KUD (core) (50%)	KUD (outer) (95%)
Pilibhit1	2014	277	22.44	178.65	27.66	191.85
	2015	202	21.07	182.7	29.89	212.82
	2016	277	65.42	305.1	28.75	200.99
Pilibhit2	2014	92	23.58	146.15	39.77	203.14
Pilibhit3	2014	148	70.07	428.68	72.78	331.86
	2015	237	121.19	798.12	85.69	539.39
	2016	269	46.6	480.03	36.67	279.97
Dudhwa1	2016	278	11.45	88.49	13.42	84.77
average		222.50	47.73	325.99	41.83	255.60
S.D.		70.10	36.76	235.62	24.59	135.10

**Table 16: Non-breeding season home ranges (in hectares) of PTT-tagged Bengal Floricans in 2014-2015 and 2015-2016 (all home range figures are reported in hectares)**

Bird ID	Year	# points	MCP 50	MCP 95	KUD (core) (50%)	KUD (outer) (95%)
Pilibhit1	2014-15	358	145.06	891.5	109.19	636.39
	2015-16	322	141.68	560.97	61.49	302.58
Pilibhit3	2014-15	311	143.91	1332.32	97.3	574.2
	2015-16	390	109.65	1417.12	48.69	382.96
Dudhwa1	2015-16	509	357.98	2909.23	166	813.12
average		378.00	179.66	1422.23	96.53	541.85
S.D.		79.58	100.77	900.38	46.11	203.76

#### Computing home-ranges of PTT-tagged birds

We computed traditional estimators of home range in the form of 50 percent and 95 percent minimum convex polygons (MCP) as well as 50 percent (core) and 95 percent (outer) kernel utilization distributions (KUD) for the four PTT-tagged birds during breeding and non-breeding seasons separately through the years 2014-16 (May 2014 up till July 2016). For this purpose, we used only high accuracy location fixes belonging to class LC3. A high frequency of LC3 data transmissions in the present study (Table 14) permitted us to do this as using the relatively inaccurate data points may have overestimated home ranges, since errors with these PTTs have been found to be higher than those quoted by Argos (Nicholls and Robertson 2007, Thomas *et al.* 2010).

The data locations were recorded in latitude/longitude WGS84 and were transformed to the appropriate projection zone (44N) in the Universal Transverse Mercator (UTM) for analysis. Movement-based maps were generated using a Geographic Information System (GIS) (QGIS Development Team 2016). Home range estimates (MCP and Kernel UD) were calculated using the 'adehabitathR' package (Calenge 2015) within the open-source analytical software R (version 3.3) (R Core Team 2016).

MCP estimators are thought to overestimate space use (Kenward *et al.* 2001); however, they were used here to enable comparison with other studies and to map the maximum area potentially required by each adult bird. A kernel-based home range utilising the 95% probability contour was used as a second measure to reduce outlier bias (Fieberg and Kochanny 2005, Thomas *et al.* 2010). The least-squares cross validation procedure was used to determine the smoothing parameter (Seaman and Powell 1996). The number of points used to generate seasonal utilization distributions ranged from 92 to 509, providing robust kernel density estimates (KDE) (Seaman *et al.* 1999).

**Table 17: Paired t-test between differences in tagged Bengal Floricans' breeding and non-breeding core-use home ranges (KUD 50) (hectares) were statistically not significant**

Bird ID	Year/Season	KUD 50 (breeding) (hectares)	KUD 50 (nonbreeding) (hectares)	p-value	df	t-score
Pilibhit1	2015-16	28.75	61.49	0.2721	2	1.5015
Pilibhit3	2015-16	36.67	48.69			
Dudhwa1	2015-16	13.42	166			

**Table 18: Paired t-test between differences in tagged Bengal Floricans' breeding and non-breeding outer home ranges (MCP 95) (hectares) were statistically not significant**

Bird ID	Year/Season	MCP 95 (breeding)	MCP 95 (nonbreeding)	p-value	df	t-score
Pilibhit1	2015-16	305.1	560.97	0.2232	2	1.7442
Pilibhit3	2015-16	480.03	1417.12			
Dudhwa1	2015-16	88.49	2909.23			

Although KDE assumes that the data are independent and identically distributed, we did not consider autocorrelation between location fixes as a significant factor influencing our home-range estimates since multiple simulation-based evaluations (Blundell *et al.* 2001, Fieberg 2007) have shown that subsampling data in order to achieve serial independence of observations is counter-productive and results in reducing the biological relevance of such derived home range estimates (De Solla *et al.* 1999, although see Fleming *et al.* 2015 presenting a more refined approach).

The PTT-tag for bird 'Pilibhit2' failed in the third week of August 2014 near Tattarganj due to unknown reasons (device failure, tag detachment, death of the bird), and thus its non-breeding home ranges could not be computed. However, the bird had already vacated its breeding territory at PTR by then (on July 22) and there were enough location fixes to compute its breeding home range for the year 2014. Similarly, the breeding home range of 'Dudhwa1' could not be computed for the 2015 season since the bird was captured late into the breeding season in June 2015 and we obtained too few high-accuracy locations points until it vacated its breeding territory.

### **Relating vegetation phenology to habitat-use and movement patterns**

Vegetation indices are quantitative measures that attempt to measure vegetation biomass or vegetative vigour. Satellite-derived vegetation indices, such as the normalised difference vegetation index (NDVI), has been established as a crucial tool for assessing past and future animal population and biodiversity consequences of change in climate, vegetation phenology, and primary productivity (Petorelli *et al.* 2011). NDVI essentially is a measure of vegetation 'greenness' based on the ratio between near-infrared and visible reflectance (i.e.,  $(\text{NIR}-\text{VIS})/(\text{NIR}+\text{VIS})$ ) (see: <http://earthobservatory.nasa.gov>). NDVI values range from -1.0 to +1.0, with negative values indicating surfaces with little or no vegetation (i.e. barren ground, water, rock) and positive values indicating increasing amount of green vegetation.

NDVI has also proven to be extremely useful to ecologists dealing with assessing and correlating ecological responses to environmental change (Petorelli 2013). Specifically, NDVI data can be used to characterize broad scale movement patterns in animals' response to phenological shifts across

**Table 19: Paired t-test between differences in mean NDVI values at tagged Bengal Floricans' breeding territories during the breeding and non-breeding seasons**

Bird	Period	NDVI-breeding (mean ± S.E.)	Period	NDVI- non-breeding	p-value	df	t-score
Dudhwa1	March 21 - July 10, 2016	0.554 ± 0.014	July 11, 2015 - January 10, 2016	0.699 ± 0.01	0.009	2	10.458
Pilibhit1		0.446 ± 0.012		0.636 ± 0.01			
Pilibhit3		0.483 ± 0.012		0.627 ± 0.01			

**Table 20: Paired t-test between differences in mean NDVI values at tagged Bengal Floricans' breeding territories and NDVI associated with non-breeding 'use' during the given period**

Bird	Period	NDVI- non-breeding 'use' (mean ± S.E.)	NDVI- breeding territory	p-value	df	t-score
Dudhwa1	July 21 - September 20, 2016	0.412 ± 0.018	0.728 ± 0.017	0.2359	2	1.675
Pilibhit1		0.635 ± 0.016	0.684 ± 0.018			
Pilibhit3		0.65 ± 0.023	0.718 ± 0.016			

**Table 21: Paired t-test between differences in mean NDVI values at tagged Bengal Floricans' breeding territories and NDVI associated with non-breeding 'use' during the given period**

Bird	Period	NDVI- non-breeding 'use'	NDVI- breeding territory	p-value	df	t-score
Dudhwa1	September 21 - November 20, 2016	0.417 ± 0.017	0.767 ± 0.007	0.2359	2	1.675
Pilibhit1		0.438 ± 0.019	0.706 ± 0.009			
Pilibhit3		0.521 ± 0.017	0.681 ± 0.007			

**Table 22: Paired t-test between differences in mean NDVI values at tagged Bengal Floricans' breeding territories and NDVI associated with non-breeding 'use' during the given period**

Bird	Period	NDVI- non-breeding 'use'	NDVI- breeding territory	p-value	df	t-score
Dudhwa 1	November 21, 2015 - January 20, 2016	0.254 ± 0.013	0.542 ± 0.017	0.2359	2	1.675
Pilibhit 1		0.395 ± 0.013	0.501 ± 0.009			
Pilibhit 3		0.439 ± 0.01	0.389 ± 0.01			

home ranges (Mueller *et al.* 2008), providing an understanding of movement that can be applied to the conservation and restoration of ecosystems and landscapes (Chynoweth *et al.* 2015).

PROBA-V is a miniaturised European Space Agency satellite tasked with a dedicated mission to map land cover and vegetation growth across the entire planet every two days (see <https://earth.esa.int/ESA> for more details), and provides such data free-of-cost to the public. To determine if movement patterns relate to patterns in vegetation phenology, we used relevant PROBA-V ('V' stands for vegetation) ten-day composite NDVI data sets acquired through [www.vito-eodata.be](http://www.vito-eodata.be) at 333-m resolution associated with birds' high-accuracy location fixes. The resolution of downloaded imagery was in consonance with our high-accuracy Argos location fixes (c.150 m radius accuracy).

We used two-sided (or two-tailed) paired Student's t-test (Student 1908) to examine differences in mean NDVI values during the breeding and non-breeding seasons at breeding territories, as well as between mean NDVI values associated with the birds' post-breeding habitat 'use' during different periods with corresponding values at their core breeding territories. The paired t-test compares the

means of two matched groups, assuming the distribution of the before-after differences (in our case differences in NDVI during and after breeding season) follows a Gaussian distribution. Two-tailed significance values were reported as the hypotheses were two-sided, and significance was assessed at  $\alpha = 0.05$ . Although we usually worked with a very low sample-size (only four tagged birds), paired t-tests have been shown to be feasible with sample sizes as low as even two if the within pair correlation is high, although such research findings must be cautiously interpreted (de Winter 2013).

We were not able to use the Mann-Whitney U-test due to restrictions imposed by a low sample size in this study ( $n < 5$ ). The Welch test too was not used since it tends to reduce statistical power (de Winter 2013). All phenology-movement analyses were performed in ArcMap (ArcGIS ArcMap 10.4, Environmental Systems Research Institute Inc., Redlands, CA, USA) and within the open-source analytical software R (R Core Team 2016).

## RESULTS

All results presented in this section must be carefully and modestly interpreted with the knowledge that these have been derived from only four adult territorial male birds tagged with satellite devices at two reserves within a single landscape unit.

### **Movement of PTT-tagged birds during 2014-16**

#### ***Movement of birds 'Pilibhit1', 'Pilibhit2' and 'Pilibhit3' during 2014-15***

The three birds satellite-tagged in the Mahof range of PTR were christened as 'Pilibhit1', 'Pilibhit2' and 'Pilibhit3'. The centres of their breeding territories in the reserve were determined to be as follows:

Pilibhit1: N 28.71521°, E 79.99815° (Near Bheem Taal)

Pilibhit2: N 28.70858°, E 80.01077° (Chougebi, compartment 105)

Pilibhit3: N 28.70306°, E 80.01212° (Chougebi, compartment 105)

'Pilibhit2' was the first of the three tagged birds to leave its core breeding territory on July 02, 2014 itself even if it occupied other close-by situated grasslands in PTR up till July 22-23. Subsequently, it flew to Tattarganj (N 28.748596°, E 80.210950°), an area close to the Sharda river near the Indo-Nepal international border, about twenty-two km eastward from its breeding territory, reaching there between July 25-26, 2014 (Map 19). Unfortunately, signals ceased coming from this bird from August 20, 2014 onward due to reasons stated earlier.

'Pilibhit1' occupied its core breeding territory near Bheem Taal right up till August 28-29, 2014 without exhibiting any post-breeding movement. Thereafter, it flew straight to Tattarganj about twenty-three km eastward across river Sharda reaching there between August 29-31, 2014 (Map 18).

'Pilibhit3' though, interestingly, left its core breeding territory on July 11, 2014 itself but continued its stay near close-by grasslands inside the reserve in compartment 105 up till August 08-09, 2014. Thereafter, it travelled around five km northward to reach the fenced/protected grassland patches near Baggha village in the Surai range of the Terai East Forest Division in the state of Uttarakhand abutting the Mahof range of PTR. The bird stayed there for about twenty days before it travelled back to the reserve near its core breeding territory in compartment 105 between September 01-02, 2014.

After about a week's stay here, the bird flew back to Baggha's protected grassland patches to stay there for another ten to eleven days, before ultimately flying across river Sharda towards its non-breeding abode sometime between September 17-18, 2014. The bird subsequently reached Tattarganj on September 21, 2014 traversing about twenty-six km as the crow flies (Map 20).

The PTT-tagged birds subsequently spent the next six to seven months in and around Tattarganj in the Sharda river's floodplain-agriscape dominated by crops such as sugarcane, mustard, lentil, rice and wheat, occasionally making short-distance and small duration forays into neighbouring Nepal as well in the buffer area of Suklapahanta Wildlife Reserve. During this entire duration, the birds exhibited few large-scale movements (> 5 km) even if they exhibited frequent nomadic movements within the larger area in consideration, possibly driven by time-specific agricultural activities such as burning of fields prior to next season's sowing, harrowing-sowing and crop harvesting (Figure 22).

More importantly, the birds did not make any sorties to their breeding territories in PTR. Yet, between March 31 and April 02, 2015, both the transmitting PTT-tagged birds returned to exactly their same breeding territories as in 2014 where they were captured in the first place. This phenomenon of site-fidelity is prevalent among many bird species, and is particularly well-documented in the bustard family (Rahmani 1989).

#### **Movement of birds 'Pilibhit1', 'Pilibhit3' and 'Dudhwa1' during 2015-16**

Upon the return of 'Pilibhit1' and 'Pilibhit3' to their same respective breeding territories in PTR in April 2015, both the birds exhibited a fair degree of short local movements post the breeding season from late July onward within the larger compartment 105 grassland (Chougebi) area. Notably, 'Pilibhit3' came to 'share' a large proportion of 'Pilibhit1's core breeding territory near Bheem Taal grassland for a period of about fifty days during May 01 to July 20, 2015 (Figure 18, 2015 and Map 28).

Subsequently, while 'Pilibhit3' continued its local movements in different patches of grasslands within compartment 105 of Mahof range from July-end till mid-September, 'Pilibhit1' flew approximately four km northward to reach the fenced/protected grassland patches near Baggha village in the Surai range of the Terai East Forest Division in the state of Uttarakhand abutting PTR's Mahof range between July 19-20, 2015, mimicking 'Pilibhit3's movement during the previous year. After exhibiting much short-scale 'post-breeding movements' within various grassland areas inside PTR and in Baggha's protected/fenced grassland patches, both birds ultimately flew to river Sharda's floodplain-agriscape near Tattarganj yet again to spend their non-breeding period there (Maps 21, 22). While 'Pilibhit3' reached there slightly earlier sometime on September 13-14, 2015, 'Pilibhit1' reached on September 22-23, 2015 traversing approximately twenty-three and twenty-four km respectively from their breeding territories as the crow flies.

As during 2014-15, both 'Pilibhit1' and 'Pilibhit3' birds spent about six months at Tattarganj during 2015-16 as well exhibiting frequent short-scale movements in the larger area occupying different patches at different points of time, perhaps driven by anthropogenic activities. As the breeding season neared, both birds almost simultaneously departed from Tattarganj to arrive at their respective breeding territories between March 12 and 14, 2016. There was a considerable degree of overlap between areas used by different birds during the latter half of both non-breeding seasons.

After being strapped with a PTT-tag on June 27, 2015, 'Dudhwa1' vacated its Chandan chowki 2<sup>nd</sup> rail crossing grassland *phanta* breeding territory between July 27-28, 2015. Thereafter, it stayed for a few days in grassland patches within the Dudhwa National Park's Sonaripur range around Bhaadi Taal and Sonaripur Forest Rest House. By August 02, 2016, the bird flew away from here as well and ventured outside the south-eastern boundary of DNP and stayed for a couple of days in paddy fields around villages Bhagwant Nagar and Ballipur. The bird finally moved to and settled in the floodplain-agriculture near river Sharda's northern bank (N 28.28990°, E 80.66006°) further south off Murgaha village between August 03-05, 2015, traversing a total of approximately twenty-two km from its breeding territory inside DNP (Map 23).

Thereafter, 'Dudhwa1' displayed a considerable and significantly wider breadth of local movement within the larger floodplain agriculture than the two Pilibhit birds (figure 13). After spending slightly less than eight months (231-234 days) in such areas, 'Dudhwa1' initiated the journey back to its breeding territory sometime between March 22-23, 2016 and reached its very same grassland *phanta* territory from where it was captured sometime between March 31 and April 01, 2016 displaying tremendous site-fidelity/site-faithfulness. Subsequently, at the onset of monsoon in July 2016, and in spite of certain habitat restoration/management efforts designed to suppress the urge of the bird to fly away (see chapter III), 'Dudhwa1' vacated its breeding territory on July 12, 2016. During the 2015-16 non-breeding season though, the bird occupied areas as far as 50 km away from its breeding territory in the Sharda river floodplain-agriculture.

In a nutshell, Bengal Floricans were strongly site faithful in both breeding (much stronger) and non-breeding ranges (relatively weak) (Figures 16, 17). Migratory floricans were tracked to non-breeding areas, up to 50 km from breeding sites. Birds from PTR and DNP did not overlap in non-breeding areas, although they occupied similar habitats (floodplain-agricultures). A concurrent satellite-tracking study in Nepal at Suklaphanta Wildlife Reserve revealed that birds from Pilibhit and Suklaphanta reserves frequently crossed borders near Tattarganj/Suklaphanta buffer during the non-breeding season. While Bengal Floricans exclusively used open grassland savanna habitats within PAs away from human disturbance during the breeding season, they avoided intensively cultivated agriculture areas and forested areas during the non-breeding season.

#### **Season-wise home ranges of PTT-tagged birds during 2014-16**

Season-wise (breeding and non-breeding) home ranges for all the four PTT-tagged birds is presented in tables 15 and 16. For all home range calculations, we used only the high-accuracy location fixes (of class LC3) from the PTT-tagged birds.

We delineated breeding season as between the day of arrival of birds at their respective breeding territories till the first local movement exhibited outside of their core territories during any time in July when the breeding season ends. We have considered the local short-scale movements of birds within grasslands in PTR/DNP/Baggha (during July to September) until their departure to their non-breeding areas as 'post-breeding nomadic movements'.

The average MCP 50 and KUD 50 (denoting the birds' core home range) home range sizes of the four PTT-tagged birds across three breeding seasons (2014-16) is  $47.73 \pm 36.76$  and  $41.83 \pm 24.59$  hectares respectively. Similarly, the average MCP 95 and KUD 95 (denoting the birds' overall home ranges discounting outliers) is  $325.99 \pm 235.62$  and  $255.60 \pm 135.1$  hectares respectively.

Similarly, the non-breeding season is delineated as between the day of arrival of birds at their final non-breeding destination in the Sharda river floodplain-agriculture (Tattarganj/Ramnagar-Gadiyana) till they leave such areas at the onset of the next breeding season.

The average MCP 50 and KUD 50 (denoting the birds' core-use areas) home range sizes of three of the four ('Pilibhit2' did not have enough data) PTT-tagged birds across two non-breeding seasons (2014-15 and 2015-16) was much larger than the corresponding breeding area ranges at  $179.99 \pm 100.77$  and  $96.53 \pm 46.11$  hectares respectively. Similarly, the average MCP 95 and KUD 95 (denoting the birds' overall home ranges discounting outliers) home range sizes during the non-breeding season too were much larger than the corresponding figures for the breeding season at  $1422.23 \pm 900.38$  and  $541.85 \pm 203.76$  hectares respectively.

Notably, the differences in home range sizes (compared for three birds during 2015-16) between breeding and non-breeding seasons were not statistically significant across any of the metrics, whether MCP or KUD (Tables 17, 18). This may have been a result of the low sample size and large variation between home range sizes of the three birds.

#### **Correlation between habitat-use, movement pattern and habitat quality**

After the first season's movement data was received from birds tagged at PTR, we hypothesised that birds were perhaps 'forced' to move away from their established breeding territories inside safe and well protected reserves to the relatively unsafe environs of an agricultural landscape as grassland habitats inside PAs became 'unsuitable' for Bengal Floricans.

With the advent of monsoon rains from mid-June to July onward, grass growth is greatly accelerated and attain an average height of about 2 metre soon enough with very few available short to medium grass patches around. Since the Wildlife (Protection) Act (MoEF 1972) does not allow for any harvesting activities inside PAs coupled with the fact that the megaherbivore community of *terai's* forests is generally lost or occur in relatively low densities than in the past, there is no natural or human-influenced regulation on grass vegetation growth. For a largely cursorial bird like the Bengal Florican, tall grass habitats all around may act as an impediment to general movement as well as towards detecting lurking predators. Food availability too, perhaps, is affected as insects do not prefer tough grasses to eat. A combination of these factors (not entirely known) may be the reason why the tagged birds of Pilibhit displayed nomadic movements, perhaps in search of structurally 'suitable' habitats, post the breeding season from the second-third week of July onward (on an average) all the way till mid-September, after which they chose to move to a possibly traditional non-breeding site near Tattarganj.

To test this hypothesis and the relationship between the density of vegetation and movement of birds, we downloaded relevant satellite images and extracted NDVI values from them associated with high-accuracy locations from PTT-tagged birds during the 2015-16 season. European Space Agency's

decad-wise PROBA-V satellite/mission distributes remotely-sensed imagery free-of-cost to scientists through the interactive portal [www.vito-eodata.be](http://www.vito-eodata.be) at approximately 100 m and 300 m resolutions. The advantage with PROBA-V satellite imagery as compared to MODIS images distributed by the US Geological Survey is that images for the researcher's area of interest are auto-stitched and provided in the GeoTIFF format which can be further analysed with the help of GIS software such as ArcMap and QGIS.

We performed paired two-tailed t-tests to detect any statistically significant differences between NDVI values. Specifically, we wanted to see if there were significant pairwise differences between:

1. Mean NDVI values between the peak breeding season (March 21-July 10, 2016) and the non-breeding season (July 11, 2015-January 10, 2016) at the respective three breeding territories of Pilibhit1, Pilibhit3 and Dudhwa1;
2. Mean NDVI values between areas 'used' by the tagged birds post the breeding season (July 21-January 20, in three blocks of two-month duration each) with NDVI during the same period at their respective breeding territories.

We found that NDVI values were significantly higher ( $p=0.009$ ,  $t=10.4578$ ,  $df=2$ ) at the tagged birds' breeding territories during the non-breeding period than during the peak breeding period (Table 19). This implies that vegetation at birds' breeding territories does indeed become significantly denser in the non-breeding period during and following monsoon rains.

Interestingly, we found no statistically significant difference ( $p=0.2359$ ,  $t=1.6748$ ,  $df=2$ ) between NDVI values associated with high-accuracy location fixes obtained from birds during their post-breeding movements 'use' (roughly a two-month period during July 21-September 20, 2016) and the corresponding values from the birds' breeding territories during the same period (Table 20). This implies that, at least in 2016, birds ventured away from their breeding territories in late-July but were perhaps unable to find habitats any different from those at their respective breeding territories.

Teasing data at the individual bird level though, 'Dudhwa1' did seem to find/occupy habitats more suitable right after leaving its breeding territory in mid-July. Unlike the Pilibhit birds, 'Dudhwa1' notably does not show any significant post-breeding movement and reaches its non-breeding areas within a week's time.

Upon reaching their respective final (and possibly traditional) non-breeding abodes, the Pilibhit birds did seem to find more habitable environments in the floodplain-agriculture at Tattarganj. We found that NDVI values associated with birds' high-accuracy location fixes during a two-month period between September 21-November 20, 2016 were significantly lower ( $p=0.0419$ ,  $t=4.7281$ ,  $df=2$ ) as compared to the corresponding NDVI values at the birds' respective breeding territories within PTR and DNP (Table 21).

For the following two-month period (November 21, 2015-January 20, 2016) though, we found no significant differences between NDVI values associated with birds' high-accuracy location fixes and the corresponding NDVI values at their respective breeding territories (Table 22).

## DISCUSSION AND RECOMMENDATIONS

### Reconciling habitat-movement relationships with conservation objectives

In 2014, all the three PTT-tagged birds at Pilibhit flew towards the same larger area in the non-breeding season (in and around Tattarganj) but at different points of time in the year (spread between July to September), while in 2015 and 2016 both remaining PTT-tagged birds (Pilibhit1 and Pilibhit3) flew to Tattarganj in September at the end of their nomadic post-breeding movements. Contrastingly enough, the PTT-tagged bird at DNP does not display any significant post-breeding movements and flies to its non-breeding abode near villages Ramnagar and Gadiyana within a short span of time after vacating its breeding territory during July-August. This may indicate two things:

1. Movement to the Sharda river floodplain-agriculture may be facultative and a learned behaviour. Similar facultative movements away from breeding territories during the wet season was documented in the *H.b.blandini* population in Cambodia as well by Packman (2011).
2. For the Pilibhit sub-population, these facultative movements may be a more recent phenomenon than the DNP sub-population as indicated by an almost two-month long post-breeding 'searching' period for more 'suitable' habitats at the end of the breeding season.

The latter is a point of significance from the habitat-management point of view. Since birds do not find significantly different habitats during their nomadic post-breeding movements away from breeding territories, it may be possible to suppress the birds' urge to move to the relatively unprotected environments in the Tattarganj floodplain-agriculture by managing grassland habitats at their respective core breeding territories. The movement of bird 'Dudhwa1' away from its breeding territory though seem to be more "hard-wired" as conditions at its breeding territory becomes extremely unsuitable with only tall dense grassland habitat around.

The fact that all the four PTT-tagged birds moved away from their breeding territories coupled with the finding that vegetation (NDVI) does indeed become significantly denser at the advent of monsoon than during the breeding period is consistent with our hypothesis that Bengal Floricans respond to intra-seasonal vegetation dynamics. This also suggests that current grassland management practices may be out of sync with Bengal Florican's habitat requirements through a year.

We admit that this may be only one interpretation of these results obtained. Considering the small sample size, and variations within individuals studied, it is possible that birds' decision to move away from their breeding territories within PAs may be influenced by factors such as food availability, behavioural plasticity in terms of site-fidelity, human disturbances and possibly yet unknown other factors.

The kind of habitat that Bengal Floricans use after moving out from their breeding territories seem to indicate that they 'prefer' shorter vegetation areas primarily within crops such as paddy, wheat, lentil, mustard, young sugarcane or fallow land interspersed with unmanaged grassland patches. These areas are essentially low-intensity floodplain-agricultures along Sharda River away from permanent human settlements with variable intensity of disturbance throughout the year. The birds also show a fair bit of pronounced and sometimes repeated local movement- probably associated with disturbance



Figure 10: Three Bengal Florican adult males (two of them are PTT-tagged birds) engage in agonistic behavior (see inflated size and ruffled feathers) towards each other near Bheem Taal ('Pilibhit1' territory) on April 17, 2015; at the end of this five-minute interaction, two birds were forced to move away, perhaps by the 'dominant' territorial male (Photo credit: Rohit Jha)

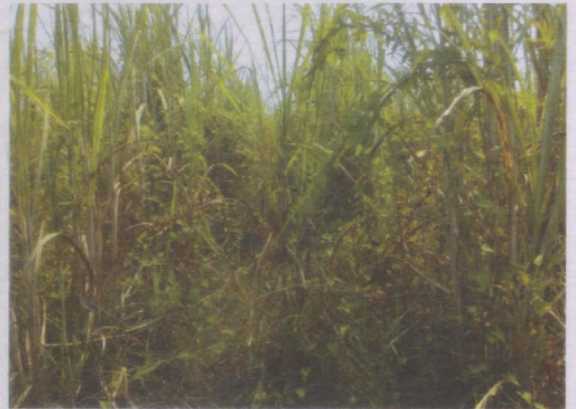


Figure 11: Short-grass habitat interspersed with trees such as Teak, Sal and Sisam at Baggha's fenced (to prevent cattle grazing from neighbouring Baggha village) grassland patches in the Surai Range of Terai East Forest Division, Uttarakhand (Photo credit: Rohit Jha)



Figures 12 & 13: Bengal Florican photographed at Tattarganj. Please note the PTT antenna (below)  
Photo credits: Rohit Jha (above), Khursheed Khan (below)





**Figure 14:** A collage of photographs depicting the mosaic of short and tall vegetation areas in the Sharda river floodplain-agricscape near Tattarganj/Gunhan at the Pilibhit birds' non-breeding abode with wheat, sugarcane, red lentil, mustard and paddy cultivation intermixed with patches of unmanaged grassland (Photos: Rohit Jha)



Figure 15: A collage of photographs depicting different types of human activities in the floodplain-agriculture area including grass-harvesting, cattle-grazing, crop-harvesting and 'resting' (fallow) fields (Photos: Rohit Jha)

events (perhaps due to agricultural activities such as burning, tilling, sowing, harvesting throughout the year)- within the larger agriscape during the non-breeding season.

Overall, movement patterns of PTT-tagged Bengal Florican birds at both PTR and DNP show striking resemblance to each other. The data also suggest that Bengal Florican males display tremendous site-fidelity during both the breeding and non-breeding seasons, as has been observed in some populations of Great Bustard *Otis tarda* (Alonso *et al.* 2000, Lane *et al.* 2001, Morales *et al.* 2000, Palacín *et al.* 2009), Houbara Bustard *Chlamydotis (undulata) macqueenii* (Judas *et al.* 2006) and Great Indian Bustard (Rahmani 1989). Such site-faithfulness function as 'double-edged swords' and may limit the ability of adults with an established set pattern of migration to adapt to local scale habitat loss/modification at traditional sites. Thus, it becomes extremely important to conserve and scientifically manage remaining tracts of such traditional savanna grassland sites in line with the habitat-use patterns of the Bengal Floricans.

The observed phenomenon of site-fidelity also has important ramifications when considering grassland habitat and corridor restoration strategies for the species. Any creation of new 'suitable' or restoration of previously suitable habitat, and even protection of areas that appear 'suitable' based on habitat may fail to attract floricans faithful to specific areas, even when no suitable habitat remains in them ("ghosts of habitats past" Knick and Rotenberry 2000). Thus, for Bengal Florican grassland habitat restoration strategies, known florican locations must form the basis of area choice. Given site fidelity, consideration should be given to habitat restoration efforts in areas that have supported savanna grasslands and were occupied by floricans in the recent past.

A suitable conservation strategy may also be developed tailor-made for Sharda river's floodplain-agriscapes considering that birds spend anywhere from five and up to eight months in such areas with largely private ownership of land.

#### **Home-range, movement and population monitoring**

Home range analysis of Bengal Floricans suggests that the size of birds' core breeding territories as well as non-breeding range is variable among years and individuals. Core use areas (50% MCP and 50% KUD) were substantially smaller than outer home ranges (95% MCP and 95% KUD), thus suggesting that Bengal Floricans use space non-randomly. In fact, kernel core home ranges (50% KUD) during the breeding season reported in this study (mean  $41.83 \pm 24.59$  hectares) are significantly smaller than those reported by Packman (2011) from 12 tagged male birds in Tonle Sap Lake area, Cambodia (mean  $160 \pm 30$  hectares). This suggests that the landscape may have a naturally higher carrying capacity for floricans and holds enough promise towards genuine population recovery efforts and measures.

During the non-breeding season, birds spread quite widely across the floodplain-agriscape, relative to their breeding ranges. This is starkly visible in 'Dudhwa1' whose non-breeding home-range was many times greater than its corresponding breeding home-range. The mechanistic factors driving this trend maybe any of reasons such as increased human activity in the birds' non-breeding floodplain-agriscapes as compared to negligible disturbance in PAs, wider search for food and/or cover, agonistic

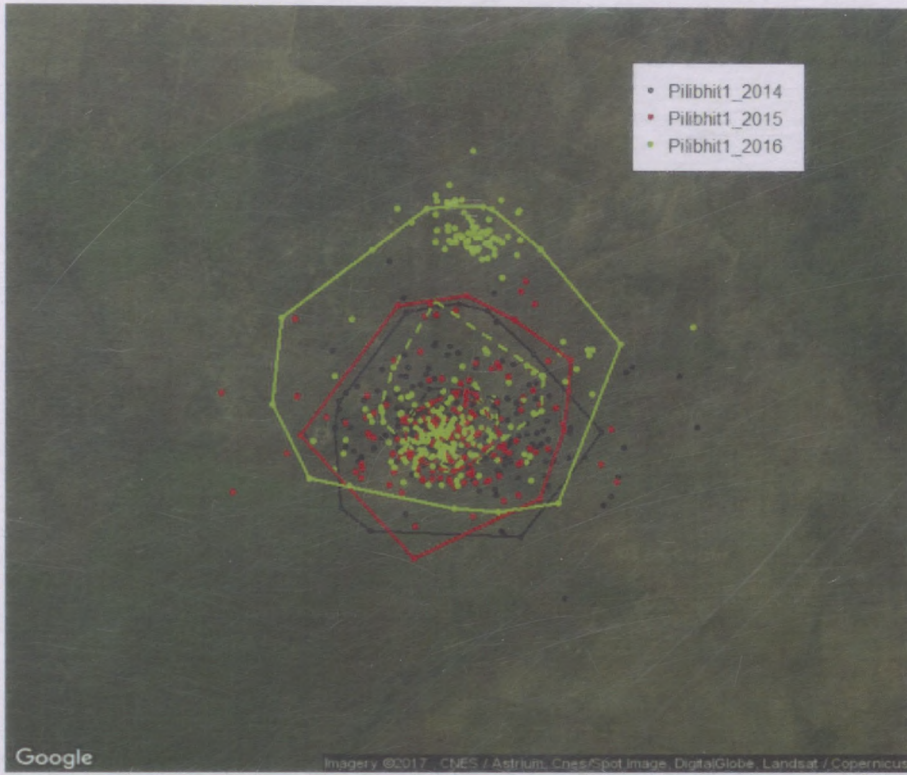
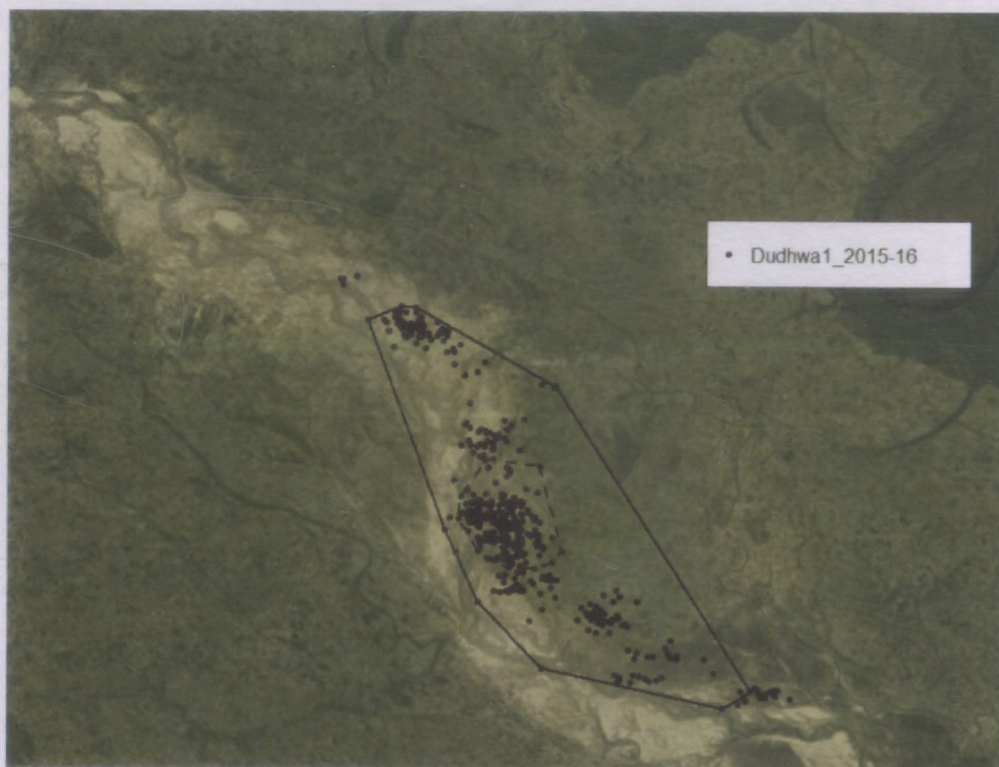


Figure 16: Breeding season home ranges (MCP-50- dashed lines, MCP95-solid lines) of 'Pilibhit1' (top) and 'Pilibhit3' (below) through 2014-2016 displaying slightly varying degrees of site-fidelity to their breeding territories





Figure 17: Breeding season home ranges (MCP-50- dashed lines, MCP95-solid lines) of 'Dudhwa1' in 2015-2016 showing strong sites-fidelity to its breeding territory



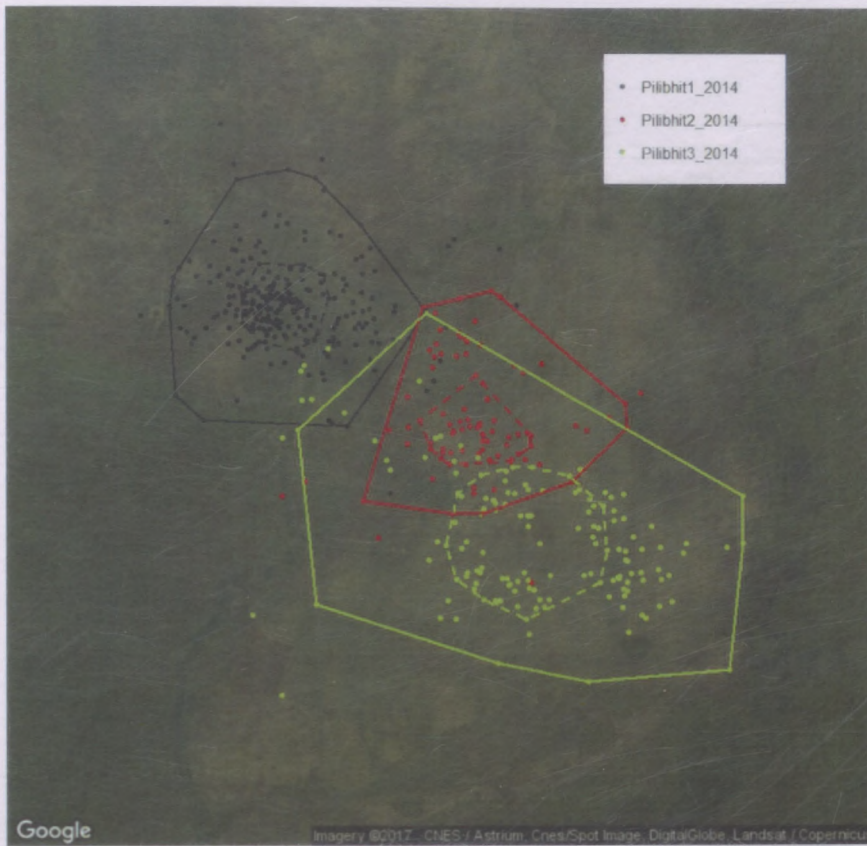
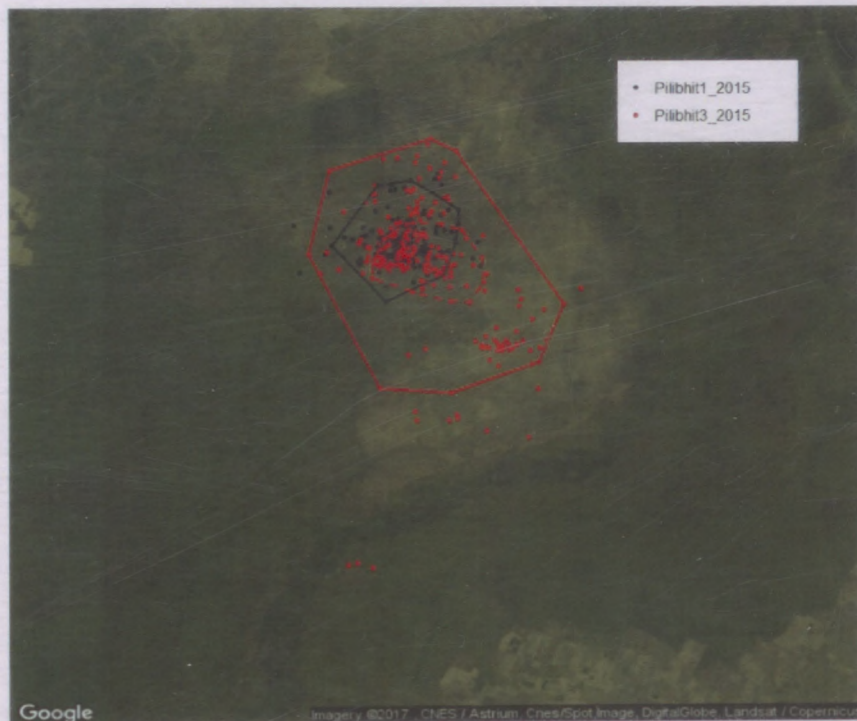


Figure 18: Breeding season home ranges (MCP50- dashed lines, MCP95- solid lines) overlap between adult territorial Bengal Florican males at PTR during 2014 (top) and 2015 (below). While core-use areas do not overlap between the three PTT-tagged birds in 2014, there is significant overlap between core-use areas of 'Pilibhit1' and 'Pilibhit3' in 2015 (signals from 'Pilibhit2' ceased coming after a few months)



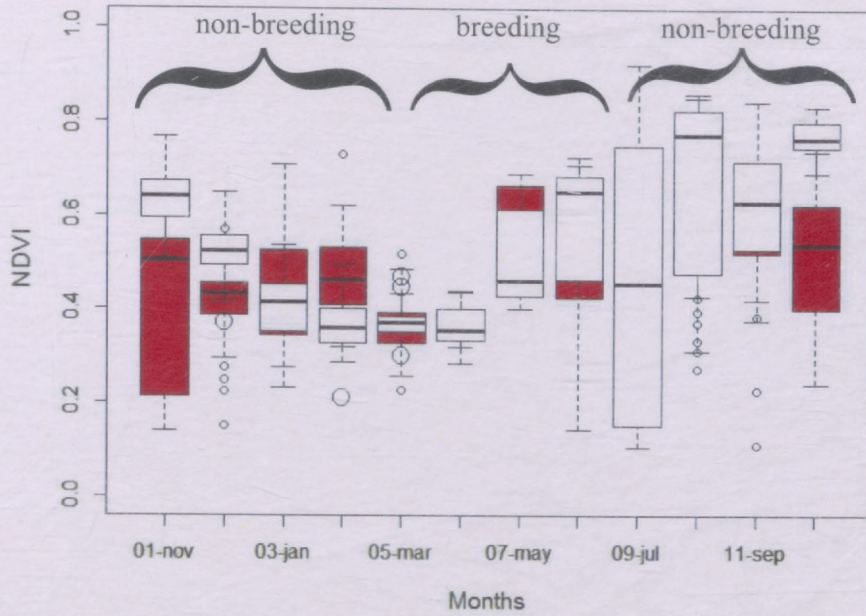


**Figure 19:** Depiction of breeding season kernel utilization distribution isopleths (KUD50- dashed lines, KUD95- solid lines) of birds at PTR during the 2014 breeding season- note the largely non-overlapping core-use areas; also, note the multimodal home ranges of birds ‘Pilibhit2’ and ‘Pilibhit3’ while ‘Pilibhit1’ maintains a unimodal core-use area; for corresponding land cover information, see Map 27. The square box is an approximate area of 5 km x 5 km

behaviour from conspecifics, and/or density dependence effects. While the difference in area between breeding and non-breeding home ranges had no statistically significant difference, there may be an ecologically significant difference undetected due to small sample size.

During both the breeding and non-breeding seasons, birds frequently showed multi-modal home ranges with two or more core use areas, sometimes overlapping with another male’s core-use area during both the breeding (2014 and 2015) and non-breeding seasons 2014-15 and 2015-16 (Figure 18). Where home ranges were multimodal, the modes were generally occupied during different periods of the season. These findings have implications for the monitoring strategy currently used to assess Bengal Florican population numbers, which is based on the sightings of displaying territorial males in various grassland patches/*phantas*. The method assumes that the males remain within their ‘fixed’ territories and are likely to be detected during the peak period of conspicuous display behaviour (April-May) when the monitoring is conducted, and will not be counted displaying in more than one patch. If adult males occupy multi-modal cores but display in a single core, the current method may still be appropriate. If, however, males occupy and display in more than one core area, the current method could lead to an overestimation in the total number of reported adult males.

NDVI-use (red) and NDVI-breeding territory (white): 2015-16 (P1)



NDVI-use (red) and NDVI-breeding territory (white): 2015-16 (P3)

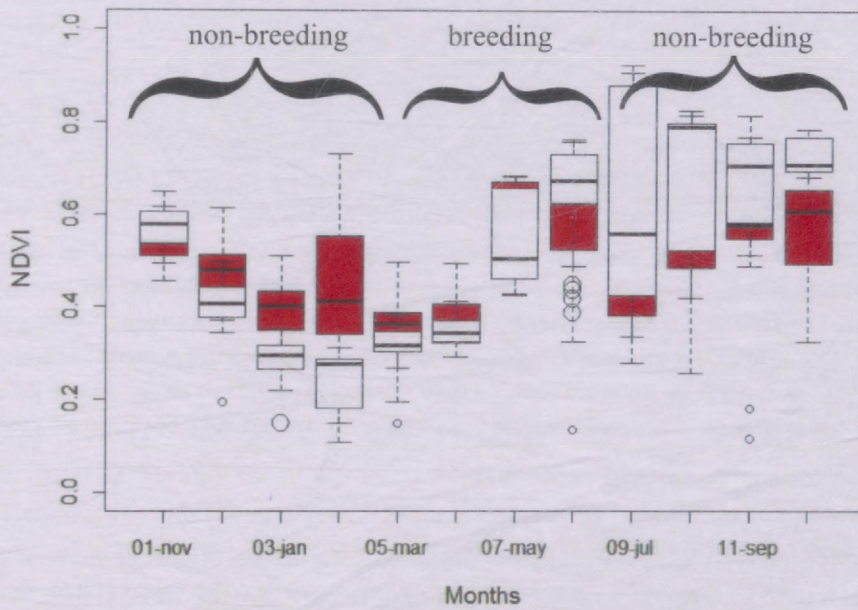


Figure 20: Boxplots of NDVI values associated with 'Pilibhit1' (top) and 'Pilibhit3' (below) birds' high-accuracy locations through a period of 12-months (November 2015 to October 2016) superimposed on corresponding values at their breeding territories (derived from high-accuracy locations during the breeding period) in PTR. While overlap between the red and white boxes is expected during the breeding months (since NDVI values for breeding territories are derived from birds' 'use' points during the breeding period), the boxes are out-of-sync with each other during October-November consisting of tall and dense vegetation (median NDVI > 0.55), signifying the incompatibility of habitat at the birds' breeding territories with respect to Bengal Florican habitat requirements, and point toward the chief reason for migration. While serial decreases in NDVI at breeding territories from December onward reflect habitat management (in the form of grass burning and grass cutting) by PA-managers, serial and rapid increase from May onward reflect the influence of pre-monsoon showers on grass biomass.

### NDVI-use (red) and NDVI-breeding territory (white): 2015-16 (D1)

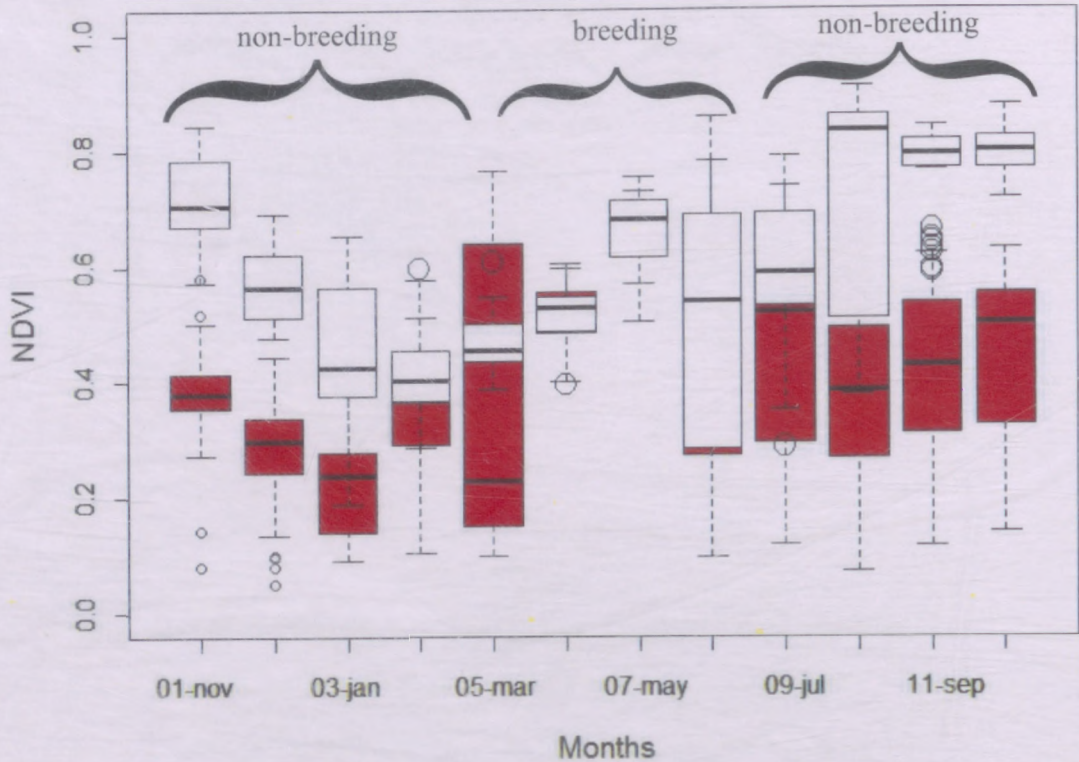


Figure 21: Boxplot of NDVI associated with 'Dudhwa1' bird's high-accuracy locations through a 12-month period (November 2015 to October 2016) superimposed on corresponding values at its breeding territory (derived from high-accuracy locations during the breeding period) in DNP. While overlap between the red and white boxes is expected during the breeding months (since NDVI values for breeding territories are derived from birds' 'use' points during the breeding period), the boxes are out-of-sync with each other during August-December consisting of tall and dense vegetation (median NDVI > 0.55) signifying the incompatibility of habitat at the birds' breeding territories with respect to Bengal Florican habitat requirements, and point toward the chief reason for migration. While serial decrease in NDVI at breeding territories from November onward reflect habitat management (in the form of grass burning and grass cutting) by PA-managers, serial and rapid increase from April onward reflect the influence of pre-monsoon showers on grass biomass.

Alternatively, multimodal cores and large home ranges could also be indicative of subordinate males that do not hold a clearly defined territory and rather are 'floaters' who behave submissively around other males (Packman 2011). These males may thus be tolerated in the territories of others and gain 'sneak' copulations if access to females is a limitation. Another lekking species in which such opportunistic behaviour has been reported is the Ruff *Philomachus pugnax* where the strategy is believed to be a low-cost, low-benefit alternative, but one which may result in similar lifetime reproductive success as for 'fixed' territorial males (Widemo 1998). If this reproductive strategy does occur in the florican population then, contrary to the statement above, population monitoring based on the reported number of displaying territorial males could instead result in an underestimation.

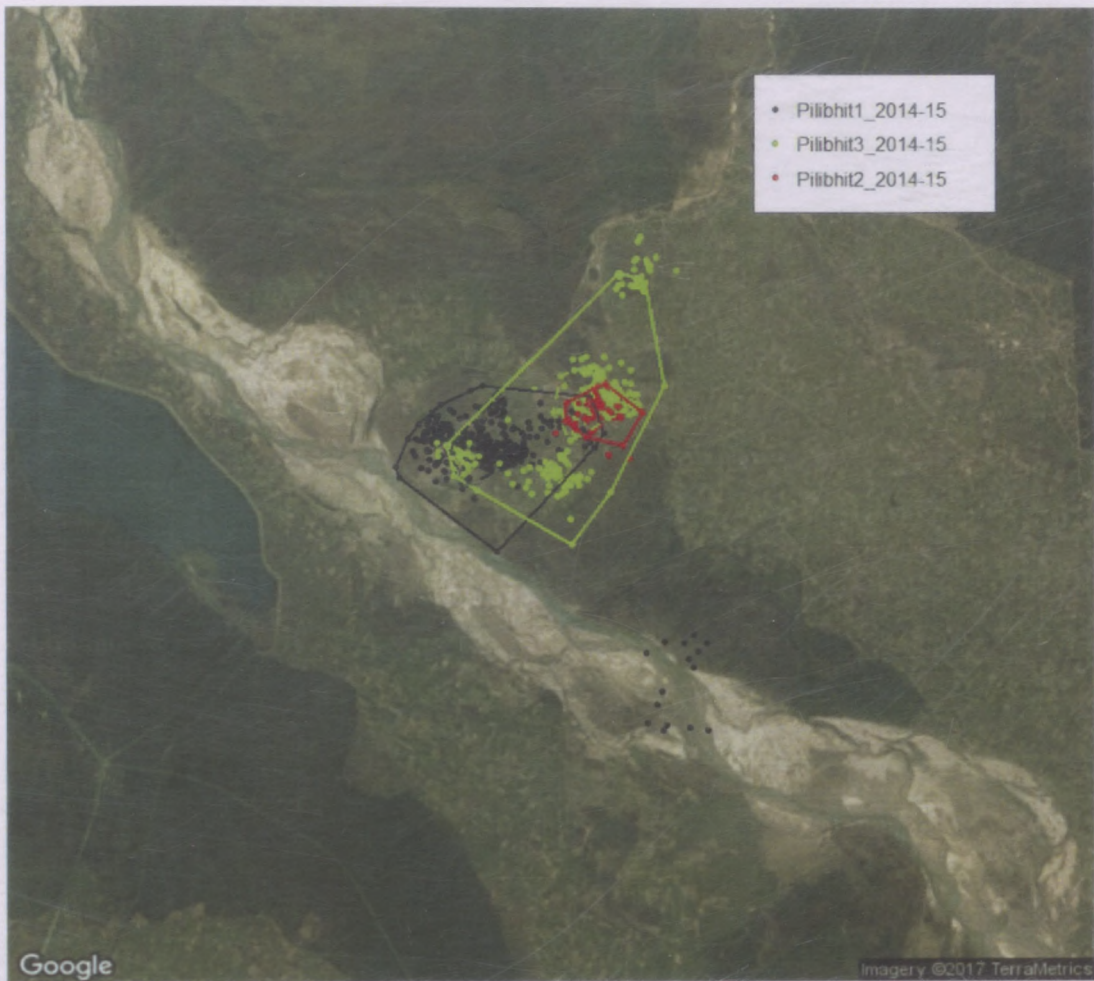


Figure 22: Non-breeding season home ranges (MCP50- dashed lines, MCP95- solid lines) of birds 'Pilibhit1' and 'Pilibhit3' during 2014-15 in the Tattarganj floodplain-agriscape showing a wider breadth of movements and significant overlap; note that the signals ceased coming from bird 'Pilibhit2' within a month of it reaching Tattarganj and thus its home range seems a much smaller polygon

### Looking ahead

Results presented here contribute to a growing field of research in movement ecology that combines telemetry data with remotely sensed phenological data to test hypotheses of movement in response to changes in primary productivity in various groups of animals, and offer important implications for conservation and management beyond just the Bengal Florican and the grasslands of *terai*.

Overall, even though much progress has been made in furthering our knowledge about Bengal Florican ecology with this pilot project, a considerable vacuum still exists that need to be fulfilled by further research, especially with respect to nesting ecology and towards deciphering reasons for low breeding success or maybe even total breeding failure of Bengal Floricans in Uttar Pradesh that has resulted in the severe observed decline in their population in the state over the last couple of decades.

Examination of the importance of habitat mosaics and patch size too warrant investigation, along with the influence of physical factors on Bengal Florican distribution such as elevation and flooding extent, especially in the Brahmaputra floodplains. Investigation into food availability in different habitats across seasons too would be very useful in examining florican distribution.

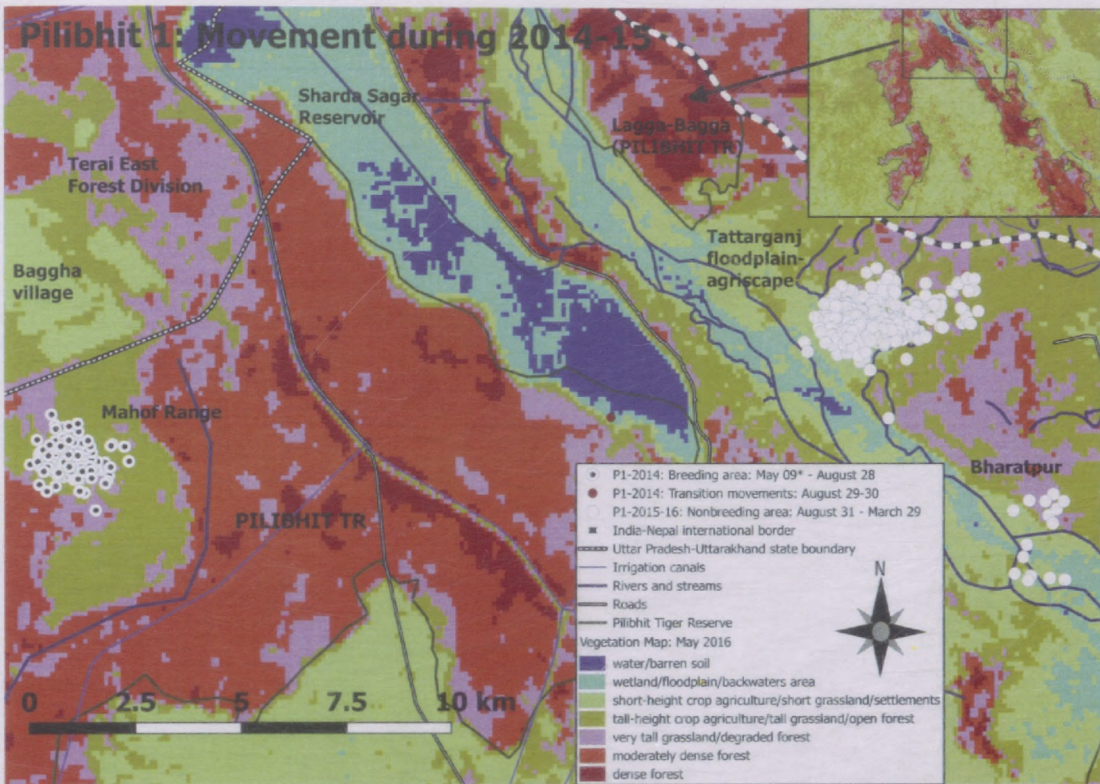
Conservation of migratory species is complex, with different threats often faced during different parts of the year and in different areas (Martin *et al.* 2007). This key population of Bengal Florican is clearly facing major threats not only to breeding season habitat (due to out-of-sync habitat management), but also to non-breeding season habitat (due to anthropogenic factors).

To date, conservation measures in PAs in these parts have been more focused on providing 'suitable' areas for large mammals, but a lack of knowledge of grassland bird ecology and habitat-use has inhibited the identification and tackling of threats looming on this guild of avian life. Failure to address these threats at both breeding and non-breeding areas could result in conservation efforts being in vain. A multi-faceted approach involving multi-stakeholders, therefore, is required if conservation measures for species such as the Bengal Florican are to succeed in the long run.

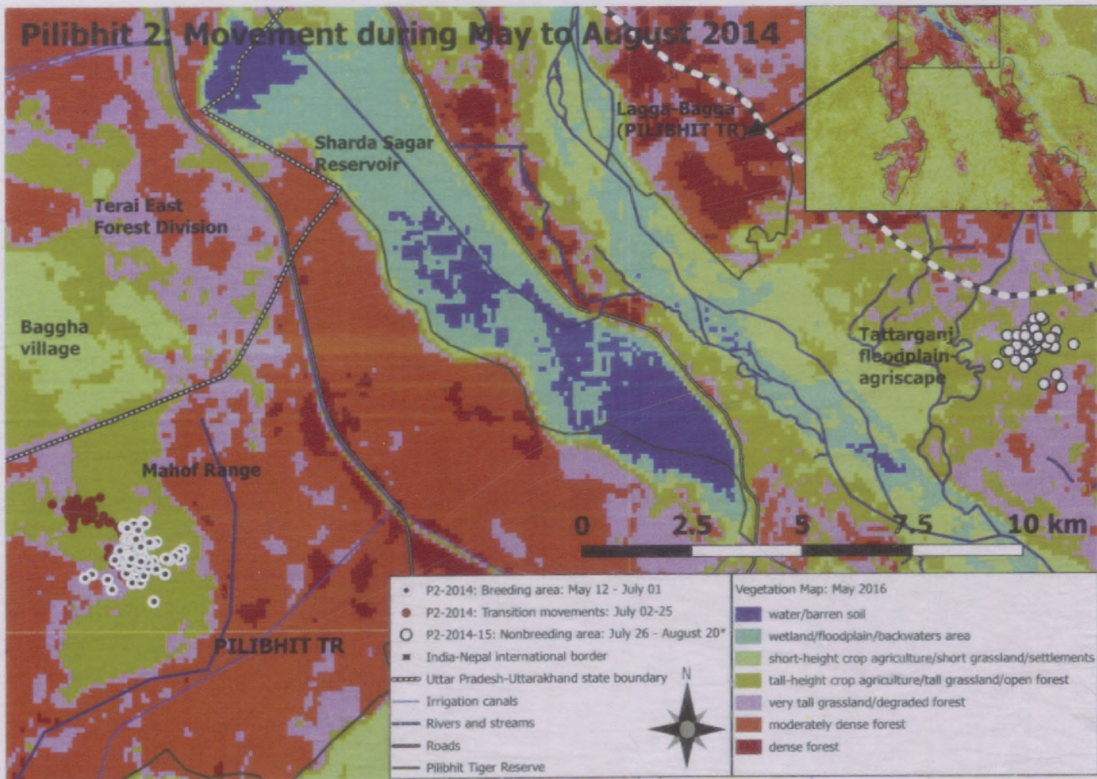
### **Specific Recommendations**

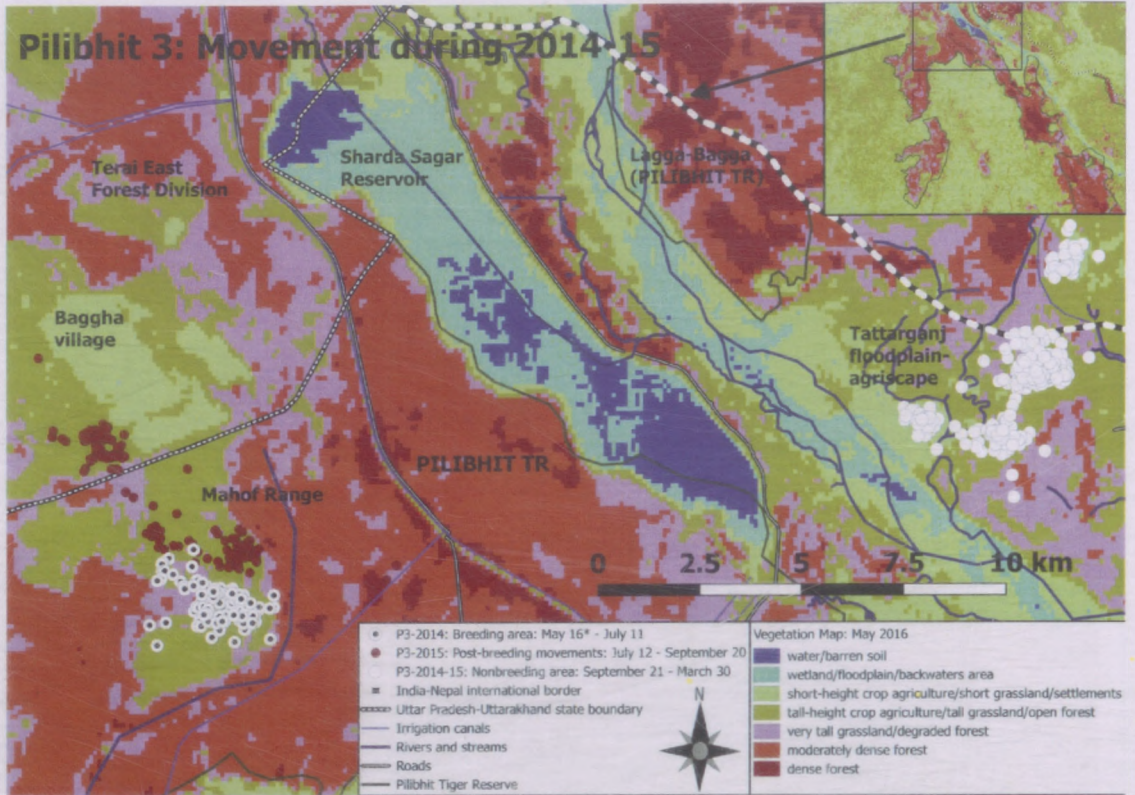
1. With a view to further our knowledge of movement patterns and breeding ecology of Bengal Floricans, it is important that more birds, especially females, are captured and tagged with high-accuracy GPS-GSM satellite devices. This must be done at several places in the Indo-Nepal *terai* and Brahmaputra floodplain areas where breeding populations of Bengal Florican are found.
2. Long-term research with respect to the effect of a variety of managerial interventionist measures (such as grass-cutting, burning, grazing) on grassland vegetation must be initiated with a view to evolve better and adaptive habitat management strategies for a suite of associated threatened avifauna.
3. A simple yet scientifically sound and uniform Bengal Florican population monitoring protocol incorporating detection probability should be developed. Requisite and regular training for conducting this exercise on an annual basis must be provided to resident forest staff in various states.
4. A comprehensive year-round scientific grassland management strategy in line with the habitat requirements of Bengal Florican and other grassland birds need to be developed at the earliest with clear and measurable goals, and with sustainable funding support from the government. This must replace the *ad hoc* approach adopted today in the form of one-time annual dry-season burning of grasslands.
5. Traditional breeding and non-breeding sites should be secured and protected in accordance with extant laws, and land-use changes in the floodplain-agriculture be monitored. Habitat restoration strategies must focus on areas occupied by Bengal Floricans in the recent past and towards connecting smaller sub-populations to facilitate genetic exchange.
6. Establish and support community-based Bengal Florican and associated wildlife monitoring programs at relevant sites, such as in and around known non-breeding habitat floodplain-agricultures in partnership with the Forest Department that also reports illegal activities such as shooting, trapping, bait-poisoning, of birds and other wildlife.

The following maps show the movement of tagged Bengal Floricans in India from 2014-2016



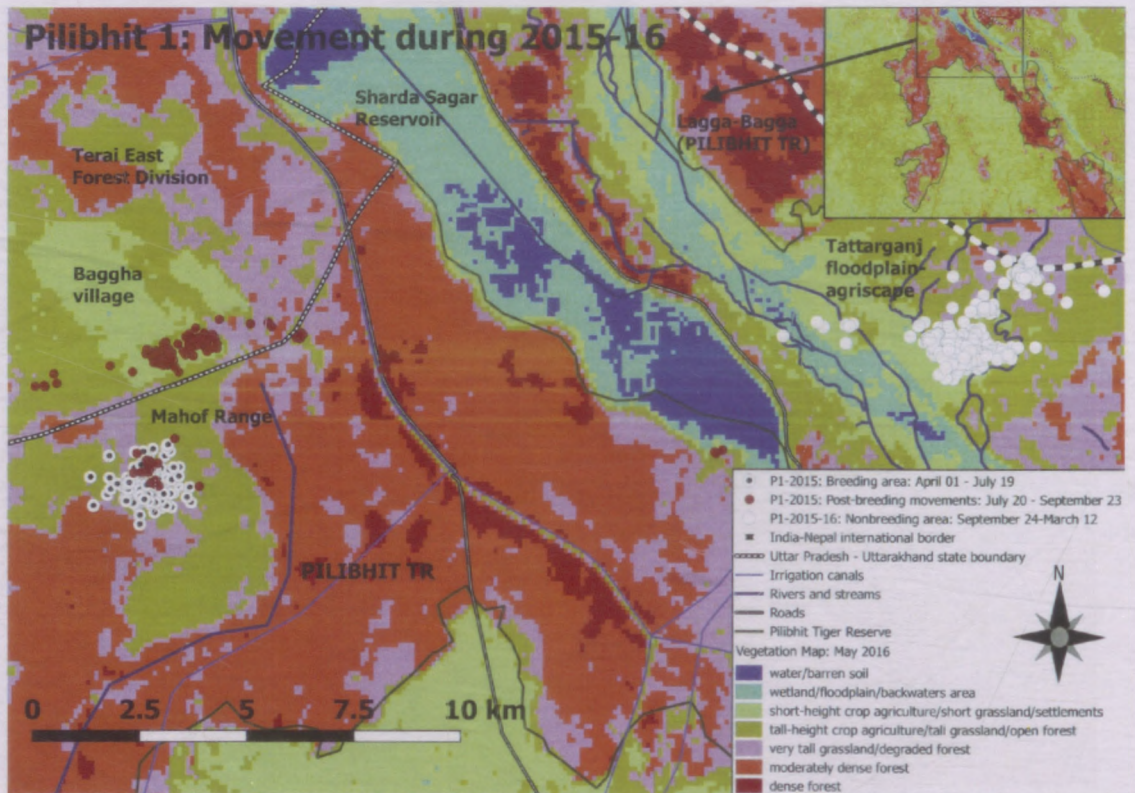
Map 18 (above): Movement of bird 'Pilibhit 1' during 2014-15; \* is date of first transmission  
 Map 19 (below): Movement of bird 'Pilibhit 2' during 2014-15; \* is date of first transmission

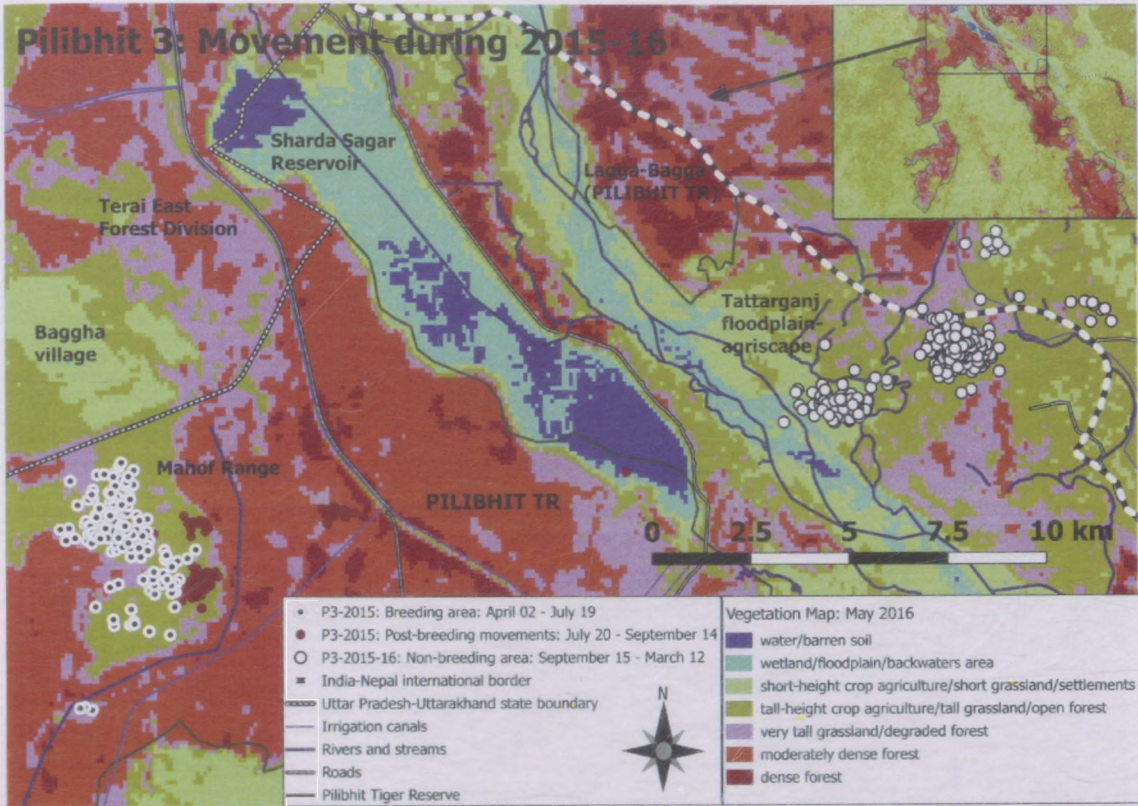




Map 20 (above): Movement of bird 'Pilibhit 3' during 2014-15; \* is date of first transmission

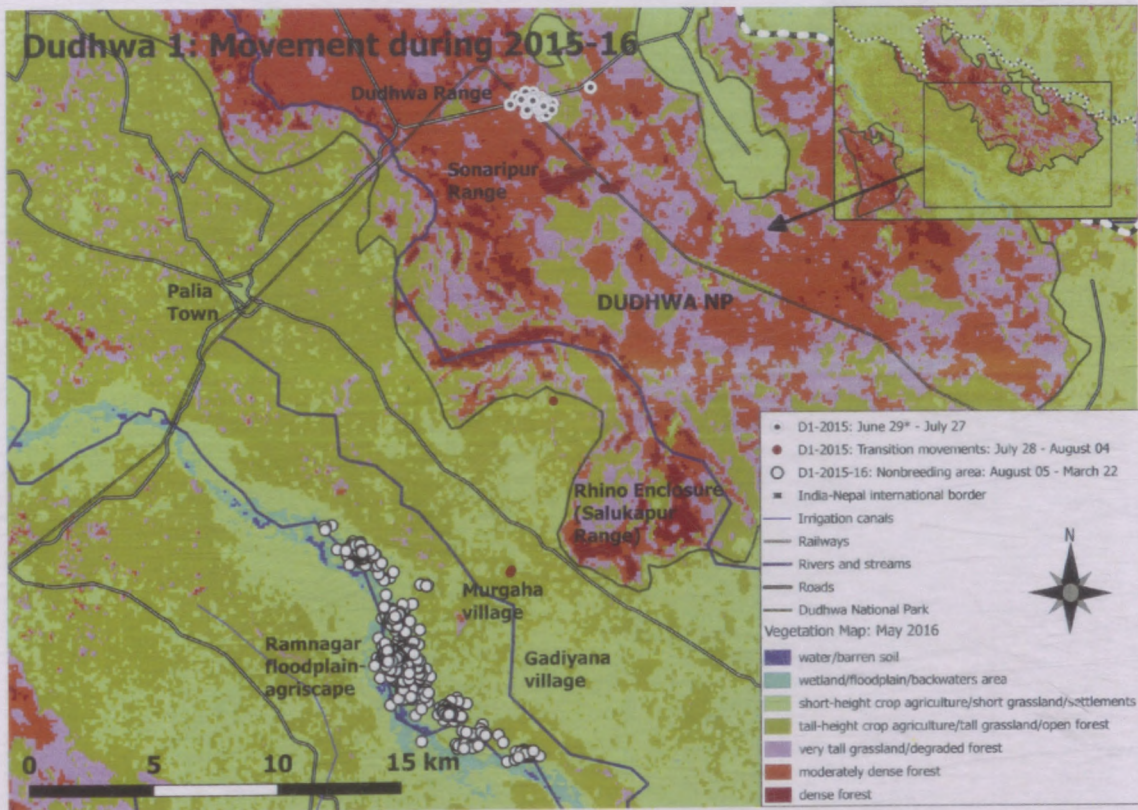
Map 21 (below): Movement of bird 'Pilibhit 1' during 2015-16

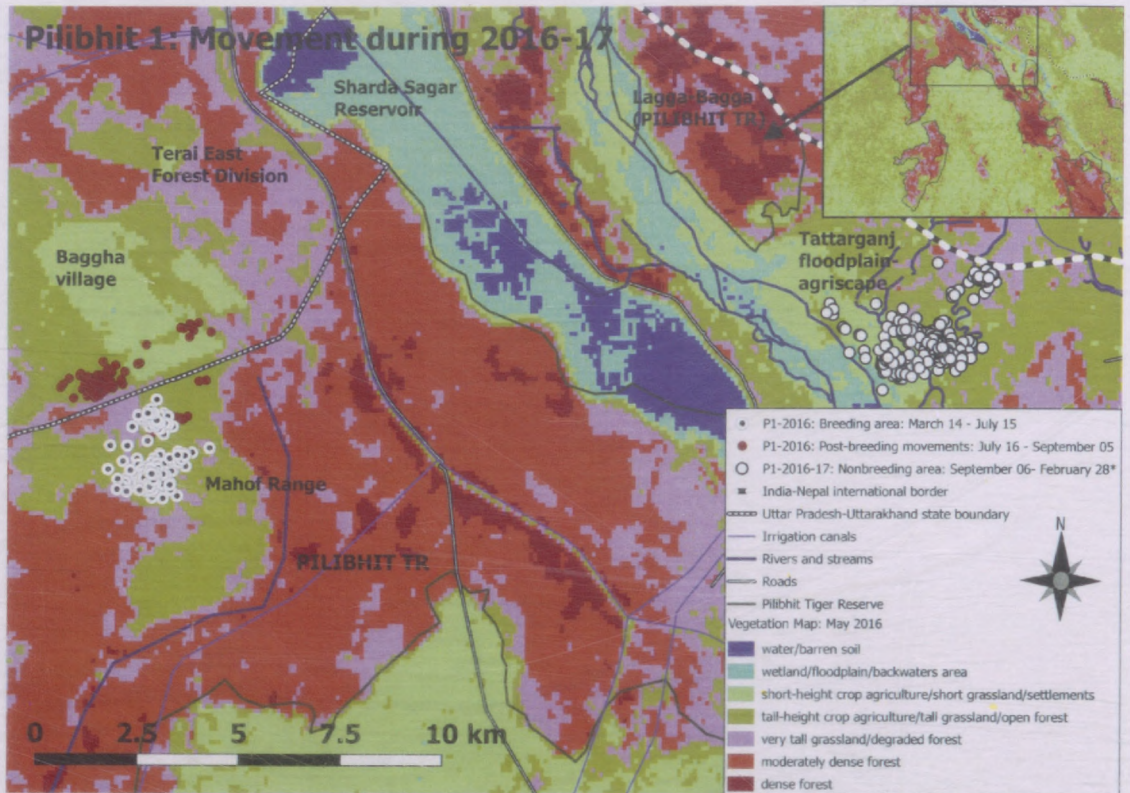




Map 22 (above): Movement of bird 'Pilibhit 3' during 2015-16

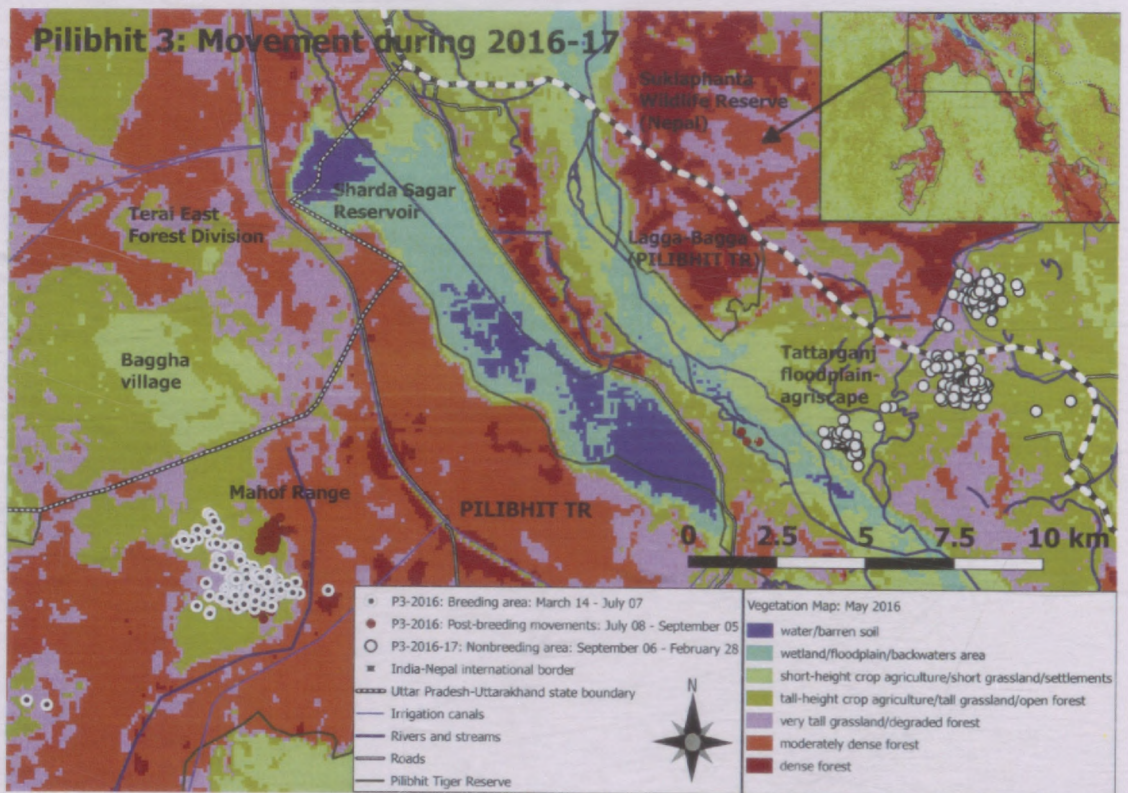
Map 23 (below): Movement of bird 'Dudhwa 1' during 2015-16; \* is date of first transmission

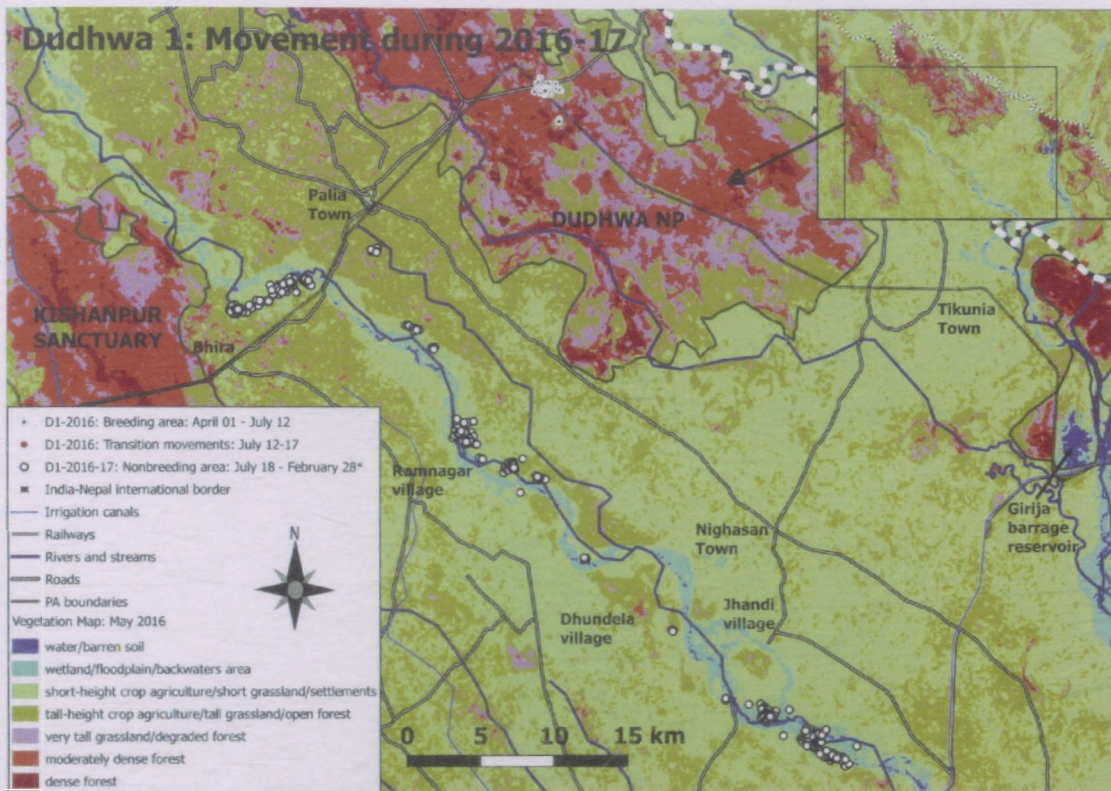




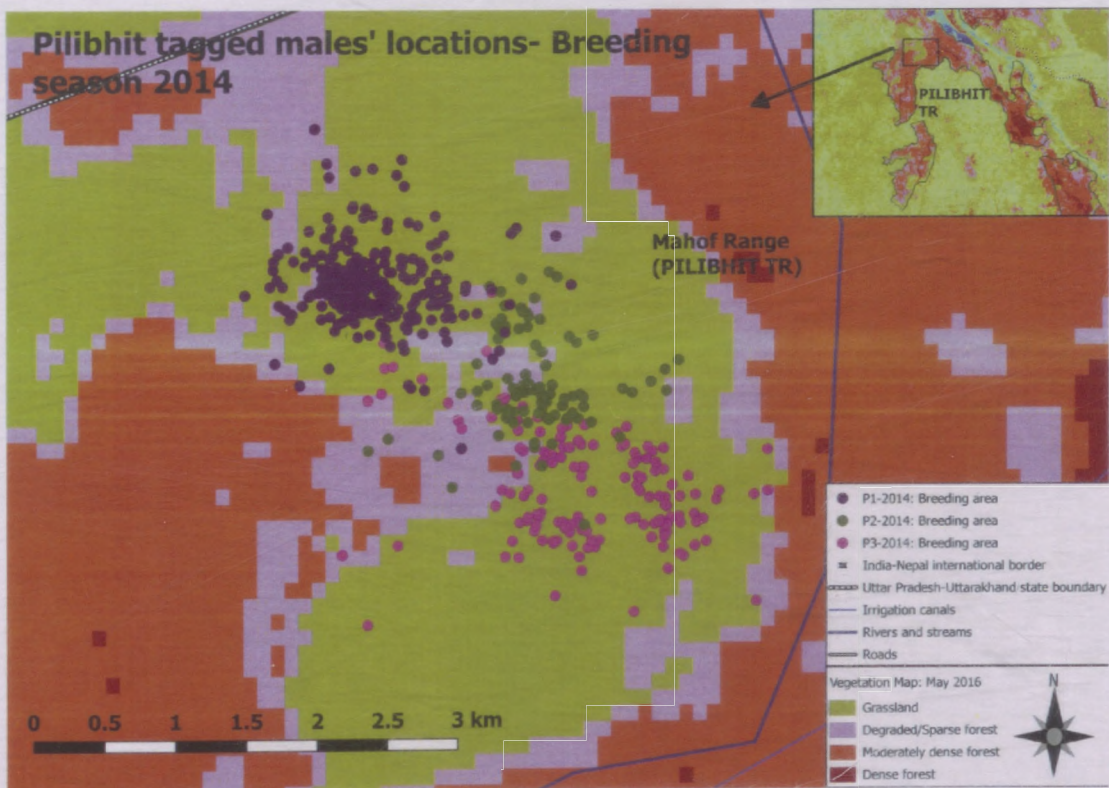
Map 24 (above): Movement of bird 'Pilibhit 1' during 2016-17; \* date till which data is available

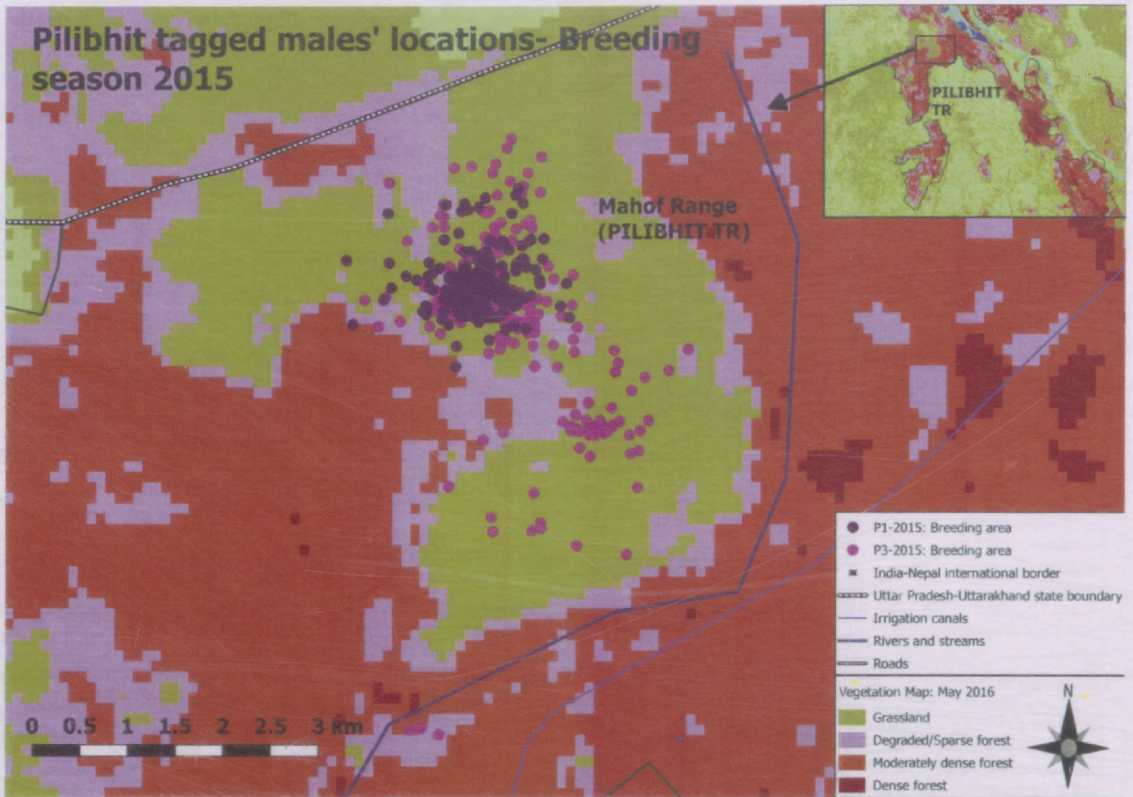
Map 25 (below): Movement of bird 'Pilibhit 3' during 2016-17; \* date till which data is available





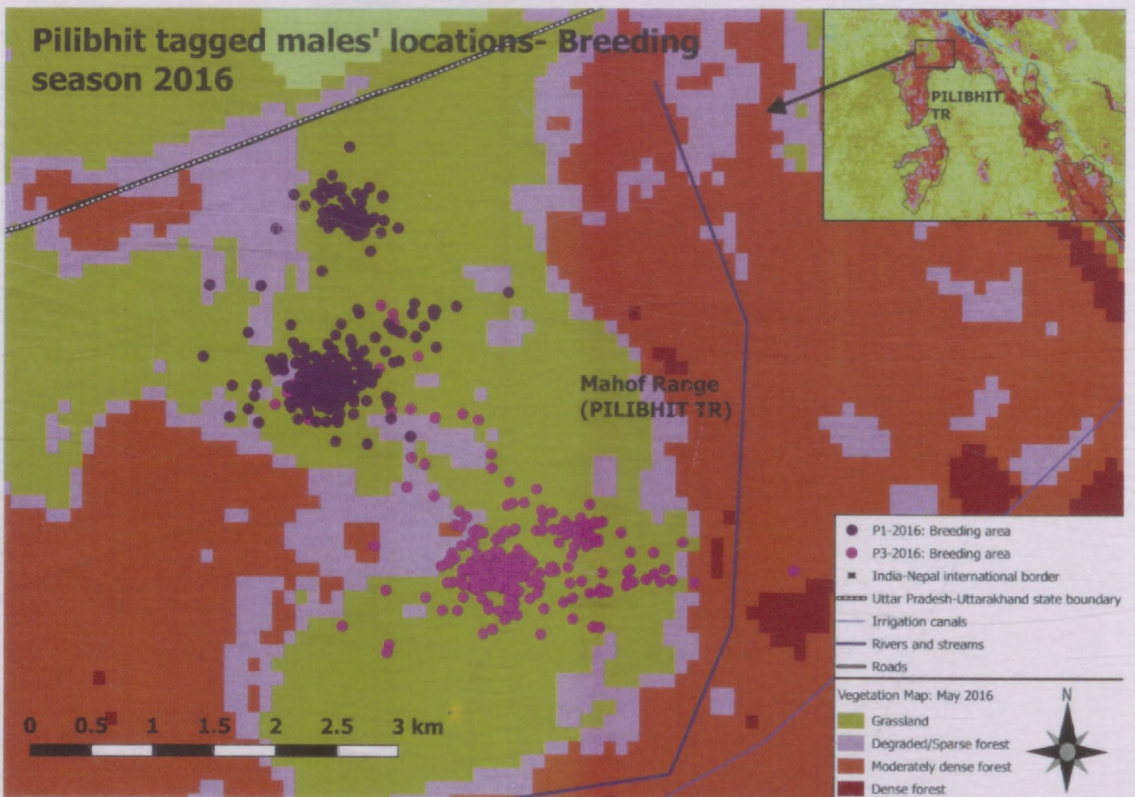
Map 26 (above): Movement of bird 'Dudhwa 1' during 2016-17; \* date till which data is available  
 Map 27 (below): High-accuracy locations of tagged birds during the breeding season in 2014

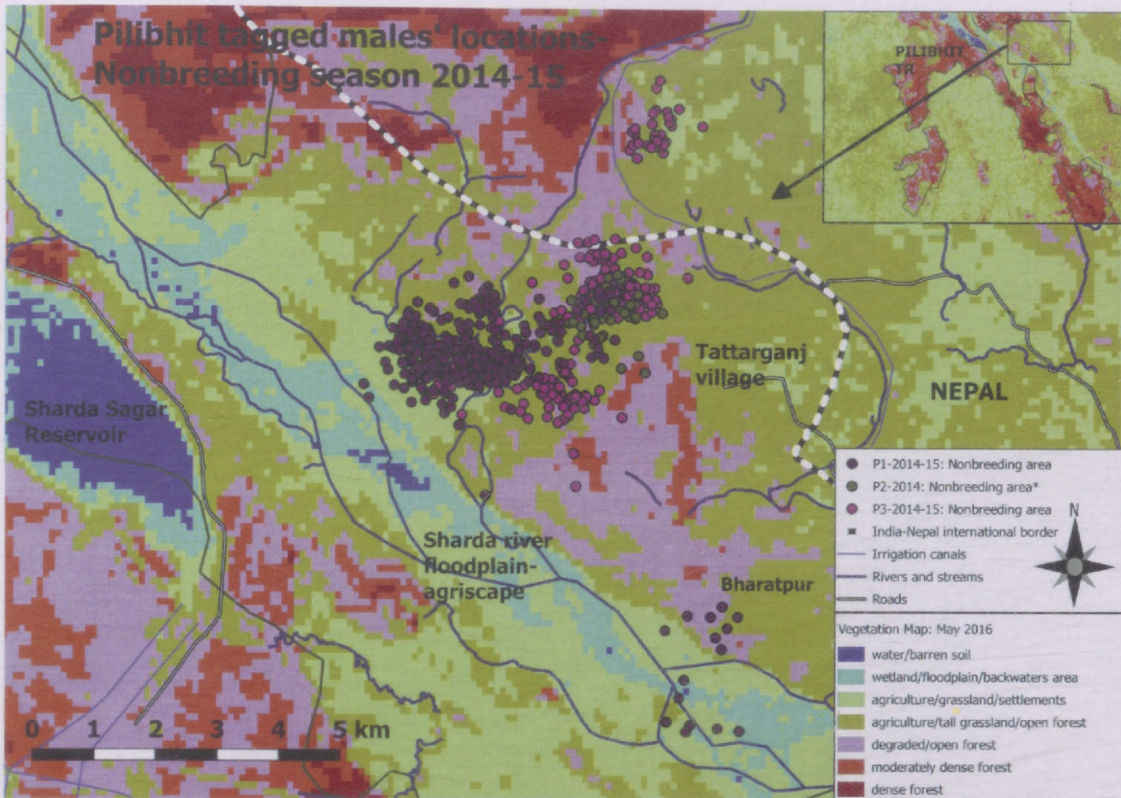




Map 28 (above): High-accuracy locations of tagged birds during the breeding season in 2015

Map 29 (below): High-accuracy locations of tagged birds during the breeding season in 2016

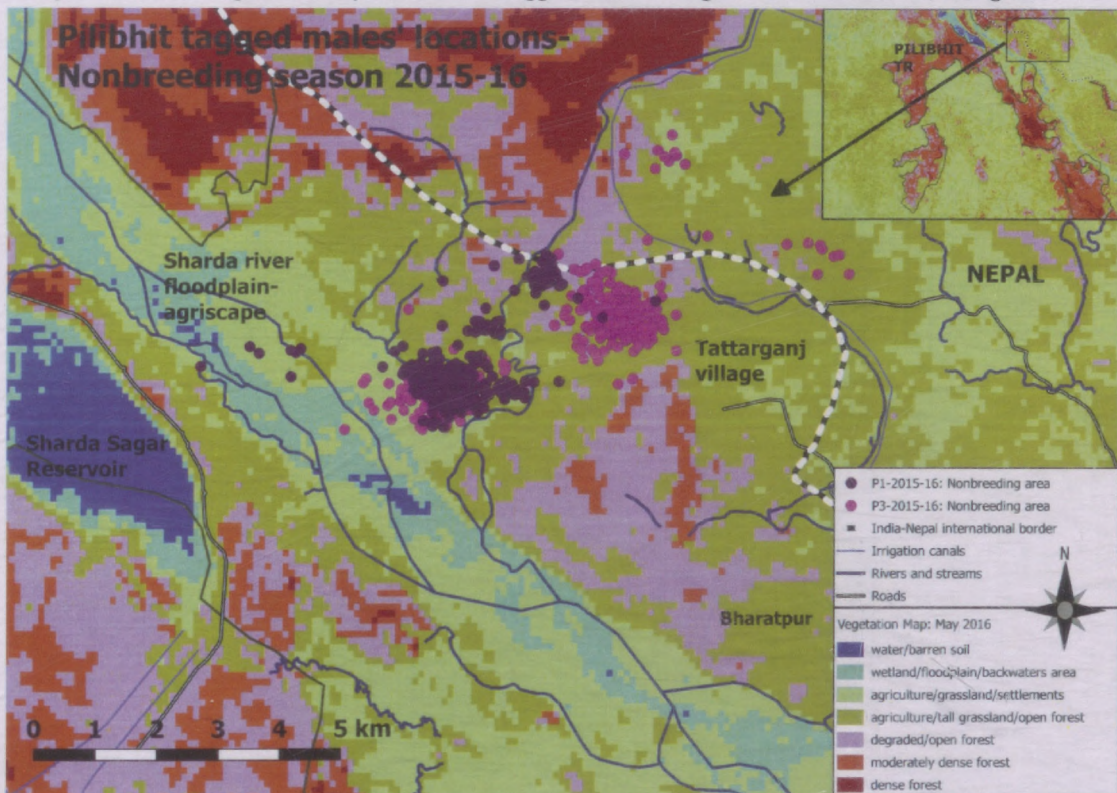


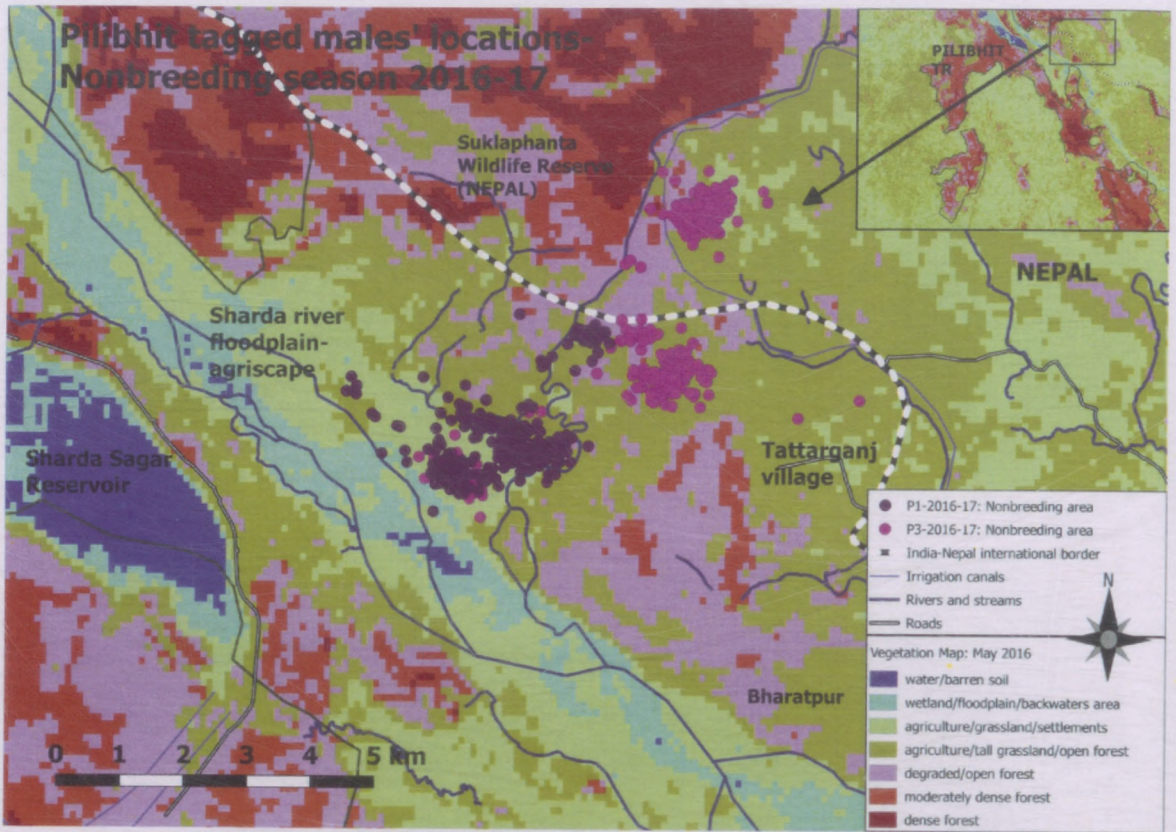


Map 30 (above): High-accuracy locations of tagged birds during the 2014-15 non-breeding season;

\* no transmissions were received from 'Pilbhit 2' post August 20, 2014

Map 31 (below): High-accuracy locations of tagged birds during the 2015-16 non-breeding season





Map 32: High-accuracy locations of tagged birds during the 2016-17 non-breeding season



**Figure 23: Grass burning is practiced as an annual grassland management practice by the Uttar Pradesh Forest Department**



**Figure 24: Contractual grass collection/harvest is allowed in Pilibhit during November-January**

## Chapter III

### Pilot Grassland Habitat Restoration Trial for the Bengal Florican at Dudhwa National Park

#### Introduction

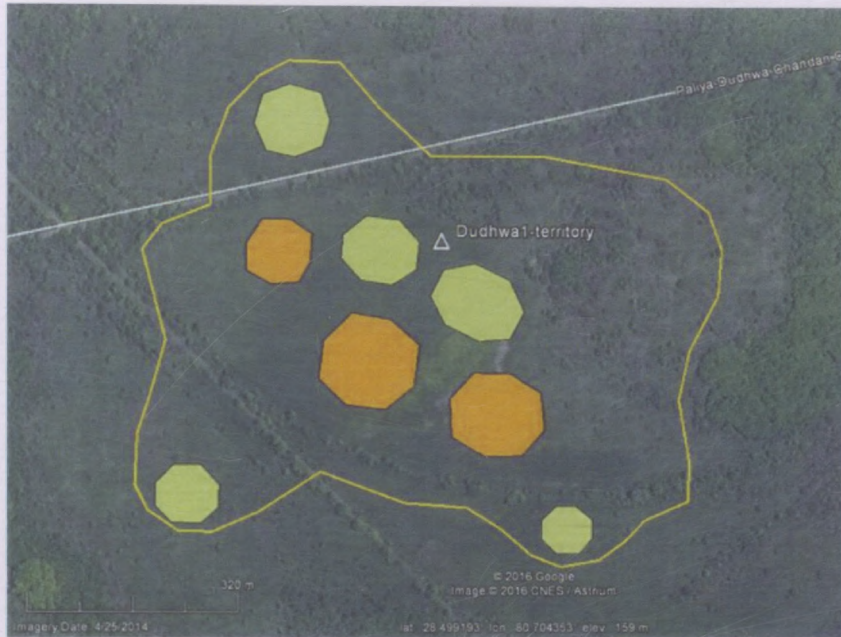
Grassland is one of the world's largest vegetation types, accounting for nearly one-fourth of the world's total land surface area, and contributing significantly to food security by providing a portion of the feed requirements of ruminants used for meat and milk production (Scurlock and Hall 1998, O'Mara 2012). Grassland ecosystem plays a key role in balancing greenhouse gases, particularly in terms of global carbon storage, and further carbon sequestration (French 1979, Hu *et al.* 2001).

Biodiversity in grassland ecosystems is seriously threatened by human activity (Sala *et al.* 2013). In particular, declines among bird species' populations that have affinities for grassland and grass-shrub habitats (hereafter referred to as grassland birds) have been well-documented in certain regions such as in North America (Brennan and Kuvlesky Jr. 2005), but have been found to be exceptionally consistent among geographic areas (Knopf 1994, With *et al.* 2008).

Chief reasons for declines in grassland birds has been the large scale loss and degradation of grassland habitats (Hill *et al.* 2014). Climate change and human activities are commonly recognized as the two broad underlying drivers that lead to grassland degradation (Gang *et al.* 2014). In the future too, grasslands are among the biomes that are going to experience the largest conversion in land use, particularly for agriculture, because of their mild climate and favourable soil conditions (Sala *et al.* 2013). This is particularly of concern since protection of drier tropical habitats, including grasslands, savannas, and shrublands, is somewhat lower, with only 5.9% coverage in strictly protected areas (PAs) and 12.5% in all reserve categories (Jenkins and Joppa 2009).

In India, despite being one of the most productive ecosystems, grasslands have been considered as 'wasteland' which could be diverted for any other use (Planning Commission of India 2006). Until recently, policies of various state Forest Departments too had been to convert grasslands into 'forests' with plantation of fuel/fodder shrub/tree species under various central- and state-sponsored schemes. Furthermore, grassland habitats are proportionately under-represented in India's terrestrial PA network (Rahmani and Manakadan 1988, Rodgers and Panwar 1988) of more than 600 reserves (ENVIS 2016). Outside the PA system, where much of grasslands in India lie, most such habitats have been degraded primarily due to overgrazing (of livestock) coupled with non-sustainable harvest practices (Roy and Singh 2013) in a fate mirroring the 'tragedy of the commons' phenomenon (Hardin 1968).

Inhabiting Indian grasslands are some of the most threatened birds on the precipice of extinction from the wild such as the Great Indian Bustard *Ardeotis nigriceps* (less than 200 birds), Bengal Florican *Houbaropsis bengalensis* (less than 1500 birds), Bristled Grassbird *Chaetornis striatus*, Swamp Prinia/ Swamp Grass-babbler *Laticilla cinerascens* and Manipur Bush-quail *Perdicula manipurensis* among others (Rahmani 1989, Rahmani *et al.* 2016).



**Figure 25: Area within yellow outline polygon roughly depicts Dudhwa1's core use areas during 2015-16; octagonal polygons filled with light orange colour indicate areas where grass was trimmed by a grass-cutting machine and those filled with light green colour indicate areas where grass was trimmed by manual labour; satellite imagery courtesy GoogleEarth (2014)**

In this scenario, one of the ways by which the future of grasslands and its inhabiting biodiversity along with all its vital ecosystem services can be protected is through ecological restoration. Ecological restoration is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity and sustainability (SER 2004). Restoration strategies may be suitably adapted and modified in view of end objectives at various places. As a means of conserving biodiversity, any successful restoration program will require a focused effort to identify remaining habitat and implement habitat management activities that maximize the production of multiple species (Askins 2000, Vickery *et al.* 2000).

#### **Rationale for habitat restoration at Dudhwa for Bengal Florican**

Understanding the ecological processes that originally maintained grassland systems is critically important for efforts to improve, restore, or create habitat for grassland birds and other grassland organisms (Askins *et al.* 2007). Historically, the agents principally responsible for maintaining grassland habitats were flood/drought regimes, grazing by native herbivores, and fire (Vickery *et al.* 2000).

Bustards originated more than 70 million years ago (del Hoyo *et al.* 1996) in Africa and speciated over discreet ranges of the Old World grasslands (Johnsgard 1991) being adapted to temperate and tropical open grass plains (Broders *et al.* 2003). Their coevolution with wild ungulates has meant that they depend on a community of grazers to maintain a suitable habitat structure (Dutta *et al.* 2011). Since the last thousand years, the community of wild grazers has been steadily replaced by domestic livestock in most of the bustards' range outside Africa (Skarpe 1991).

In India too, the wild grazers' community in particular (and all large mammals in general) has declined rapidly and they only survive within and because of the relatively well protected PA-network of



Figure 26: Manual grass-trimming activity being conducted at PTT-tagged male Dudhwa1's breeding territory abutting the Dudhwa-Chandan Chowki road in June 2016 (Photo credit: Rohit Jha)



Figure 27: Grass-trimming activity by machine being conducted at PTT-tagged male Dudhwa1's breeding territory in June 2016 (Photo credit: Rohit Jha)

reserves (Karanth *et al.* 2010) or in certain community forests protected as sacred groves (Gadgil and Vartak 1975). Even in PAs, their numbers have considerably dwindled from what they were at the turn of the 20<sup>th</sup> century and are threatened by widespread hunting and illegal wildlife trade to this day (Madhusudan and Karanth 2002).

Spread across the Indian states of Uttarakhand, Uttar Pradesh and Bihar, and the low lying hills of Nepal, the 'Terai Arc Landscape' (TAL) is a more than 800 km stretch between the river Yamuna in the west and the river Bhagmati in the east, comprising the Shivalik hills, the adjoining bhabhar areas and the Terai flood plains (WWF- India). These three strata run in the form of narrow strips parallel to the south of the main Himalayan range. Comprising of alluvial grasslands (savannas) interspersed by dense forests and swamps, only less than 60 years ago, the TAL was a contiguous expanse of a vast natural habitat (Semwal 2005) inhabited by a large number of large herbivores and other mammals, apart from a suite of distinctly adapted avian species. In fact, historically, the diversity and biomass of large herbivores in undisturbed Terai ecosystem equated or perhaps exceeded that of many wildlife areas in East Africa (Lehmkuhl 1994). Today, perhaps no more than two percent of the alluvial grasslands of the Gangetic floodplain remain intact (WWF, n.d.).

Terai grasslands have been described as a seral stage community in the succession continuum between the primary colonization of new alluvial deposits by flood climax grass and herbaceous species, and the non-flood climax deciduous forest dominated by *Sal Shorea robusta* (Champion and Seth 1968, Dabadghao and Shankarnarayan 1973; Lehmkuhl 1989, 1994). Since most of the grasslands have now been converted to agriculture amongst other land uses, and intervening non-protected forests lost to commercial logging, the handful of PAs in the TAL have been reduced to isolated refuges unable to sustain important ecosystem processes (Semwal 2005). Remnant natural savanna grasslands now only survive in the form of various sized *phantas* (as grassland patches are locally called) enclosed by sal forests in such PAs (Kumar 2013).

Following the rapid disappearance of their natural habitat, megaherbivores such as rhinos, wild buffaloes and elephants have all but disappeared from much of the TAL, while cervids such as the swamp deer, sambar, chital and hog deer survive at relatively low densities. This community of large wild grazing mammals, by their slightly varying grazing habits and food preferences, had in the past naturally maintained a mosaic of short and tall grass areas within grasslands thus facilitating the existence of several grassland-dependent avifauna with varying habitat requirements.

At current low densities of occurrence, this wild grazers' community is perhaps unable to fulfil this function. Moreover, the Wildlife (Protection) Act of India, which governs PAs in the country, explicitly prohibit forest produce harvest activities as well as livestock grazing inside national parks and core/critical tiger habitat areas within tiger reserves (MoEF 2006). Thus, the ecosystem function that was rendered by the wild grazers' community cannot be replaced either by domestic cattle and/or activities by local human communities.

The Bengal Florican has been experiencing a continual decline in the state of Uttar Pradesh. The latest survey enumerated a total of only ten adult territorial male birds- seven in Dudhwa National Park and

three in Pilibhit Tiger Reserve, whereas Rahmani (2001) had recorded a total of 31 territorial male birds from Dudhwa, Kishanpur and Katerniaghat reserves, and from the Lagga-Bagga grassland (now part of Pilibhit Tiger Reserve). Since then, the Bengal Florican has probably disappeared from Katerniaghat Sanctuary while it has not been documented at Kishanpur Sanctuary from 2014 onward.

In the face of such a rapid decline, it is of utmost importance that habitat management strategies specifically aimed at improving the Bengal Florican's grassland habitat in line with its habitat-use patterns are implemented. This is especially of concern when the deleterious effects of present day management practices such as the annual large scale burning of grasslands (after an initial round of cutting or harrowing) late in the dry season on the vegetation composition as well as on different faunal groups has been realised (Bell 1986, Javed 1996, Kumar 2012, Oliver 1980) including that on the Bengal Florican (Sankaran and Rahmani 1991).

Research done in similar mesic grasslands in North America suggest the adoption of controlled and staggered patch burning as a conservation measure in fire-prone areas along with grass cutting (Churchwell *et al.* 2008). Staggered cutting and burning would also create different patches providing varying forage and cover conditions (Kumar 2012). It is hoped that structural heterogeneity, both in temporal and spatial terms, in the form of mosaic of habitats created by cut, uncut, burned and unburned patches, would provide suitable habitats for the persistence of diverse faunal species (Fuhlendorf *et al.* 2006).

#### **Grassland Restoration Pilot Exercise at the Chandan-chowki 2<sup>nd</sup> rail crossing *phanta*, Dudhwa National Park**

In a multi-stakeholder workshop held at the state forest headquarter complex in Lucknow in February 2016 to discuss Bengal Florican conservation in Uttar Pradesh, it was decided that proactive and adaptive strategies should be designed and adopted in order to bring the species back from the brink of local extinction in the state. In this regard, a pilot habitat restoration exercise was conducted at a known grassland territory of a satellite device (PTT)-tagged Bengal Florican male bird (designated and hereafter referred to as 'Dudhwa1', strapped with the device in June 2015) in the Dudhwa range of Dudhwa National Park. This was thought to be a good opportunity to conduct such an exercise since one could relate the effect of such a habitat management/engineering measure to actual movements of the bird derived from accurate location information obtained from the PTT-tagged bird.

Satellite-tracking studies by BNHS in Dudhwa and Pilibhit reserves of Uttar Pradesh during 2014-16 has revealed that while birds displayed tremendous site-fidelity to breeding grounds inhabiting and displaying in the same territory year after year during the breeding season (March to June), much like other bustards, they moved away a considerable distance (ranging from 15-50 km) to the floodplain-agricapes of river Sharada during July-August and stayed there until the beginning of the next breeding season.

One of the explanations/hypothesis behind this phenomenon was that since grass-shrub vegetation in the birds' breeding territories within PAs grows very dense and tall at the advent of the monsoon in July, the Bengal Florican, being a largely cursorial bird, finds it extremely difficult to live in such

conditions. In the past it may have always found short grass patches nearby due to wild megaherbivores' grazing activity. Since the wild grazers' community, both in terms of numbers and species diversity, has diminished, vegetation grows thick and dense within grasslands in these reserves. This leaves these open grassy plains' bird with perhaps no 'suitable' habitat inside these PAs. This may then prompt them to move to the nearest structurally 'suitable' available areas with short grass habitat or under short height agricultural crop such as mustard, lentil, paddy, young sugarcane etc. which happens to be in the floodplain-agricultural landscape flanking both sides of the river Sharada. The agricultural activity in this landscape is characterised by low-intensity cultivation with minimum use of technology, small to large land holdings, presence of several agricultural fallow land patches, and limited use of agro-chemical inputs such as synthetic pesticides and insecticides.

These areas have a very high water table, largely quick drain sandy-clayey soil, and are seasonally flooded every monsoon. Being a flood-prone landscape, there is little to no permanent settlement or infrastructure at these places and human presence/disturbance, although constant due to agricultural activity, is relatively low. Remnant upland grassland areas spread across in small and large disjointed patches under the administrative jurisdiction of the North Kheri Forest Division are heavily grazed by thousands of cattle heads from nearby villages and cattle camps (locally called *ghoudis*). This landscape also has standing sugarcane of various ages throughout the year spread across, while some lowland areas are under tall grassland cover (chiefly *Typha-Phragmites* community of grasses). Mature sugarcane and tall lowland grassy areas/patches may provide the Bengal Florican with adequate cover during its up to seven months stay in this landscape throughout the non-breeding season.

Yet, this unprotected floodplain-agricultural landscape poses its own suite of threats to the survival of the Bengal Florican and perhaps other cohabiting wildlife. Since this landscape is occupied by wild animals such as the Nilgai *Boselaphus tragocamelus* and Wild Pig *Sus scrofa*, which opportunistically feed on agricultural crops, illegal activities such as poaching by use of firearms or by methods such as snaring and trapping are clandestinely carried on. Large number of waterfowl birds such as the Ruddy Shelduck *Tadorna ferruginea* too occupy this landscape during winter months and incidents of attempted poaching by trapping and bait-poisoning are widely and regularly reported in the local media (Shukla 2016). Being a largely cursorial bird, the Bengal Florican is prone to accidentally being poached through all such means. This is compounded by the near absence of Forest Department personnel in these usually remote areas. Additionally, the possible deleterious indirect effects of pesticides operating through the food chain on the reproductive biology (Fry 1995) of the Bengal Florican is unknown in the absence of any scientific investigation in this regard.

Thus, the thought process behind the pilot restoration exercise attempted in Dudhwa was to gain valuable insight and first hand knowledge of the outcome of such an interventionist measure. The chief objective of this exercise was to suppress the territorial bird Dudhwa1's urge to move to unprotected floodplain-agricultural landscapes outside the purview of near foolproof protection that may be guaranteed within the PA. This was thought to be achieved by providing Dudhwa1 with an admixture of short and tall grass patches within its traditional breeding territory. This was also in concurrence with the findings of a year-long habitat-use study (vegetation correlated with location data) which suggested that the Bengal Florican used both tall grass/vegetation habitat patches (possibly as cover) as well as open short grass plains/short agricultural crop areas (possibly for feeding and roosting) (see Chapter II).

Accordingly, a habitat restoration design that provided such an admixture was implemented just before the onset of monsoon during the second and third week of June 2016 (Figure 25). Due to several staggered pre-monsoon shower events during May-June, vegetation had already grown very tall, on an average 2-3 m tall, throughout Dudhwa1's territory. Location data from Dudhwa1 informed that the bird still inhabited the area, although field surveys indicated that its aerial display activity had ceased by then. Tall grass vegetation on a total of about eight and half hectares area (four hectares by a grass-cutting machine in three plots, rest by manual labour in five plots) (Figures 26, 27) within Dudhwa1's core territory (central point's coordinates: N28.499260°, E80.703038°) was converted to short grass plains leaving interspersed taller vegetation areas intact. If this were to succeed in preventing the bird moving away, the exercise was to be repeated after appropriate intervals of time considering the growth trajectory of grass at the trimmed plots.

### **Results**

The restoration pilot trial appeared to have succeeded at first, in that the territorial bird 'Dudhwa1' was regularly seen by the research team using the 'restored' short grassland patches for feeding. This was of some significance since the density of insects, especially that of orthopterans, had multiplied manifold perhaps due to the emergence of renewed grass swards from the cut stands which may have been palatable food for them.

Since monsoon showers had already set in, vegetation in the trimmed patches displayed tremendous growth curve and within a week's time had become as tall as they were before. Considering the logistics of manpower and available funds, the research team planned to have a second round of grass trimming done at a couple of such 'trimmed' patches after an interval of four weeks time in the third week of July.

Before this could be done though, satellite data revealed that 'Dudhwa1' flew away from its breeding territory in the second week of July itself (July 12) to the floodplain-agriscape of river Sharada where it usually spent its non-breeding months. The planned second round of grass trimming was therefore not carried out.

### **Discussion**

Although this habitat restoration exercise was not able to prevent the territorial male flying away from the relatively safe Dudhwa reserve to the relatively unsafe floodplain-agriscape, the exercise did raise a few questions worthy of scientific investigation/debate.

Out of Dudhwa1's computed total home range of approximately 85 hectares area (MCP 95%), the research team, based on available resources, managed to get approximately eight and a half hectares (about 10 percent of the home range area) trimmed. Was this area large enough so as to support an individual bird throughout the non-breeding months? It is also possible that, over time, these facultative migratory movements have become so 'hard-wired' into birds (Newton 2012) that they now move on to the floodplain-agriscape wintering areas notwithstanding the state/structure of habitat at their breeding territories. Perhaps a second round of grass trimming, even if repeated only at a couple of plots, within twenty days from the first exercise might have proved sufficient towards restraining the bird's urge to migrate.

What also need to be highlighted and acknowledged are the slight differences, both in economic terms and the manner in which grass was trimmed, by men and machine. Whereas it took only two full working days for two men (a driver and an assistant) with the grass-cutter machine attached to a tractor vehicle (12 hour total run) to trim four hectares of vegetation, twenty-seven men spent four days of hard labour to trim another four and a half hectares.

Taking into account the cost of hiring a grass-cutter/tractor for two days (at INR 2500/day) and remuneration for two people (at INR 250/person/day) along with the cost of fuel (~ 3.5 litres diesel/hour at INR 55/l of diesel) and a nominal cost of providing food and water (INR 75/person/day) to personnel involved, the total cost of grass-trimming by machine works out to be INR 2,152.5/hectare area trimmed.

Correspondingly, it took 108 man-days or 702 man-hours (27 men worked on four days, each working day translates to about six and half hours of actual work time) to manually trim four-and-half hectares area of vegetation. Taking into consideration the cost of labour (INR 250/person/day) and their nominal transport and food allowances (INR 75/person/day), the total cost of grass-trimming by labour works out to be INR 7800/hectare area trimmed. The economic cost of employing labour to trim vegetation is thus almost four times costlier than vegetation trimming by machine and far more logistically challenging.

The grass-cutter machine attached to a tractor was moved in concentric circles along each earmarked plot. Its strong and motor-driven steel rotating blades cut vegetation at about ten to fifteen inches height from the ground (adjustable) and dropped the trimmed vegetation within the plot itself. The machine was capable of trimming all kinds of vegetation in the plot, including shrubs and saplings, leaving only tough woody vegetation intact. In contrast, men were given instructions to cut all vegetation, including invasive plants such as *Parthenium* but excluding native shrubs like *Crewia asiatica* (locally known as *phalsa*), whose berries have been documented as part of the Bengal Florican diet (Sankaran and Rahmani 1991), at one foot (or twelve inches) height from the ground. They were also advised to not cut any visibly grown woody species' sapling. All men used their own sickle to trim vegetation as instructed, and the trimmed bunches of grass and invasive shrubs were deposited near tall mature trees outside all earmarked plots.

The different ways in which vegetation was trimmed by men and machine resulted in significantly different growth trajectories of emergent vegetation post the trimming exercise. While trimmed vegetation slowly wilted and dried away within the machine-trimmed plots and the growth of new grass sward was considerably slow (possibly due to the physical stress imposed on grasses by the activity of a heavy machine), the corresponding growth of vegetation in the manually trimmed plots was almost instant and rapid, mimicking the profitable response that many grasses show towards overcompensation for herbivory activity by animals (in this case, simulated grazing) (Frame and Hunt 1971, van der 1990). Devoid of any trimmed vegetation residue, the manually-trimmed plots had a significantly higher proportion of bare ground cover than the machine-trimmed plots. Subsequent field observations of bird 'Dudhwa1' as well as its satellite location data revealed that 'Dudhwa1' used plots trimmed by manual labour more frequently than those trimmed by machine.

Thus, although on pure economic criteria grass-trimming by machine may seem more viable, regular grass trimming by labour as a grassland restoration measure may present its own ecological benefits to the Bengal Florican. It also provides a generally poor population living close to such PAs with an additional source of income, thereby making them an important stakeholder in the restoration activity. PA managers may thus need to seriously consider the tradeoffs between the use of man and machine in such ecological management efforts and perhaps need to devise ways to optimally use both methods as per relevant situation and circumstances.

Today, grassland management practices in most PAs are related to enhancing/maintaining the habitat of mega-vertebrates, and little attention is given to habitat requirements of grassland birds. It is thus essential that research on ways to scientifically manage the remaining Bengal Florican occupied and suitable grassland patches/habitats in the region in line with Bengal Florican habitat-use patterns be urgently undertaken. This may include the establishment of several trial management plots in known Bengal Florican territories and other 'suitable' grassland *phantas* towards developing a comprehensive grassland management protocol which aims to benefit a suite of grassland-obligatory threatened avifauna.

This should also include the need to experimentally evaluate the efficacy of livestock, within the bounds of extant laws, to achieve desired modifications to vegetation structure both inside and outside PAs, especially during the non-breeding season of the Bengal Florican, along with the economic aspects associated with implementing such heterogeneity-based management practices (Derner *et al.* 2009). Behavioural studies to decipher the Bengal Florican's usage of space with time/seasons/disturbance events in different populations could be undertaken with the help of high accuracy GPS-GSM tags.

Another essential area of research might be to look at how existing small and isolated areas of grassland within closely situated PAs can be connected with each other, possibly through the restoration and maintenance of now degraded grassland patches in various Reserved Forests, using best practices. It is also crucial that long-term studies on grassland habitat management and the response of avian density and nesting success to vegetation measures and various environmental perturbations in the *terai* are initiated since management guidelines developed from small-scale, short-term studies may lead to misrepresentations of the needs of grassland-nesting birds (Winter *et al.* 2005).

Restoration efforts, wherever necessary and required, must be implemented and try to adhere to a set of fourteen clearly laid out guidelines outlined by Keenleyside *et al.* (2012). It must be remembered that measurable project objectives, appropriate control and restoration techniques, and robust monitoring are all critical to effective restoration planning and execution (Sogge *et al.* 2008). The criteria of restoration success (such as increase in nesting success at restoration sites) should also be clearly established in order to objectively evaluate restoration projects (Wortley *et al.* 2013).

On the advocacy front, it will be of utmost importance to engage and apprise officials and field staff of the Uttar Pradesh Forest Department on the urgent need to undertake large scale grassland ecological restoration and ecological management efforts in the state, as the Bengal Florican faces an uncertain future and certain local extinction in the absence of such an initiative.

## Chapter IV

### ***Chapori* (river island) survey of the river Brahmaputra, Assam**

#### **Survey Team Members**

Mr. Ngulkhohal Khongsai, BNHS

Mr. Rustom Basumatary, Guide, Manas Maozigendri Ecotourism Society

Mr. Swapan Jyoti Das, Field Assistant-cum-Driver

Survey Boat: "S.B. Kohua"

**Start Date:** May 20, 2015; Place: Uzan Bazaar, Guwahati

**End Date:** June 19, 2015; Place: Fancy Bazaar, Guwahati

Text and Figures by Ngulkhohal Khongsai

#### **Introduction**

The Brahmaputra River is one of the largest rivers of the world, traversing about 2,900 km, with an average water discharge of 19,300 m<sup>3</sup>/s (681,600 cu ft/s). The Brahmaputra is known as Tsangpo in Tibet, and when it reaches Arunachal Pradesh it is known as Siang. It is joined by Dibang and Lohit rivers. Below Lohit River, it is called Brahmaputra when it reaches Assam plains. It becomes very wide here- as wide as 10 km in some parts of Assam. Between Dibrugarh and Lakhimpur districts, the river divides into two channels- the northern Kherkutia channels and the southern Brahmaputra channels. The two channels join again about 100 km downstream, forming the Majuli island.

In Assam, river islands are called *chaporis*. Many of these islands are covered with grasses and hence suitable for Bengal Floricans. The Sadia plains and *chaporis* of northern Assam are famous for harbouring Bengal Floricans. We conducted a month-long survey of these islands from May 20 to June 19, 2015, with the following objectives:

- 1) Survey of *chaporis* of the Brahmaputra River for presence/absence of Bengal Florican
- 2) To spread awareness/conservation of Bengal Florican in the *chaporis* of the river Brahmaputra
- 3) Compile a checklist of birds seen during the survey
- 4) Compile a list of *chaporis* which will be used for future reference

#### **Methodology:**

Simple field methods were used for detecting Bengal Florican presence at grasslands. Selection of areas to be surveyed was done based on the availability of suitable grassland patches and accessibility of the *chapori* for the survey boat. The aim was to detect the presence of Bengal Floricans. These surveys were done with the help of 8×42 binoculars. Geo-coordinates of the grasslands surveyed were recorded with the help of Garmin hand-held GPS devices.

### **Flushing Method**

To optimize the effectiveness of our survey, two of the boat staff, after safely anchoring the survey boat, would go to the roof of the boat (the height of the boat was around 5 m from the river level) to monitor wildlife and to see if any Bengal Florican was flushed. The boat staff were also instructed to warn researchers/field-workers in case any potentially dangerous wild animal (rhinoceros, elephant) was detected. Before each grassland/*chaporis* survey, the area's alignment was followed, a marker was set up taking help of the magnetic compass and the distance to be covered was kept in mind. Thereafter, four persons standing 3-5 m apart from each other, would walk in Z-shape formations in order to cover a larger area. All avian species seen/detected during these surveys were noted. This survey methodology was followed at most of the *chaporis*.

### **Observation by sitting for three hours**

At *chaporis*/grassland patches where Bengal Florican was reported by local people, we conducted dedicated observation/detection surveys. In the absence of suitable vantage point in and around the *chaporis*, we were restricted to standing at the grassland edge to look for any territorial male Bengal Florican's aerial display. Total time spent at each site during such detection surveys was three hours.

### **Boat Survey- Field Challenges**

Due to the constant and yearly changes in river trajectories/course, older satellite images available from Google Earth might have proven unreliable. Thus, in order to get a better knowledge of the area to be covered, we stopped at *khuttis* (cattle camps) or fishermen camps and acquired local knowledge of the surrounding river areas where there was a possibility of finding grassland patches dominated by either *Saccharum* or *Impereta cylindrica*, or any *chaporis* which was still not submerged by the Brahmaputra river and its various tributaries. With the information thus acquired, these surveys were conducted.

Names of most *chaporis* were given by local boatmen or *khutti* owners. Upon arrival at a new place, if there was no *khutti* or no one to tell us the name of the islands, we numbered the island as Tappu (island) 1, 2 and so on.

Due to the ever-changing nature of the Brahmaputra, we found that islands that we wished to survey were sometimes out of reach, due to reasons such as the water depth and dimensions of the boat. Thus, our survey of *chaporis* was not extensive, often restricted due to reasons mentioned earlier.

Table 23: *Chaporis* seen/surveyed during May-June 2015

Date	Place	Longitude (N)	Latitude (E)	Elevation (m)
20/5/2015	Nikandi Tappu	26°18'27.5"	92°01'58.2"	50
21/5/2015	Elephant tappu	26°30'40.4"	92°16'07.4"	47
21/5/2015	Orang National Park	26°31'25.6"	92°16'58.1"	54
21/5/2015	Singri tappu	26°37'09.2"	92°35'02.2"	65
22/5/2015	Tappu	26°33'59.3"	92°38'24.3"	56
24/5/2015	Sildubi Tintika	26°38'50.7"	93°00'26.1"	63
24/5/2015	Tiwari	26°39'07.8"	93°02' 27.5"	58
24/5/2015	Bogoriati Tappu	26°38'30.1"	93°04'54.7"	61
24/5/2015	Bogoriahati Khutti	26°53' 26.7"	93°06'28.2"	61
25/5/2016	Boroimukh Tappu	26°44'58.9"	93°25'19.2"	64
25/5/2015	May Morning	26°41'38.6"	93°14'40.6"	61
25/5/2015	Near Arimora	26°42'22.6"	93°18'31.2"	68
26/5/2015	Kartika Tappu	26°46'45.2"	93°30'46.7"	66
26/5/2015	Tutte Chapori	26°46'38.2"	93°33'28.7"	63
26/5/2015	Jeroni Chapori	26°43' 28.4"	93°38'33.9"	66
26/5/2015	Lonku Tappu	26°43' 12.8"	93°34'55.9"	60
26/5/2015	Nastey Tappu	26°42'45.9"	93°38'55.8"	73
27/5/2015	Near Ganesh	26°45' 01.2"	93°42'11.1"	63
27/5/2015	Bamun Chapory	26°44'16.0"	93°42'58.7"	67
27/5/2015	Pohu mara	26°44'34.1"	93°43'19.8"	68
27/5/2015	Ratan Sahni Tappu	26°45'15.8"	93°43'56.3"	65
27/5/2015	Bikas Tappu	26°47'53.2"	93°46'36.0"	60
27/5/2015	Autura Chapori	26°50'50.7"	93°48'58.9"	68
28/5/2015	Hikulimara tappu	26°51'55.7"	93°54'36.8"	71
28/5/2015	Gunai Tappu	26°51'45.9"	93°55'20.1"	70
28/5/2015	Gonas Tappu	26°52'01.1"	93°56'12.6"	67
29/5/2015	Komulia Chapori	26°52'44.9"	93°56'34.0"	74
29/5/2015	Bonoria Tappu	26°51'58.5"	93°59'49.9"	68
29/5/2015	Pogola Chapori	26°52'16.4"	94°00'00.4"	70
29/5/2015	Rojabari Chapori	26°52'44.7"	93°59'59.1"	68
29/5/2015	B.F Seen	26°52'54.2"	94°00'36.4"	69
30/5/2015	Kareng Gaon	26°51'07.5"	94°05'00.0"	71
30/5/2015	Bangmora Chapori	26°39'10.3"	94°04'52.8"	73
30/5/15	Kartic Tappu	26°50'51.3"	94°07'54.7"	68
1/6/2015	Moh Chapori	26°52'07.7"	94°16'00.6"	93
1/6/2015	Aphalo ghat	26°54'57.5"	94°17'55.6"	72
1/6/2015	Majuli Island	26°54'52.5"	94°17'43.4"	71
1/6/2015	Halmora Gaon	26°57'00.7"	94°18'25.4"	66
1/6/2015	Reserve Tappu	26°57'35.6"	94°18'43.9"	67
1/6/2015	Orchid	26°57'42.0"	94°19'04.7"	66
2/6/2015	Bogibheel	26°58'48.0"	94°20'44.9"	74
2/6/2015	Kargil Chapori	26°59'29.5"	94°20'09.1"	67

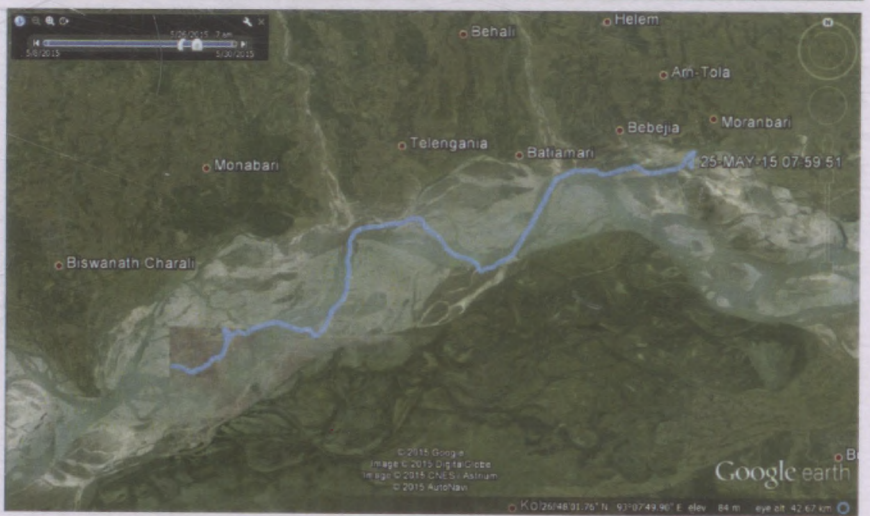
**Table 23: *Chaporis* seen/surveyed during May-June 2015 (contd.)**

Date	Place	Longitude (N)	Latitude (E)	Elevation (m)
3/6/2015	New Tappu	26°58'45.6"	94°22'27.6"	77
3/6/2015	Bonoria 2 Chapori	26°58'51.0"	94°22'17.1"	79
3/6/2015	Siv Tappu	26°58'22.9"	94°25'04.8"	75
3/6/2015	Telijunga	26°58'16.7"	94°24'32.1"	78
3/6/2015	Basamukh Tappu	27°08'14.9"	94°34'16.3"	84
4/6/2015	Camp Tappu	27°10' 28.9"	94°36'55.0"	89
4/6/2015	Dokin Chapori	27°10'23.8"	94°37'03.9"	84
4/6/2105	Tengapani	27°11'01.0"	94°38'45.7"	85
4/6/2015	Mohkhoha tappu	27°13'32.6"	94°39'42.3"	80
4/6/2015	Dihing Chapori	27°15'45.6"	94°41'40.8"	86
4/6/2015	Madhipur	27°20'23.8"	94°44' 28.3"	84
9/6/2015	Chulkhowa Bogibheel	27°22' 00.8"	94°46' 21.7"	106
11/6/2015	Manas tappu	27°01'59.7"	94°26' 58.0"	80
11/6/2015	Saguli chapori	27°01' 38.5"	94°26' 37.5"	68
12/6/2015	Bonoria2 chapori	27°01'09.8"	94°24' 25.0"	75
12/6/2015	Tappu 12	27°00'09.6"	94°23' 05.7"	78
12/6/2015	Reserve	26°57'06.5"	94°18'11.0"	71
12/6/2015	Meraghar Village	26°57'59.0"	94°18'01.6"	87
12/6/2015	Nikinikhua Village	26°58'54.2"	94°18'32.3"	83
13/6/2015	Grazing Village	26°58'33.4"	94°18'32.3"	76
13/6/2015	No 1 Bonoria Chapori	26°59'29.5"	94°19'17.6"	71
13/6/2015	Dakhinpad Kumagaon	26°54'28.8"	94°14'37.3"	71
14/6/2015	Tikirai chapori	26°53'38.6"	94°14'22.9"	76
14/6/2015	Kamlabari Ghat	26°54'57.6"	94°09'33.9"	76
15/6/2015	Tamarisk Tappu	26°53'26.7"	94°01'38.8"	74
15/6/2015	Misamora Chapori	26°54'07.1"	93°57'22.8"	73
15/6/2015	Ulu Pam Village	26°55'08.0"	94°04'02.4"	68
15/6/2015	Pokhimara tappu	26°54' 53.8"	94°03'53.4"	69
16/6/2015	Hatibali	26°46'15.4"	93°22'55.0"	66
16/6/2015	Near Arimora	26°41' 35.5"	93°19' 26.8"	67
16/6/2015	New	26°46'20.1"	93°21'45.7"	63
16/6/2015	Near Tiwaripal	26°38'56.5"	93°01'59.6"	61
17/6/2015	Jahaj Tappu	26°36'16.6"	92°45'21.7"	56
18/6/2015	Lonke Chapori	26°34'47.0"	92°42'12.2"	58
18/6/2015	Near Majarwali Tappu	26°33'59.3"	92°37'22.7"	52
18/6/2015	Thengbhanga tappu	26°33'54.4"	92°36'36.9"	46
18/6/2015	Near Singri Hills	26°35'07.9"	92°31'58.1"	52
18/6/2015	Orang F Camp	28°31'17.3"	92°16'50.9"	49

Following figures depict tracks made by observers and/or boat during the *chapor* surveys overlaid on Google Earth imagery

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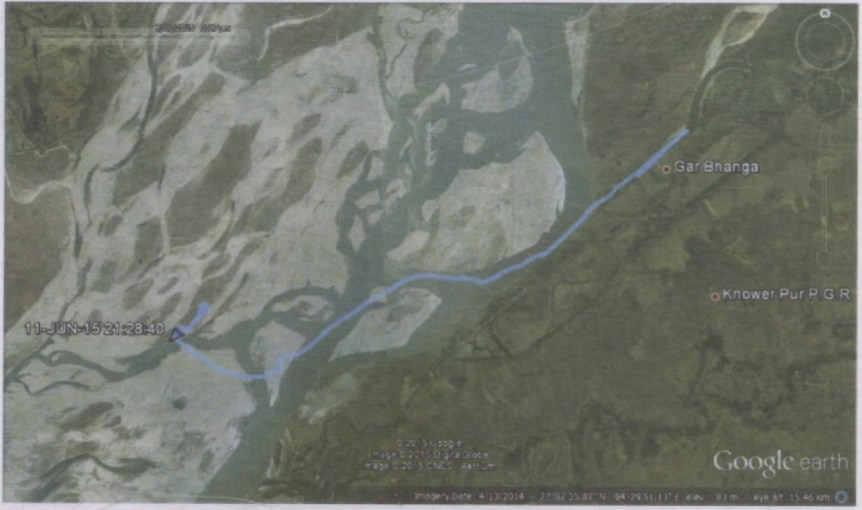
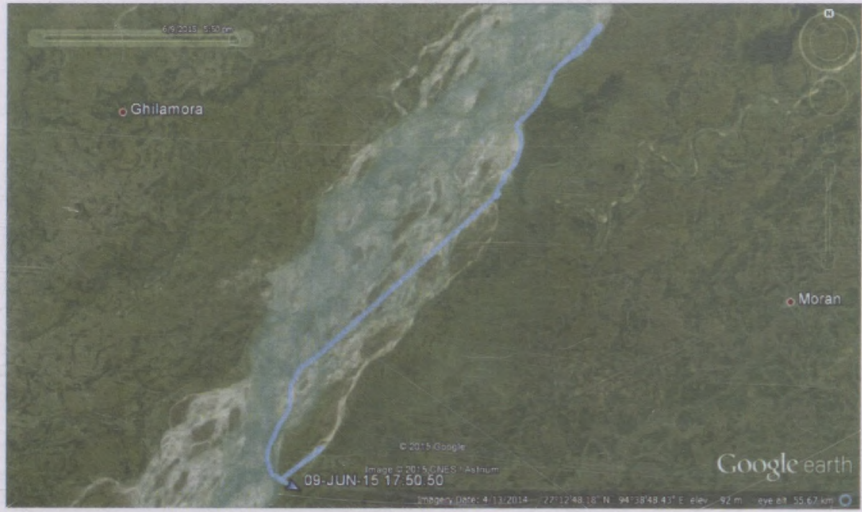
















**Table 24: Names of *chaporis* where Bengal Florican detections were confirmed by secondary sources**

Date	Chapori name	Geographic coordinates	Number of Bengal Floricans seen		Observed by
			2014	2015	
29/5/2015	Pogola Chapori	N26°52'16.4" E94°00'00.4"	2 males	2 males	Mr.Joyanta Pegu
30/5/2015	Kareng Gaon	N26°51'07.5" E94°05'00.0"	2males	2males	Mr.Niranjan Sabor & Mr.Bakuram Doley
2/6/2015	Kargil Chapori	N26°59'29.5" E94°20'09.1"	No	1 male	Mr.B.Baruah
3/6/2015	B o n o r i a 2 Chapori	N26°58'51.0" E94°22'17.1"	No	1 male	Mr.Pabin Taye
14/6/2015	Tikirai chapory	N26°53'38.6" E94°14'22.9"	1 male	No	Mr.Satyajit kolita & Mr. Maheshwar Kolita
15/6/2015	UluPam Village	N26°55'08.0" E94°04'02.4"	1 male	No	Mr.Moheshwar Kolita
17/6/2015	Jahaj Tappu	N26°36'16.6" E92°45'21.7"	2M	1M	Mr.Dipen Baruah& Mr. Smarajit Ohja

### **Chapori grassland survey**

Grassland patches on the surveyed *chaporis* can be divided into “disturbed” and “undisturbed” categories, depending on grazing and human pressures.

At ‘undisturbed’ grasslands, we found dense *Saccharum spontaneum* stands, and/or *Tamarix* thickets where even walking was difficult. Short grass patches dominated by *Impereta cylindrica* was found at fewer *chaporis*. Of the *chaporis* surveyed, at about eighty percent sites, *Tamarix* was the found to be the dominant vegetation. *Tamarix* was seen growing profusely on the sandy banks close to the river Brahmaputra.

During our month-long survey, we did not detect any Bengal Florican. Nevertheless, we obtained sighting information from secondary sources confirming the bird’s presence on a few *chaporis*. Such secondary records were collected after a detailed preliminary enquiry and only upon being convinced that the source had seen the Bengal Florican were the records accepted.

Altogether, during our *chaporis* survey, we gathered information on the presence of seven male Bengal Floricans by local people.

### **Conclusion**

Posters of Bengal Florican in both English and Assamese languages greatly helped the survey team to determine knowledge of the locals who sometimes mistake the bird for either Red-wattled Lapwing or Black-necked Stork. Considering the language barrier that the team faced at most places, it would be more prudent for survey teams in the future to carry posters/leaflets printed in Hindi and Bengali languages as well.

Since this survey was conducted during the peak flooding season of the Brahmaputra River, it would be advisable for research teams to conduct the *chaporis* surveys during the months of March and April when conditions are more favourable to fieldwork.

Vegetation composition seems to have changed significantly in terms of spread and dominance of *Saccharum*, as well as *Impereta*. However, dominance of *Tamarix* thickets on many *chaporis* cannot be overlooked. These aspects warrant long term studies in the area to better evaluate the effects of such changes in habitat on the species composition of grassland birds.

We also found that the *chaporis* within protected areas, where there was no livestock grazing observed, the grass composition was of *Vetiveria* sp. and *Tamarix*, with occasional patches of *Saccharum* sp. Notably, from most of such areas *Impereta cylindrica* was only sparsely recorded.

We also found that smaller *chaporis* with limited livestock grazing had better grass composition as well as grass height. Most of the secondary sighting records obtained by us were from *chaporis* with relatively low levels of livestock grazing. Bengal Florican was not reported on any of the large *chaporis* that harboured huge livestock population and several *khuttis*.

## Chapter V

### Recommendations

The Bengal Florican is one of the rarest members of the bustard family in the world. In 2008, IUCN and BirdLife International uplisted it to the "Critically Endangered" category. Despite its protected status in India for almost 45 years under Schedule I of the Indian Wildlife Protection Act, 1972, its population has declined from a number of sites, some even legally protected as national parks or sanctuaries. It has almost totally disappeared from non-protected grasslands. Even in well-protected PAs such Dudhwa, Kaziranga and Manas, no specific attention is given to its protection. Its habitat- flat grassy alluvial plains- is under tremendous anthropogenic pressure, and whatever is left within PAs is, at present, solely managed for mega-vertebrates. Sometimes grass is burnt during the peak breeding period of Bengal Florican and other grassland birds.

Ecology and habitat use of Bengal Florican is not fully known, mainly due to its retiring and shy nature, and moderately tall grassland habitat where it lives. We know a bit more about the male florican due to its conspicuous nature during the breeding season (with a spectacular aerial display), but the species' nesting ecology is still not known as female floricans are rarely seen. Conventional observational wildlife science is not suitable for studying the species' micro-habitat requirements, predation, nest-site selection, nesting success and dispersal of Bengal Florican. Fortunately, modern tools such as radio- and satellite-tracking offer a viable alternative and can be employed to study these aspects.

During the present project, we were able to study and monitor the movements and habitat use of three male Bengal Floricans for almost three years. This has given us novel and important information about its ranging patterns in Uttar Pradesh, particularly outside PAs. However, as we were not able to tag any female florican, several questions still remain unanswered. The long-term impacts of managerial activities such as annual grass burning on the grassland vegetation composition and on the grassland birds' community needs to be scientifically studied.

In brief, this project was a small attempt to study the ecology and movement of Bengal Florican. Much more need to be done, for which we carefully prescribe the following recommendations.

General recommendations for Bengal Florican conservation were given in the Bustards' Recovery Plan guidelines (Dutta *et al.* 2013), which we fully endorse. Additionally, we recommend a few more specific actions:

1. Monitoring: Long-term population monitoring, every 2-3 years in the whole country.
2. Grassland Ecology: Long-term study on the impact of annual grass burning through controlled and experimental grass plots to study the habitat utilization of Bengal Florican
3. Formal inclusion of Bengal Florican conservation as an integral part of habitat management activities of Dudhwa, Pilibhit, Manas, Kaziranga, Orang, D'Ering and other reserves.
4. Study of Bengal Florican temporal and spatial movement through satellite tracking of at least 10 birds each at Dudhwa, Kaziranga, Manas and D'Ering reserves
5. Special attention to tag female Bengal Floricans with satellite transmitters to acquire knowledge about nesting ecology and survival of chicks
6. Strict control on poaching and trapping of Bengal Florican throughout its range, particularly when they are outside PAs
7. General publicity amongst local communities about the importance of Bengal Florican as an indicator species of tall wet grasslands of the *terai* and Brahmaputra floodplains
8. Celebration of an annual "Bengal Florican Day", perhaps in mid-April when the bird is relatively easily seen
9. Development of popular and technical literature on Bengal Florican in Hindi, Assamese, Bengali and English
10. Drafting and implementation of state-specific Bengal Florican Species Recovery Plans

## REFERENCES

- Ali, S. and Ripley, S.D. (1987) *Compact edition of the Handbook of India and Pakistan*. Oxford University Press, New Delhi.
- Alonso, J.C., Morales, M. and Alonso, J.A. (2000) Partial migration, and lek and nesting area fidelity in female great bustards. *The Condor*, 102: 127-136.
- Anonymous (1990) *Status and ecology of the Lesser and Bengal Floricans with reports on Jerdon's Courser and Mountain Quail*. Final Report. Bombay Natural History Society, Bombay.
- Anonymous. (2016) Argos User's Manual 2016. Retrieved from: <http://www.argos-system.org/manual>.
- Askins, R. A. (2000) *Restoring North America's birds: lessons from landscape ecology*. Yale University Press, New Haven, Connecticut, USA.
- Askins, R.A., Chavez-Ramirez, F., Dale, B.C., Haas, C.A., Herkert, J.R., Knopf, F.L. and Vickery, P.D. (2007) Conservation of Grassland Birds in North America: Understanding Ecological Processes in Different Regions. *Ornithological Monographs*, 64: 1-46.
- Bander, R. and Cochran, W. (1991) *Radio-location telemetry*. Wildlife Management Techniques. Wildlife Society, Washington D.C.
- Bell, D.J. (1986) A study of the Hispid Hare *Caprolagus hispidus* in Royal Suklaphanta Wildlife Reserve, Western Nepal: A Summary Report. *Dodo, Journal of the Jersey Wildlife Preservation Trust*, 23: 24-31.
- Berthold, P., Bossche, W. V. d., Fiedler, W., Kaatz, C., Kaatz, M., Leshem, Y., Nowak, E. and Querner, U. (2001) Detection of a new important staging and wintering area of the white stork *Ciconia ciconia* by satellite tracking. *Ibis*, 143: 450-455.
- Berthold, P., Bossche, W. V. D., Jakubiec, Z., Kaatz, C., Kaatz, M. and Querner, U. (2002) Long-term satellite tracking sheds light upon variable migration strategies of white storks (*Ciconia ciconia*). *Journal of Ornithology*, 143: 489-495.
- BirdLife International (2001) *Threatened Birds of Asia: The BirdLife International Red Data Book*. Cambridge, U. K., BirdLife International.
- BirdLife International (2016) *Houbaropsis bengalensis*. The IUCN Red List of Threatened Species 2016: e.T22692015A93333629. Retrieved from: <http://www.iucnredlist.org/details/22692015/0>; downloaded on 13 December 2016.
- Blair, J., Nippert, J. and Briggs, J. (2014) Grassland Ecology in Monsoon, R.K. (Ed.). *Ecology and the Environment*. The Plant Sciences, Springer.
- Blundell, G. M., Maier, J. A. K. and Debevec, E. M. (2001) Linear home ranges: Effects of smoothing, sample size, and autocorrelation on kernel estimates. *Ecological Monographs*, 71 (3): 469-489.
- Bobek, M., Hampl, R., Peske, L., Pojer, F., Simek, J. and Bures, S. (2008) African Odyssey project- satellite tracking of Black storks *Ciconia nigra* breeding at a migratory divide. *Journal of Avian Biology*, 39: 500-506.
- Brennan, L.A. and Kuvlesky Jr., W.P. (2005) Invited Paper: North American Grassland Birds: An Unfolding Conservation Crisis? *Journal of Wildlife Management*, 69(1): 1-13.
- Broders, O., Osborne, T., and Wink, M. (2003) A mtDNA phylogeny of bustards (family Otididae) based on nucleotide sequences of the cytochrome b gene. *Journal für Ornithologie*, 144(2): 176-185.
- Calabrese, J. M., Fleming, C. H. and Gurarie, E. (2016) ctmm: an r package for analyzing animal relocation data as a continuous time stochastic process. *Methods in Ecology and Evolution*, 7(9): 1124-1132.
- Calenge, C. (2015) Home Range Estimation in R: the adehabitatHR Package. Retrieved from: <https://cran.r-project.org/web/packages/adehabitatHR/vignettes/adehabitatHR.pdf>
- Champion, H.G. and Seth, S.K. (1968) *A Revised Survey of Forest Types of India*. Government of India Press, New Delhi. Pp. 404.
- Chanchani, P., Warriar, R., Bista, A., Nair, S., Lodhi, N. and Gupta, M. (2014) *Status of Tigers in Pilibhit Forest Division, Terai Arc Landscape, Uttar Pradesh, India*. WWF- India, New Delhi. Pp. 35.
- Choudhury, A.U. (2002) Current Status and Conservation of the Bengal Florican *Houbaropsis bengalensis* in northeast India. Pp. 90-94. In: Rahmani, A.R. and Gayatri, U. (Eds) *Birds of Wetlands and Grasslands: Proceedings of the Sálím Ali Centenary Seminar on Conservation of Avifauna of Wetlands and Grasslands*. Bombay Natural History Society, Mumbai. Pp. X + 228.
- Chynoweth, M.W., Lepczyk, C.A., Litton, C.M., Hess, S.C., Kellner, J.R. and Cordell, S. (2015) Home Range Use and Movement Patterns of Non-Native Feral Goats in a Tropical Island Montane Dry Landscape. *PLoS One*, 10(3): e0119231.

- Dabadghao, P.M. and Shankamarayan, K.A. (1973) *The Grass Cover of India*. Indian Council of Agricultural Research, New Delhi. Pp. 713.
- Davidson, P. (2004) *The distribution, ecology and conservation status of the Bengal florican *Houbaropsis bengalensis* in Cambodia*. Unpublished M.Sc. Thesis. School of Environmental Sciences, University of East Anglia, Norwich, U.K.
- De Solla, S. R., Bonduriansky, R. and Brooks, R. J. (1999) Eliminating autocorrelation reduces biological relevance of home range estimates. *Journal of Animal Ecology*, 68: 221–234.
- de Winter, J.C.F. (2013) Using the Student's t-test with extremely small sample sizes. *Practical Assessment, Research & Evaluation*, 18 (10): pp12. Available online: <http://pareonline.net/getvn.asp?v=18&n=10>.
- del Hoyo, J., Elliott, A., Sargatal, J. (1996) *Handbook of the Birds of the World*, vol. 3: Hoatzin to Auks. Lynx Editions, Barcelona, Spain.
- Derner, J.D., Lauenroth, W.K., Stapp, P. and Augustine, D.J. (2009) Livestock as Ecosystem Engineers for Grassland Bird Habitat in the Western Great Plains of North America. *Rangeland Ecology & Management*, 62(2): 111–118.
- Dutta, S., Rahmani, A. R., and Jhala, Y. V. (2011) Running out of time? The great Indian bustard *Ardeotis nigriceps*- status, viability, and conservation strategies. *European Journal of Wildlife Research*, 57(3): 615–625.
- Dutta, S., Rahmani, A.R., Gautam, P., Kasambe, R. and Narwade, S., Narayan, G. (2013) *Guidelines for Preparation of State Action Plan for Resident Bustards' Recovery Programme*. MoEF, Government of India, New Delhi.
- Dwivedi, K.K. (2016) *The Mahabahu Brahmaputra*. Flood and River Erosion Management Agency of Assam. Printed by Pragati Offset Pvt. Ltd., Hyderabad. Pp. 146.
- ENVIS Centre on Wildlife and Protected Areas. (2016) Protected Areas of India. Retrieved from [http://www.wiienvs.nic.in/Database/Protected\\_Area\\_854.aspx](http://www.wiienvs.nic.in/Database/Protected_Area_854.aspx)
- Fieberg, J. (2007) Kernel density estimators of home range: Smoothing and the autocorrelation red herring. *Ecology*, 88: 1059–1066.
- Fieberg, J. and Kochanny, C.O. (2005) Quantifying Home-Range Overlap: The Importance of the Utilization Distribution. *Journal of Wildlife Management*, 69(4): 1346–1359.
- Fiedler, W. (2009) New technologies for monitoring bird migration and behaviour. *Ring and Migration*, 24: 175–179.
- Flather, C.H., Wilson, K.R. and Shriner, S.A. (2009) Geographic Approaches to Biodiversity Conservation: Implications of Scale and Error to Landscape Planning, pp. 85–121 in Millspaugh, J.J. and Thompson, F.R. (edited) *Models for planning wildlife conservation in large landscapes*, Academic Press, United States of America.
- Fleming, C.H., Fagan, W.F., Mueller, T., Olson, K.A., Leimgruber, P. and Calabrese, J. M. (2015) Rigorous home range estimation with movement data: a new autocorrelated kernel density estimator. *Ecology*, 96: 1182–1188.
- Frame, J. and Hunt, I.V. (1971) The Effects of Cutting and Grazing Systems on Herbage Production from Grass Swards. *Grass and Forage Science*, 26: 163–172.
- French, N.R. (1979) *Perspectives in grassland ecology*. Springer Verlag, New York.
- Fry, D.M. (1995) Reproductive effects in birds exposed to pesticides and industrial chemicals. *Environmental Health Perspectives*, 103(7): 165–171.
- Fuhlendorf, S.D., Harrell, W.C., Engle, D.M., Hamilton, R.G., Davis, C.A. and Leslie Jr., D.M. (2006) Should Heterogeneity be the Basis for Conservation? Grassland Bird Response to Fire and Grazing. *Ecological Applications*, 16(5): 1706–1716.
- Gadgil, M. and Vartak, V.D. (1975) Sacred groves of India- a plea for continued conservation. *Journal of the Bombay Natural History Society*, 72(2): 314–320.
- Gang, C., Zhou, W., Chen, Y., Wang, Z., Sun, Z. and Li, J. (2014) Quantitative assessment of the contributions of climate change and human activities on global grassland degradation. *Environmental Earth Sciences*, 72: 4273–4282.
- Ghosh, S., Brahma, N., Lahkar, B.P., Nath, A., and Basumatary, R. (2014) *Survey of Bengal Florican in Manas National Park*. Survey Report submitted to Field Directorate Tiger Project, Manas, Govt. of Assam. Pp 22.
- Gilbert, M., Newman, S. H., Takekawa, J. Y., Loth, L., Biradar, C., Prosser, D. J., Balachandran, S., Subba Rao, M.V., Mundkur, T., Yan, B., Xing, Z., Hou, Y., Batbayar, N., Natsagdorj, T., Hogerwerf, L., Slingenbergh, J. and Xiao, X. (2010). Flying over an infected landscape: distribution of Highly Pathogenic Avian Influenza H5N1 risk in South Asia and satellite tracking of wild waterfowl. *Ecohealth*, 7(4): 448–458.
- Gill Jr, R. E., Lee Tibbitts, T. L., Douglas, D.C., Handel, C.M., Mulcahy, D.M., Gottschalck, J.C., Warnock, N., McCaffery, B.J., Battley, P.F. and Piersma, T. (2008) Extreme endurance flights by landbirds crossing the Pacific Ocean: ecological corridor rather than barrier? *Proceedings of the Royal Society B*, doi:10.1098/rspb.2008.1142.

- Google Earth Pro v6.2.2.6613. (2014) Grassland restoration area and plots (Dudhwa National Park), N28.499193° E80.704353°. Data retrieved on April 25, 2014, accessed on December 10, 2016.
- Grimmett, R, Inskipp, C and Inskipp, T (1998). *Birds of the Indian subcontinent*. London: A. & C. Black/Christopher Helm.
- Hake, M., Kjellen, N. and Alerstam, T. (2001) Satellite tracking of Swedish ospreys *Pandion haliaetus*: autumn migration routes and orientation. *Journal of Avian Biology*, 32, 47-56.
- Hardin, G. (1968) The Tragedy of the Commons'. *Science*, 162: 1243-1248.
- Hawkes, L.A., Balachandran, S. Batbayar, N. Butler, P.J. Frappell, P.B. Milsom, W.K. Tseveenmyadag, N. Newman, S.H. Scott, G.R. Sathiyaselvam, P. Takekawa, J.Y. Wikelski, M. & Bishop, C.M. (2011). The trans-Himalayan flights of Bar-headed Geese (*Anser indicus*). *PNAS* 108: 9516-9519.
- Hill, J.M., Egan, J.F., Stauffer, G.E. and Diefenbach, D.R. (2014) Habitat Availability Is a More Plausible Explanation than Insecticide Acute Toxicity for U.S. Grassland Bird Species Declines. *PLoS ONE*, 9(5): e98064. doi:10.1371/journal.pone.0098064.
- Hu, S., Chapin, F.S., Firestone, M.K. et al. (2001). Nitrogen limitation of microbial decomposition in a grassland under elevated CO<sub>2</sub>. *Nature*, 409: 188-191.
- Inskipp, C. & Inskipp, T. (1983) Results of a preliminary survey of Bengal Florican *Houbaropsis bengalensis* in Nepal and India, 1982. Cambridge, U. K. International Council of Bird Preservation (Study Report 2).
- Islam, Z. and Rahmani, A.R. (2004) *Important Bird Areas in India: Priority Sites for Conservation*. Indian Birds Conservation Network, Bombay Natural History Society, BirdLife International and Royal Society for the Protection of Birds. Oxford University Press, Mumbai. Pp xviii + 1133.
- IUCN (2015). The IUCN Red List of Threatened Species. Version 2015-3. <<http://www.iucnredlist.org>>. Downloaded on 28 September 2015.
- Iverson, S.A. Gavrilov, A. Katzner, T. E. Takekawa, J. Y. Miller, T. A. Hagemeyer, W. Mundkur, T. Balachandran, S. Dematos, C. C. Lu'ay. Ahmed, S. & Newman, S.H. (2011). Migratory movements of waterfowl in Central Asia and H5N1 emergence: sporadic transmission of disease from east to west Published in *IBIS*, Article first published online: 11, 01, 2011 url: DOI: 10.1111/j.1474-919X.2010.01095.
- Izhaki, I., Shmueli, M., Arad, Z., Steinberg, Y. and Crivelli, A. (2002) Satellite tracking of migratory and ranging behavior of immature Great White Pelicans. *Waterbirds*, 25:295-304.
- Javed, S. (1996) Studies on Bird Community Structure of Terai Forest in Dudhwa National Park. Ph.D. Thesis. Centre for Wildlife and Ornithology, Aligarh Muslim University, Aligarh, India. Pp. 149.
- Javed, S., Higuchi, H., Nagendran, M. and Takekawa, J.Y. (2003) Satellite telemetry and wildlife studies in India: Advantages, options and challenges. *Current Science*, 85(10): 1439-1443.
- Jenkins, C.N. and Joppa, L. (2009) Expansion of the global terrestrial protected area system. *Biological Conservation*, 142: 2166-2174.
- Johnsgard, P.A. (1991) *Bustards, Hemipodes, and Sandgrouse: Birds of Dry Places*. Oxford University Press, New York.
- Judas, J., Combreau, O., Lawrence, M., Saleh, M., Launay, F. and Xingyi, G. (2006) Migration and range use of Asian houbara bustard *Chlamydotis macqueenii* breeding in the Gobi Desert, China, revealed by satellite tracking. *Ibis*, 148: 343-351.
- Kalra, M., Satish Kumar, Rahmani, A.R., Jamal A. Khan, Shah Mohammed Belal and Ahmad Masood Khan (2011) Satellite Tracking of Bar-Headed Geese *Anser indicus* wintering in Uttar Pradesh, India. *Journal of the Bombay Natural History Society* 108(2): 79-94.
- Kanai, Y., Ueta, M., Germogenov, N., Nagendran, M., Mita, N. and Higuchi, H. (2002) Migration routes and important resting areas of Siberian cranes (*Grus leucogeranus*) between northeastern Siberia and China as revealed by satellite tracking. *Biological Conservation*, 106, 339-346.
- Karanth, K.K., Nichols, J.D., Karanth, K.U., Hines, J.E. and Christensen, N.L. (2010) The shrinking ark: patterns of large mammal extinctions in India. *Proceedings of the Royal Society B*, rspb20100171. Retrieved from: <http://rspb.royalsocietypublishing.org/content/royprsb/early/2010/03/05/rspb.2010.0171.full.pdf>
- Kays, R., Crofoot, M. C., Jetz, W. and Wikelski, M. (2015) Terrestrial animal tracking as an eye on life and planet. *Science*, 348(6240): aaa2478.
- Keenleyside, K.A., Dudley, N., Cairns, S., Hall, C.M. and Stolton, S. (2012) *Ecological Restoration for Protected Areas: Principles, Guidelines and Best Practices*. Gland, Switzerland: IUCN. x + 120pp.

- Kenward, R.E., Pfeffer, R.H., Al-Bowardi, M.A., Fox, N.C., Riddle, K.E., Bragin, E.A., Levin, A., Walls, S.S. and Hodder, K.H. (2001) Setting harness sizes and other marking techniques for a falcon with strong sexual dimorphism. *Journal of Field Ornithology*, 72(2): 244-57.
- Knick, S.T. and Rotenberry, J.T. (2000) Ghosts of habitats past: Contribution of landscape change to current habitats used by shrubland birds. *Ecology*, 81: 220-227.
- Knopf F.L. (1994) Avian assemblages on altered grasslands. *Studies in Avian Biology*, 15: 247-57.
- Kumar, H. (2012) Terai Grasslands- Management and Conservation Perspectives for Avian Species. Rahmani, A. R. (2012) *Threatened Birds of India: Their Conservation Requirements*. Oxford University Press. Pp XVI + 861.
- Lane, S.J., Alonso, J.C. and Martín, C.A. (2001) Habitat preferences of great bustard *Otis tarda* flocks in the arable steppes of central Spain: are potentially suitable areas unoccupied? *Journal of Applied Ecology*, 38: 193-203.
- Lehmkuhl, J.F. (1989) *The Ecology of a South-Asian Tall-Grass Community*. Ph.D. Dissertation. University of Washington, Seattle, USA. Pp. 195.
- Lehmkuhl, J.F. (1994) A classification of sub-tropical riverine grassland and forest associations in Chitwan National Park, Nepal. *Vegetation*, 111: 29-43.
- Madhusudan, M.D. and Karanth, K.U. (2002) Local Hunting and the Conservation of Large Mammals in India. *Ambio*, 31(1): 49-54.
- Martin, T.G., Chadès, I., Arcese, P., Marra, P.P., Possingham, H.P. and Norris, D. R. (2007) Optimal conservation of migratory species. *PLoS One*, 2(8): e751. Retrieved from: <http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0000751>
- MoEF, Government of India. (2002) The National Wildlife Action Plan 2002-2016. Retrieved from: [http://awsassets.wwf-india.org/downloads/national\\_wildlife\\_action\\_plan\\_2002\\_2016\\_2.pdf](http://awsassets.wwf-india.org/downloads/national_wildlife_action_plan_2002_2016_2.pdf)
- MoEF, Government of India. (2006) The Wildlife (Protection) Amendment Act, 2006. Retrieved from: <http://www.moef.nic.in/sites/default/files/WildLifeAmedmentAct2006%20.pdf>
- MoEF. (1972) Wildlife Protection Act 1972, Schedule I. <http://www.moef.nic.in/legis/wildlife/wildlife1c4.html> (accessed 28 September 2015).
- Morales, M.B., Alonso, J.C., Alonso, J.A. and Martín, E. (2000) Migration patterns in male Great Bustards (*Otis tarda*). *The Auk*, 117: 493.
- Mueller, T., Olson, K.A., Fuller, T.K., Schaller, G.B. and Murray, M.G. (2008) In search of forage: predicting dynamic habitats of Mongolian gazelles using satellite-based estimates of vegetation productivity. *Journal of Applied Ecology*, 45: 649-658.
- Narayan, G. (1992) Ecology, Distribution and Conservation of the Bengal Florican *Houbaropsis bengalensis* (Gmelin) in India. Ph.D. thesis. University of Bombay.
- Narayan, G. and Rosalind, L. (1990) An introduction to the Bengal Florican. Pp. 9-16 in *Status and ecology of the Lesser and Bengal Floricans, with reports on Jerdon's Courser and Mountain Quail: final report*. Bombay: Bombay Natural History Society.
- Nathan, R., Getz, W.M., Revilla, E., Holyoak, M., Kadmon, R., Saltz, D. and Smouse, P.E. (2008) A movement ecology paradigm for unifying organismal movement research. *Proceedings of the National Academy of Sciences USA*, 105, 19052-19059.
- Newman, S.H., Hill, N.J., Spragens, K.A., Janies, D., Voronkin, I.O., Prosser, D.J., Yan, B., Lei, F., Batbayar, N., Natsagdorj, T., Bishop, C.M., Butler, P.J., Wikelski, M., Balachandran, S., Mundkur, T., Douglas, D.C. & Takekawa J.Y. (2012). Eco-virological approach for assessing the role of wild birds in the spread of Avian Influenza H5N1 along the Central Asian Flyway. *PLoS One* 7:e30636.
- Newton, I.J. (2012) Obligate and facultative migration in birds: ecological aspects. *Journal of Ornithology*, 153(1): 171-180.
- Nicholls, D.G. and Robertson, C.J.R. (2007) Validating locations from CLS: Argos satellite telemetry. *Notornis*, 54(3): 121-136.
- O'Mara, F.P. (2012) The role of grasslands in food security and climate change. *Annals of Botany*, 110: 1263-1270.
- Olival, K.J. and Higuchi, H. (2006) Monitoring the long-distance movement of wildlife in Asia using satellite telemetry. Wikramanayake, editors. *Conservation biology in Asia*, Society for Conservation Biology Asia Section and Resources. Himalaya Foundation, Kathmandu, Nepal, pp. 319-339.
- Oliver, W.L.R. (1980) The Pygmy Hog – The Biology and Conservation of Pygmy Hog *Sus (Porcula) salvanius* and the Hispid Hare *Caprolagushispidus*. Special Scientific Report No. 1. Jersey Wildlife Preservation Trust, Jersey. Pp. 80.

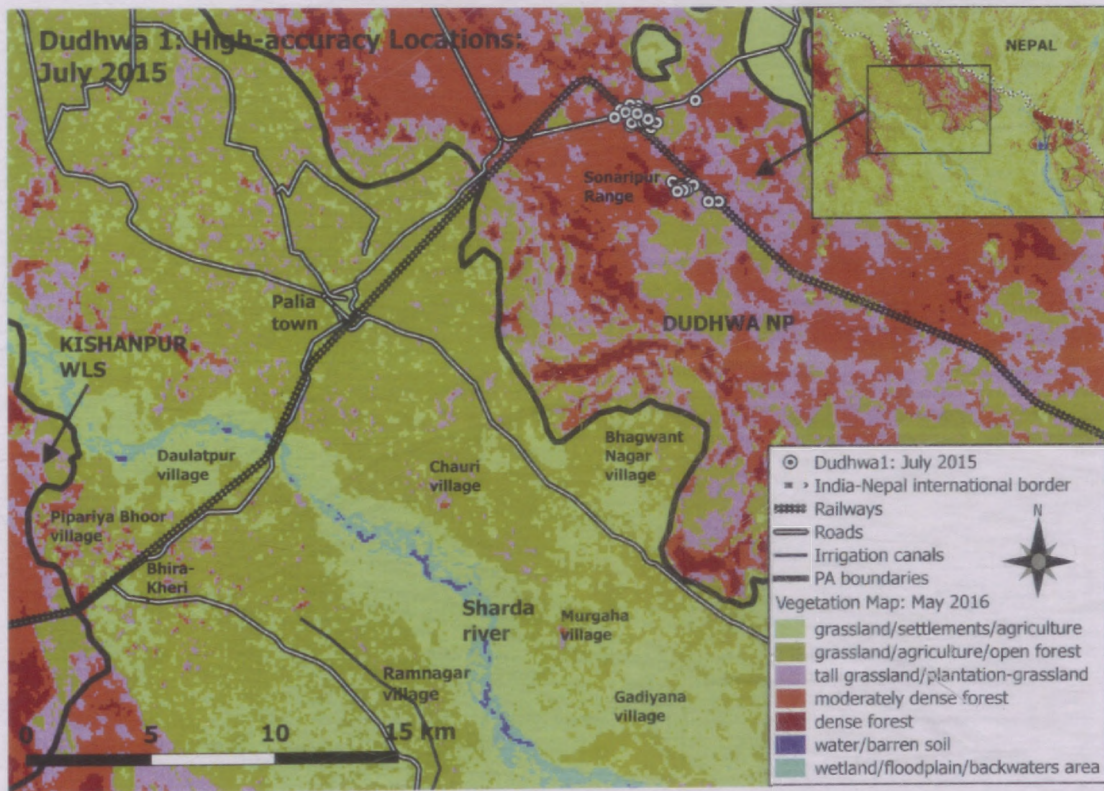
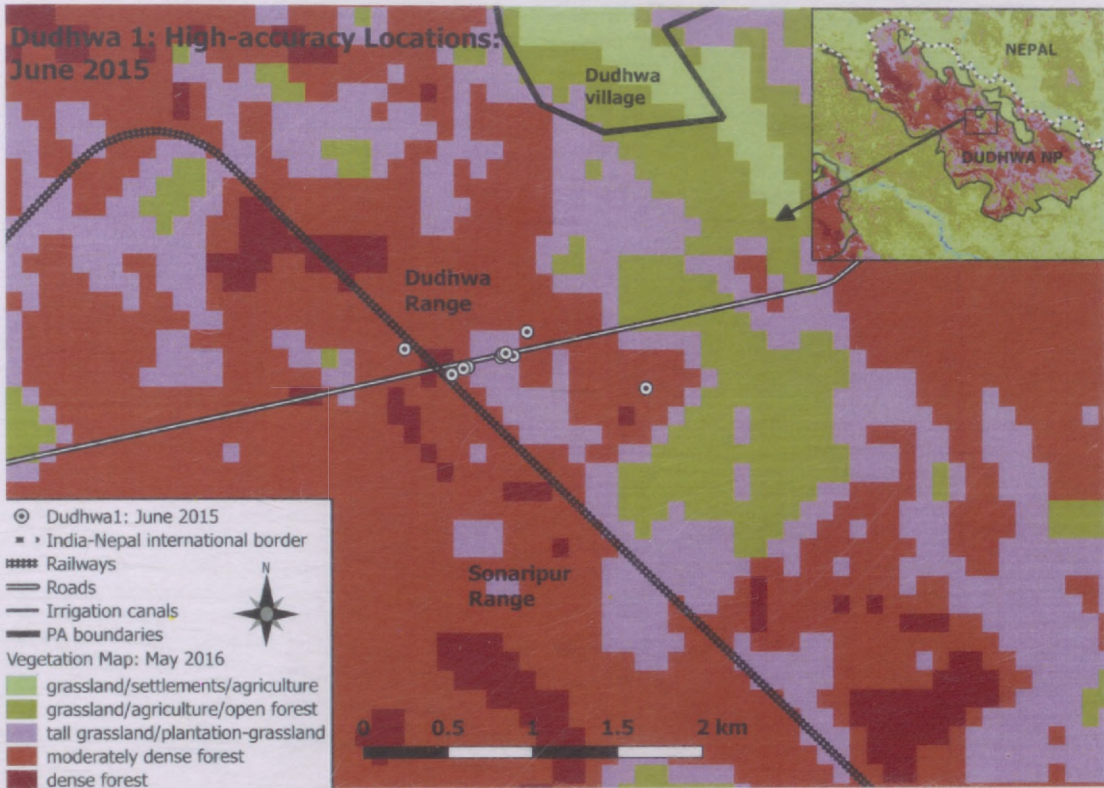
- Packman, C.E. (2011) Seasonal landscape use and conservation of a critically endangered bustard: Bengal florican in Cambodia. Ph.D. Thesis. University of East Anglia.
- Palacín, C., Alonso, J.C., Alonso, J.A., Martín, C.A., Magaña, M. and Martín, B. (2009) Differential migration by sex in the great bustard: possible consequences of an extreme sexual size dimorphism. *Ethology*, 115: 617-626.
- Peet, N.B. (1997) Biodiversity and management of tall grasslands in Nepal. Ph.D. thesis. University of East Anglia, Norwich, U.K.
- Pettorelli, N. (2013) Satellite data-based indices to monitor land use and habitat changes. In: Collen, B., Pettorelli, N., Baillie, J.E. and Durant, S.M. (Eds.) *Biodiversity Monitoring and Conservation: Bridging the Gap between Global Commitment and Local Action*, John Wiley & Sons. Pp. 95-119.
- Pettorelli, N., Ryan, S., Mueller, T., Bunnefeld, N., Jędrzejewska, B., Lima, M. and Kausrud, K. (2011) The Normalized Difference Vegetation Index (NDVI): unforeseen successes in animal ecology. *Climate Research*, 46(1): 15-27.
- QGIS Development Team. (2016) QGIS Geographic Information System, version 2.14. Open Source Geospatial Foundation Project. <http://www.qgis.org/>
- R Core Team. (2016) A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing.
- Rahmani, A.R. (1988) Grassland birds of the Indian subcontinent: a review In: *Ecology and conservation of grassland birds*. Technical publication. ICBP, UK. Pp 187-204.
- Rahmani, A.R. (1989) *The Great Indian Bustard: Final Report*. Bombay Natural History Society, Bombay.
- Rahmani, A. R. (2001) *Status of the Bengal Florican Houbaropsis bengalensis in Uttar Pradesh, India*. Bombay: Bombay Natural History Society.
- Rahmani, A. R. (2006) A Note for the Task Force on Deserts and Grasslands of India. Submitted to Planning Commission, Government of India.
- Rahmani, A. R., G. Narayan, L. Rosalind, R. Sankaran and U. Ganguli-Lachungpa (1991). Status of the Bengal Florican *Houbaropsis bengalensis* in India. *J. Bombay Natural History Society* 88: 349-375.
- Rahmani, A.R. and Manakadan, R. (1988) Bustard Sanctuaries of India. Technical Report No. 18. pp. 40. Bombay Natural History Society, Bombay.
- Rahmani, A.R, Khongsai, N., Rahman, A., Imran, M., Sagwan, T., & Ojah, S. (2016) *Conservation of Threatened Grassland birds of the Brahmaputra Floodplains*. BirdLife PEP Project and Bombay Natural History Society, Mumbai. Pp 66.
- Rahmani, A.R., Kalra, M., Shinde, N. and Khongsai, N. (2014) Studying movement patterns and dispersal of the Bengal Florican (*Houbaropsis bengalensis*): a Satellite Telemetry Pilot Project. Annual Report 2013-14. Bombay Natural History Society, Mumbai. Pp. 40.
- Rahmani, A.R., Narayan, G., Rosalind, L., Sankaran, R., and Ganguli-Lachungpa, U. (1990) Status of the Bengal Florican in India. *Journal of the Bombay Natural History Society*, 88: 349-375.
- Ramesh, K. (2007). Tragopans, the horned pheasants; their taxonomy, distribution and status. (IN) Sathyakumar, S. and K. Sivakumar (Eds.). *Galliformes of India*. ENVIS Bulletin: Wildlife and Protected Areas, Vol. 10 (1). Wildlife Institute of India, Dehradun, India. Pp 69-77.
- Rodgers, W. A. and Panwar, H. S. (1988) *Planning a Protected Area Network In India*. 2 vols. Wildlife Institute of India, Dehradun.
- Roy, A.K. and Singh, J.P. (2013) Grasslands in India: Problems and perspectives for sustaining livestock and rural livelihoods. *Tropical Grasslands- Forrajes Tropicales*, 1: 2400243.
- Sala, O.E., Vivanco, L. and Flombaum, P. (2013) Grassland Ecosystems. Pp. 1-7. In: Levin, S.A. (edited) *Encyclopedia of Biodiversity* (Second Edition). Academic Press (Elsevier).
- Sankaran, R. (1991) Some aspects of the breeding behaviour of the Lesser Florican *Syphoetides indica* (J. F. Miller) and the Bengal Florican *Houbaropsis bengalensis* (Gmelin). Ph. D. Dissertation. University of Bombay.
- Sankaran, R. (1996) Territorial displays of the Bengal Florican. *Journal of the Bombay Natural History Society*, 93: 167-177.
- Sankaran, R. and Rahmani, A.R. (1990) The Bengal Florican in Dudwa National Park. Pp. 45-54. In: Status and ecology of the Lesser and Bengal Floricans with reports on Jerdon's Courser and Mountain Quail. Final Report. Bombay Natural History Society, Bombay.
- Sankaran, R. and Rahmani, A.R. (1991) The Bengal Florican in Dudwa National Park. In: Status and Ecology of Lesser and Bengal Florican. Final Report. Bombay Natural History Society, Bombay. Pp. 45-54.
- Scurlock, J.M.O. and Hall, D.O. (1998) The global carbon sink: a grassland perspective. *Global Change Biology*, 4: 229-233.

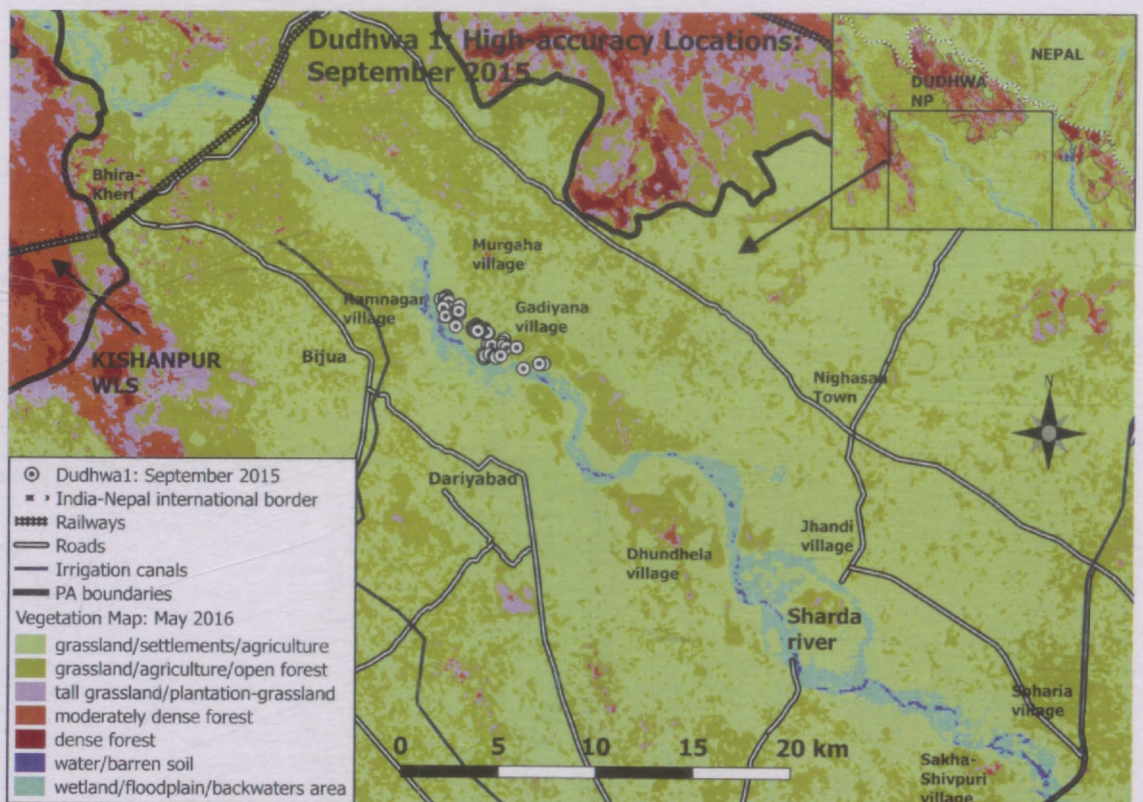
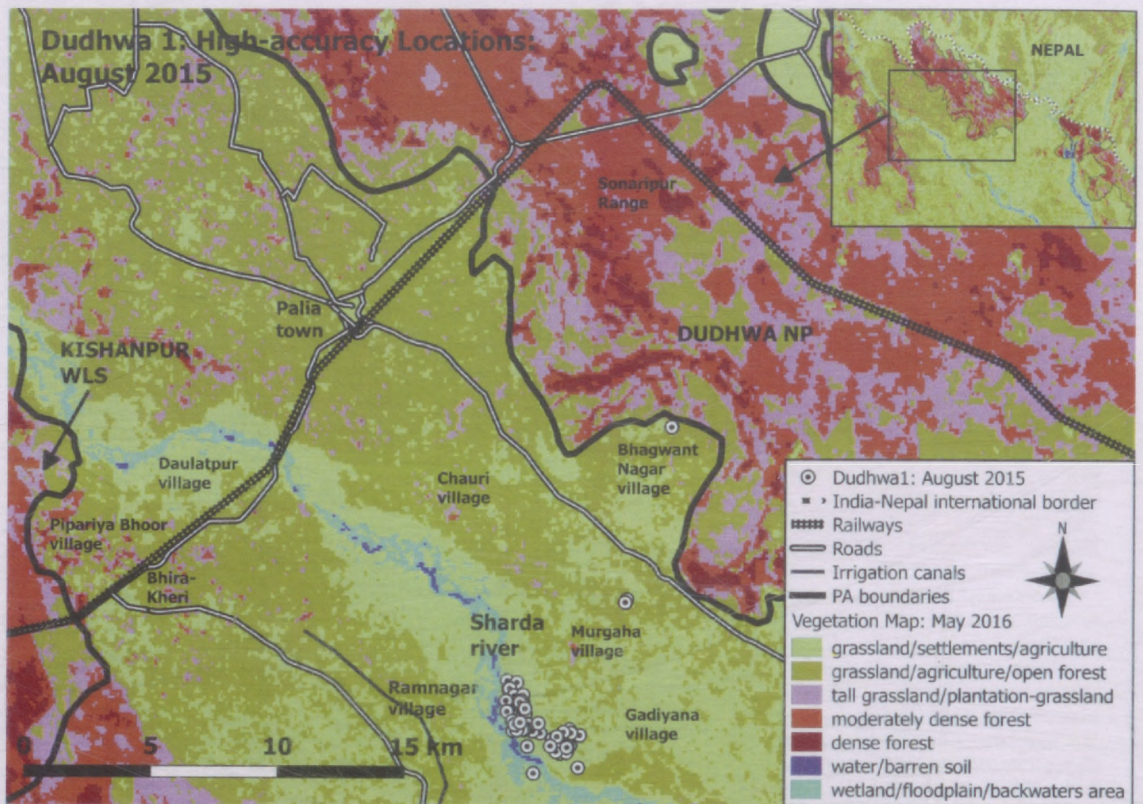
- Seaman, D.E. and Powell, R.A. (1996) An Evaluation of the Accuracy of Kernel Density Estimators for Home Range Analysis. *Ecology*, 77(7): 2075-2085.
- Seaman, D.E., Millspaugh, J.J., Kernohan, B.J., Brundige, G.C. and Raedeke, K.J. (1999) Effects of sample size on kernel home range estimates. *Journal of Wildlife Management*, 63: 739-747.
- Seegar, W. S., Cutchis, P. N., Fuller, M. R., Suter, J. J., Bhatnagar, V. and Wall, J. G. (1996) Fifteen years of satellite tracking development and application to wildlife research and conservation. Johns Hopkins APL Tech. Dig. 17:401-411.
- Seegar, W.S., Cutchis, P.N., Fuller, M.R., Suter, J. J., Bhatnagar, V. and Wall, J. G. (1996) Fifteen years of satellite tracking development and application to wildlife research and conservation. Johns Hopkins APL Technical Digest, 17(4): 401-411.
- 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.
- SER (2004) Society for Ecological Restoration International Science & Policy Working Group. (2004) The SER International Primer on Ecological Restoration. www.ser.org & Tucson: Society for Ecological Restoration International. Retrieved from: [http://c.ymcdn.com/sites/www.ser.org/resource/resmgr/custompages/publications/SER\\_Primer/ser\\_primer.pdf](http://c.ymcdn.com/sites/www.ser.org/resource/resmgr/custompages/publications/SER_Primer/ser_primer.pdf)
- Shukla, V. (2016, December 28) 'Kherimein ho rahaLalsarpakshi ka shikaar'. Amar Ujala, p. 2. Retrieved from: [www.amarujala.com](http://www.amarujala.com)
- Singh, P., Rahmani, A. R., Rawat, G.S., Chundawat, R.S. and Singh, K. D. (2006) Report of the task force on grasslands and deserts. Planning Commission, Government of India, New Delhi.
- Skarpe C. (1991) Impact of grazing in Savanna ecosystems. *AMBIO*, 20 (8): 351-356.
- Sogge, M.K., Sferra, S.J. and Paxton, E.H. (2008) *Tamarix* as Habitat for Birds: Implications for Riparian Restoration in the Southwestern United States. *Restoration Ecology*, 16(1): 146-154.
- Sterling, E.J., Hurley, M.M., Minh, L.D. and Powzyk, J. (2006) *Vietnam: A Natural History*. Yale University Press, New Haven, Connecticut.
- Student (1908). The Probable Error of a Mean. *Biometrika*, 6(1): 1-25.
- Thomas, B., Minot, E.O. and Holland, J.D. (2010) Home Range and Habitat Use of the New Zealand Falcon (*Falco novaeseelandiae*) within a Plantation Forest: A Satellite Tracking Study. *International Journal of Ecology*, doi:10.1155/2010/829702. Retrieved from:<https://www.hindawi.com/journals/ijecol/2010/829702/#B11>
- van der, M.E. (1990) Herbivory as a trigger for growth. *Functional Ecology*, 4(4): 597-598.
- Verma, A. & V. Prakash (2007). Winter roost habitat use by Eurasian Marsh Harriers *Circus aeruginosus* in and around Keoladeo National Park, Bharatpur, Rajasthan, India. *Forktail*, 23: 17-21.
- Vickery, P. D., Herkert, J.R., Knopf, F. L., Ruth, J. and Keller, C. E. (2000) Grassland birds: An overview of threats and recommended management strategies. In *Strategies for Bird Conservation: The Partners in Flight Planning Process*. Proceedings of the third Partners in Flight Workshop, pp. 74-77.
- White, R.P., Murray, S. & M. Rohweder (2000). *Pilot Analysis of Global Ecosystems: Grassland Ecosystems*. World Resources Institute, Washington D.C., 69 Pp.
- Widemo (1998). Alternative reproductive strategies in the ruff, *Philomachus pugnax*: a mixed ESS? *Animal Behaviour*, 56: 329-336.
- WII (2014) Capture and tagging of Black-necked Crane (*Grus nigrocollis*) and Bar-headed goose (*Anser indicus*) in Changthang Cold Desert Wildlife Sanctuary, Ladakh. A report by Wildlife Institute of India, Dehradun and Department of Wildlife Protection, Jammu & Kashmir. Pp. 32.
- Winter, M., Johnson, D.H. and Shaffer, J.A. (2005) Variability in Vegetation Effects on Density and Nesting Success of Grassland Birds. *Journal of Wildlife Management*, 69(1): 185-197.
- With, K.A., King, A.W. and Jensen, W.E. (2008) Remaining large grasslands may not be sufficient to prevent grassland bird declines. *Biological Conservation*, 141: 3152-3167.
- Wortley, L., Hero, J. M. and Howes, M. (2013) Evaluating ecological restoration success: a review of the literature. *Restoration Ecology*, 21(5): 537-543.
- WWF- India. (n.d.) About Terai Arc Landscape. Retrieved from:[http://www.wwfindia.org/about\\_wwf/critical\\_regions/terai\\_arc\\_landscape/about\\_terai\\_arc\\_landscape/](http://www.wwfindia.org/about_wwf/critical_regions/terai_arc_landscape/about_terai_arc_landscape/)
- WWF. (n.d.) Tropical and Subtropical Grasslands, Savannas and Shrublands- Asia: Bhutan, India and Nepal. Retrieved from: <http://www.worldwildlife.org/ecoregions/im0701>

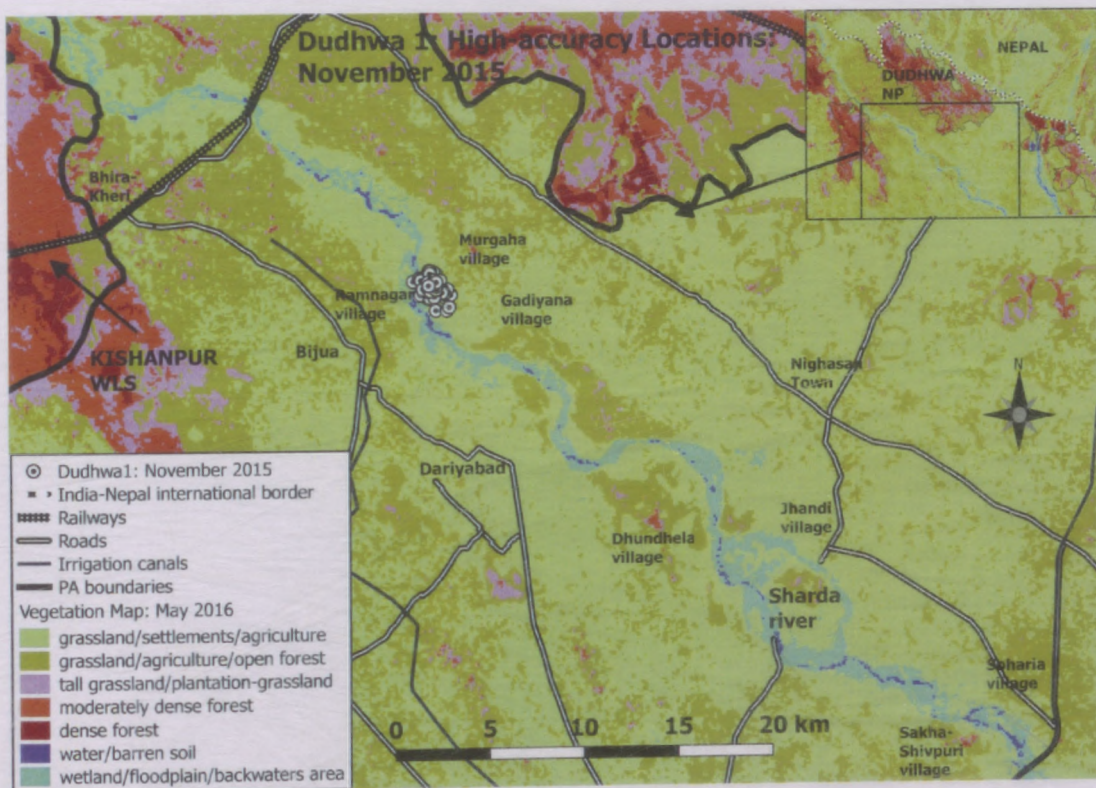
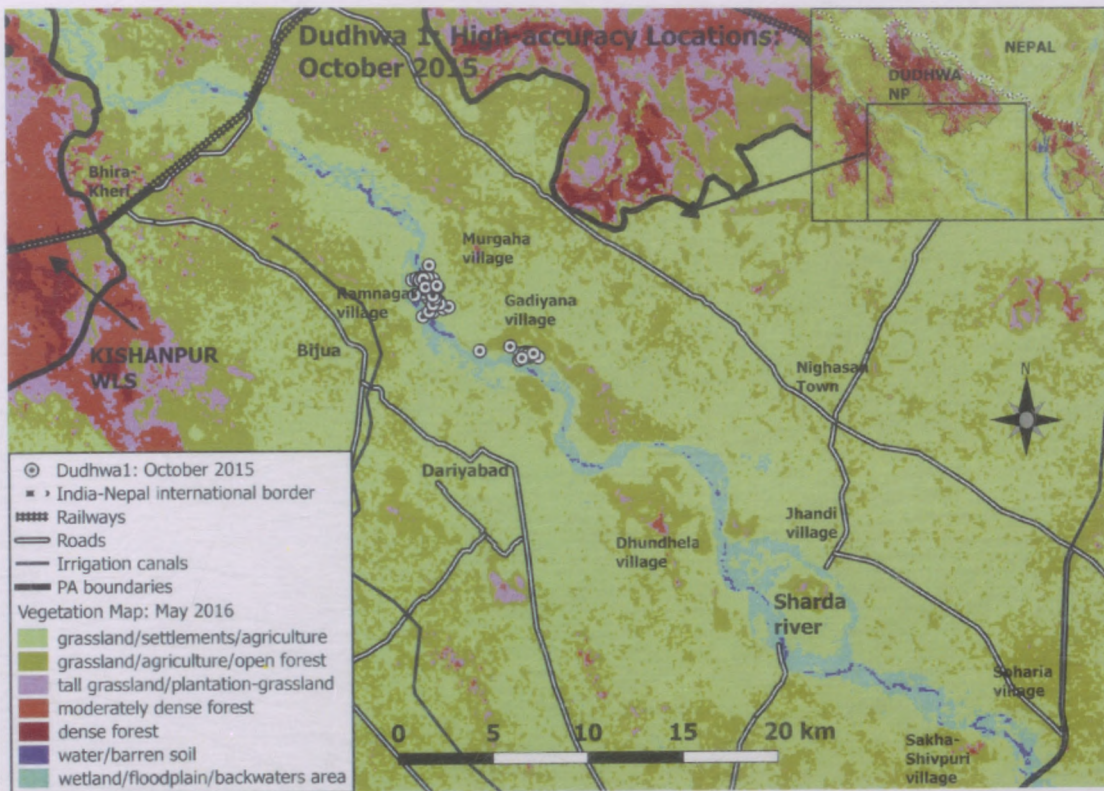
# APPENDICES

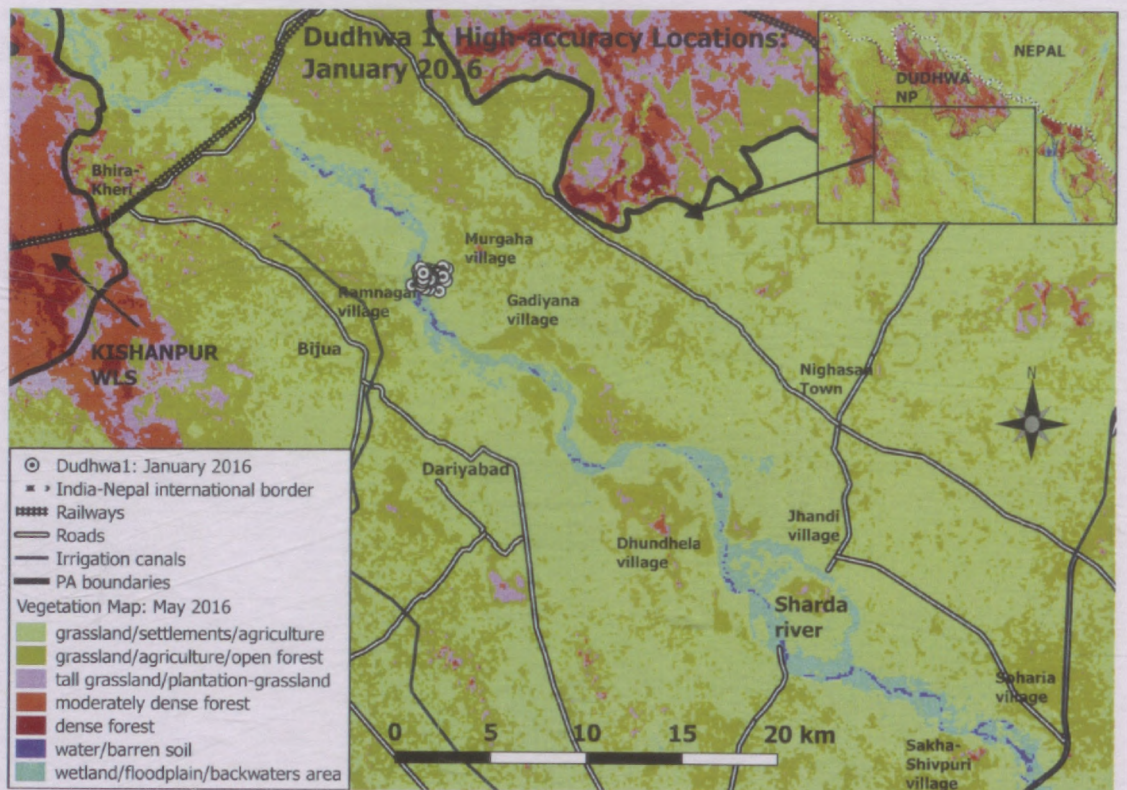
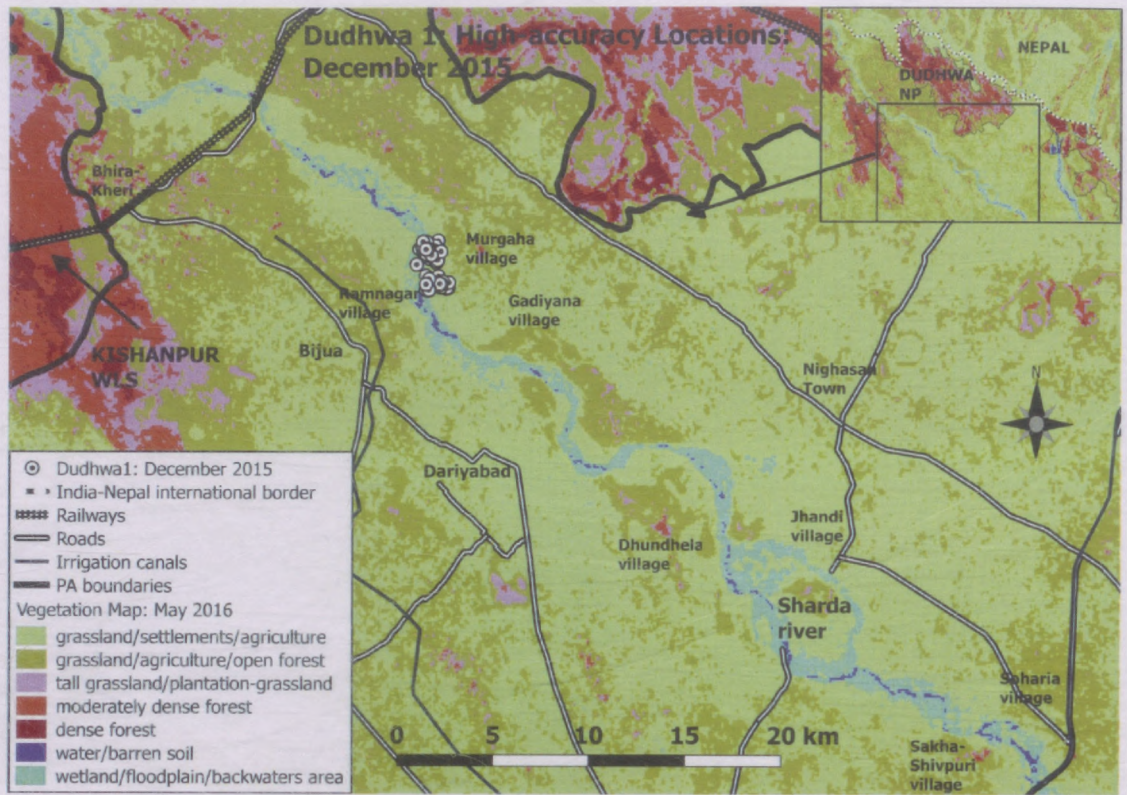
APPENDIX I: The following pages show monthly movement of three tagged Bengal Florican adult male birds in Dudhwa, Pilibhit and outside these Protected Areas. The maps are self explanatory

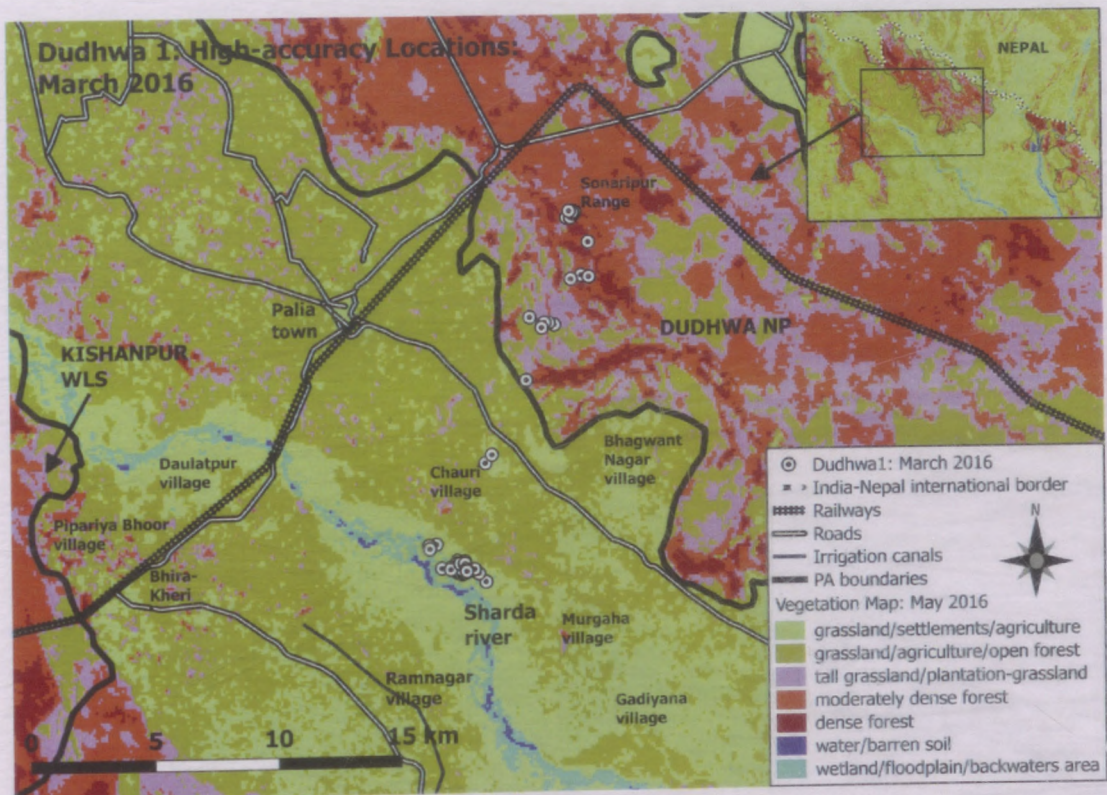
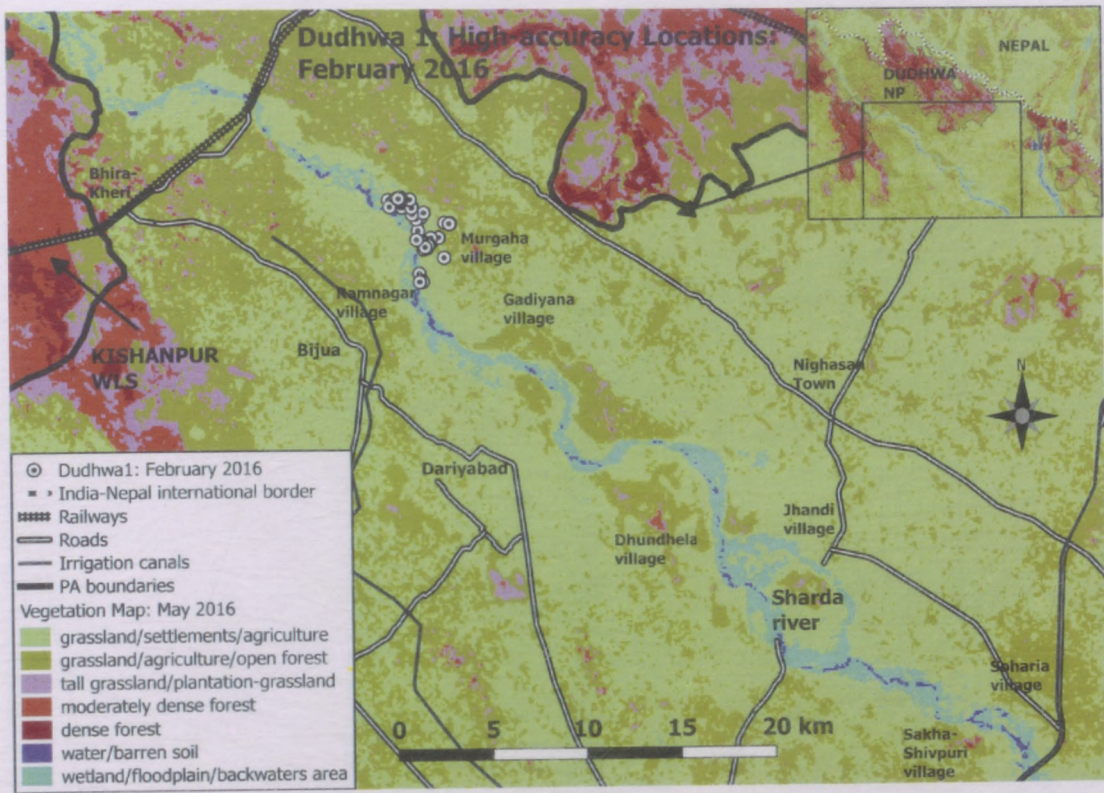
Month-wise movements of bird 'Dudhwa 1' derived from high-accuracy locations during June 2015 to December 2016

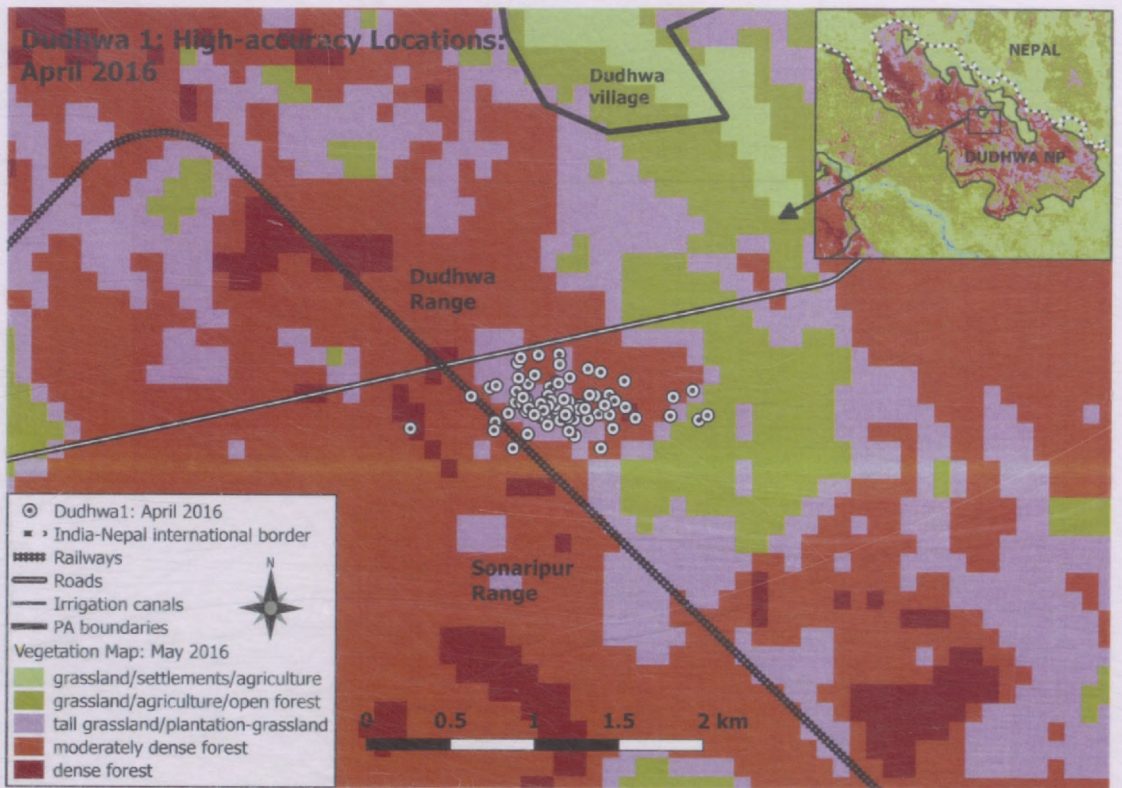


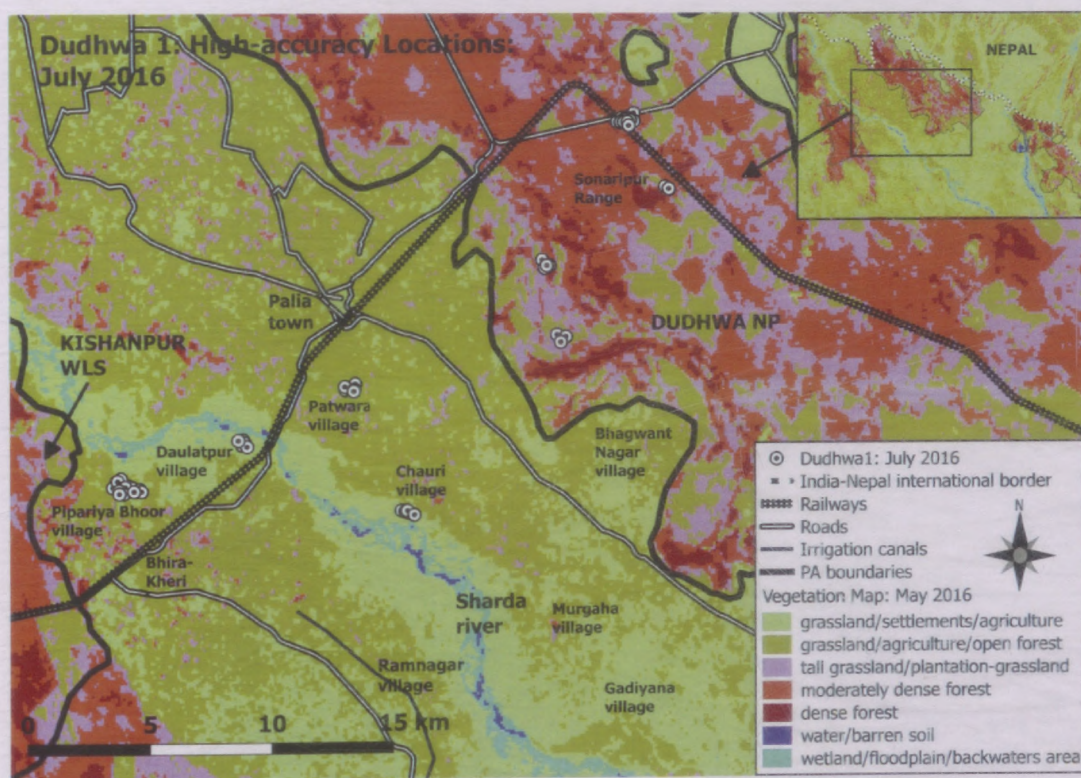
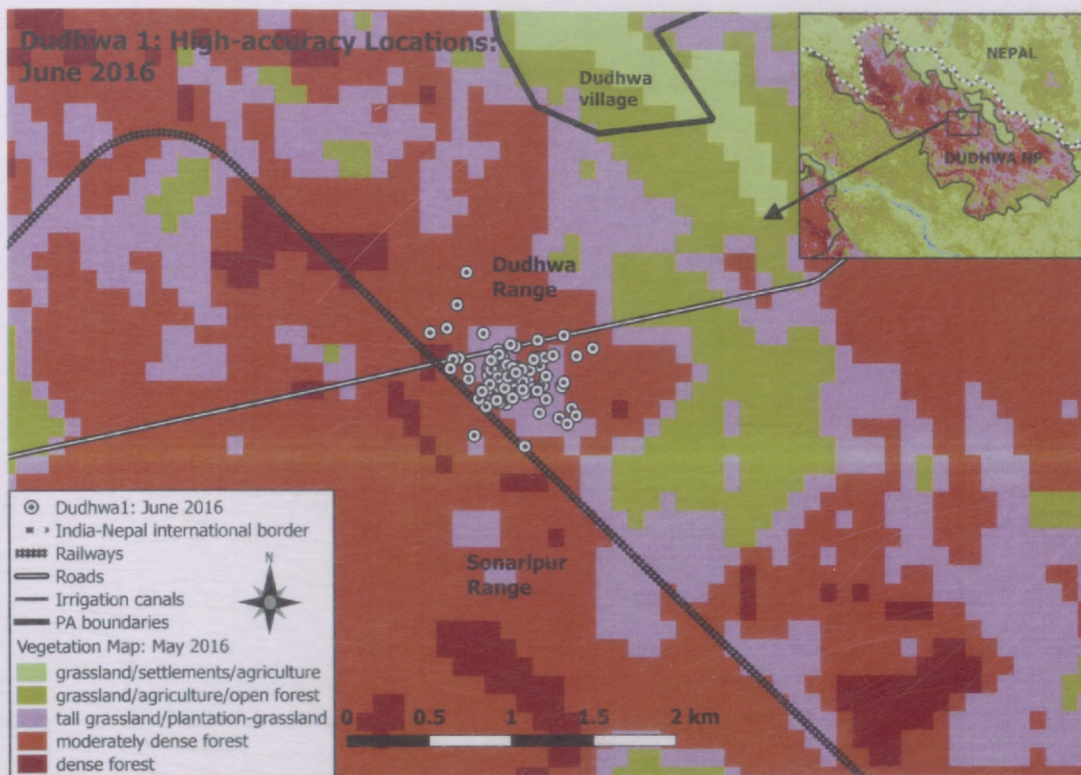


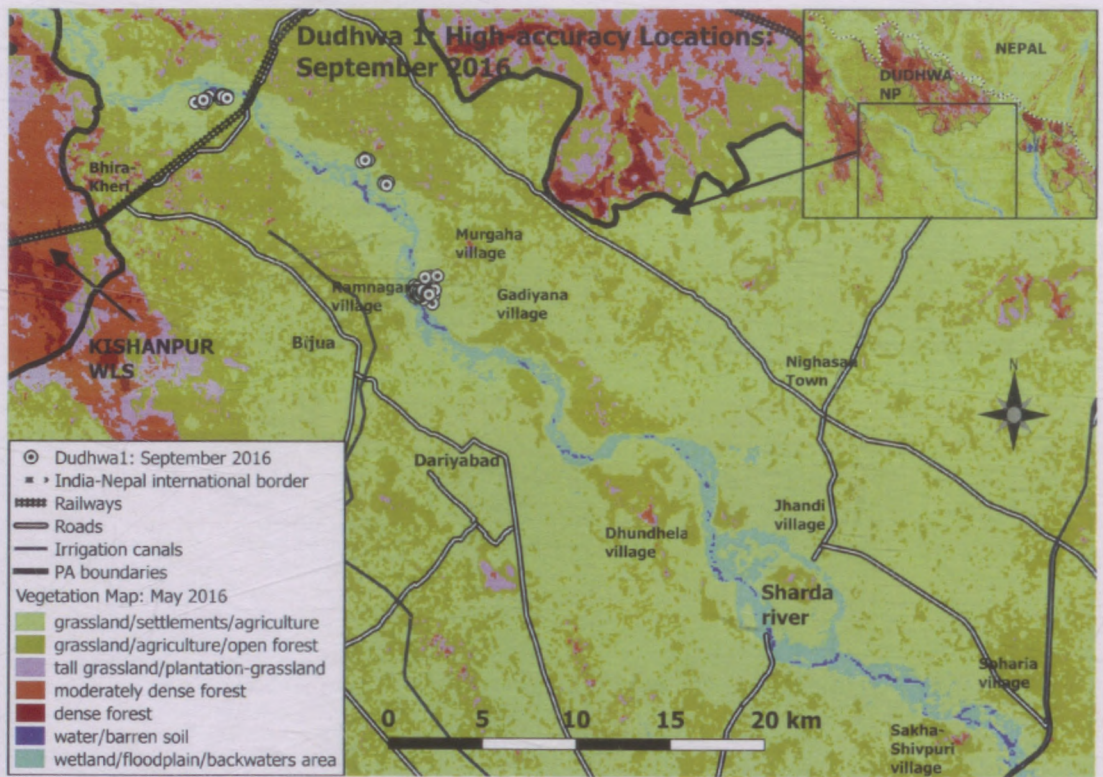
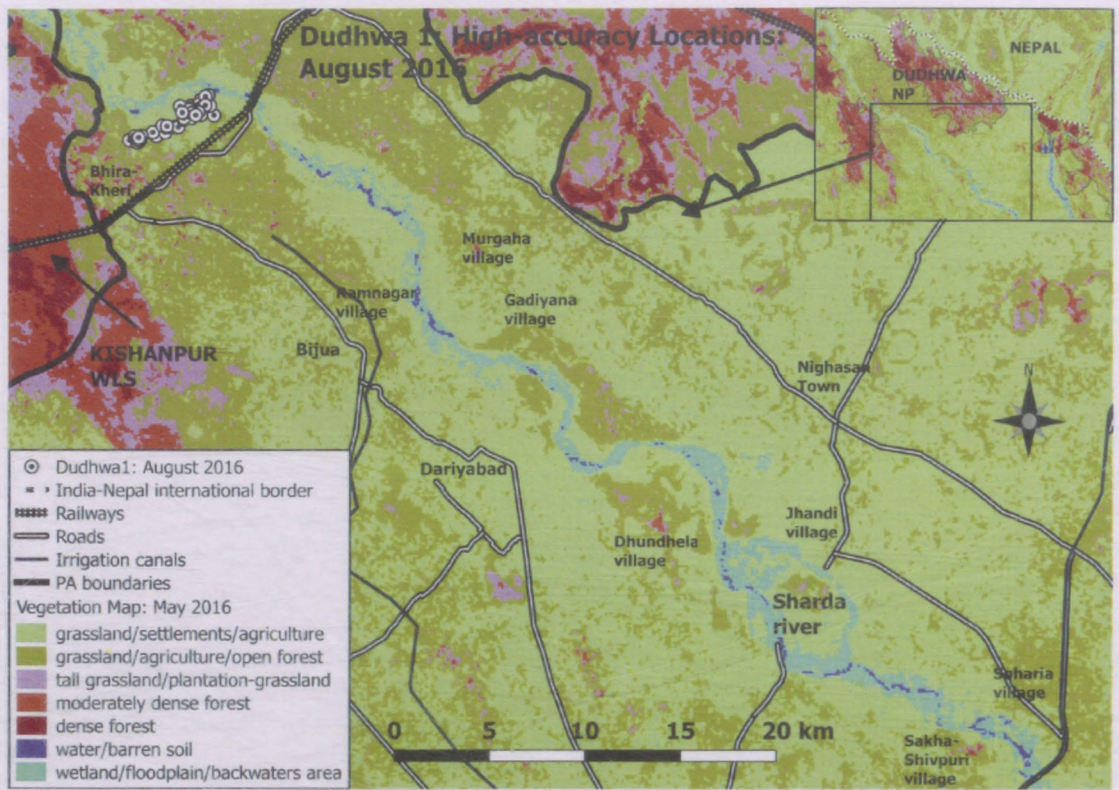


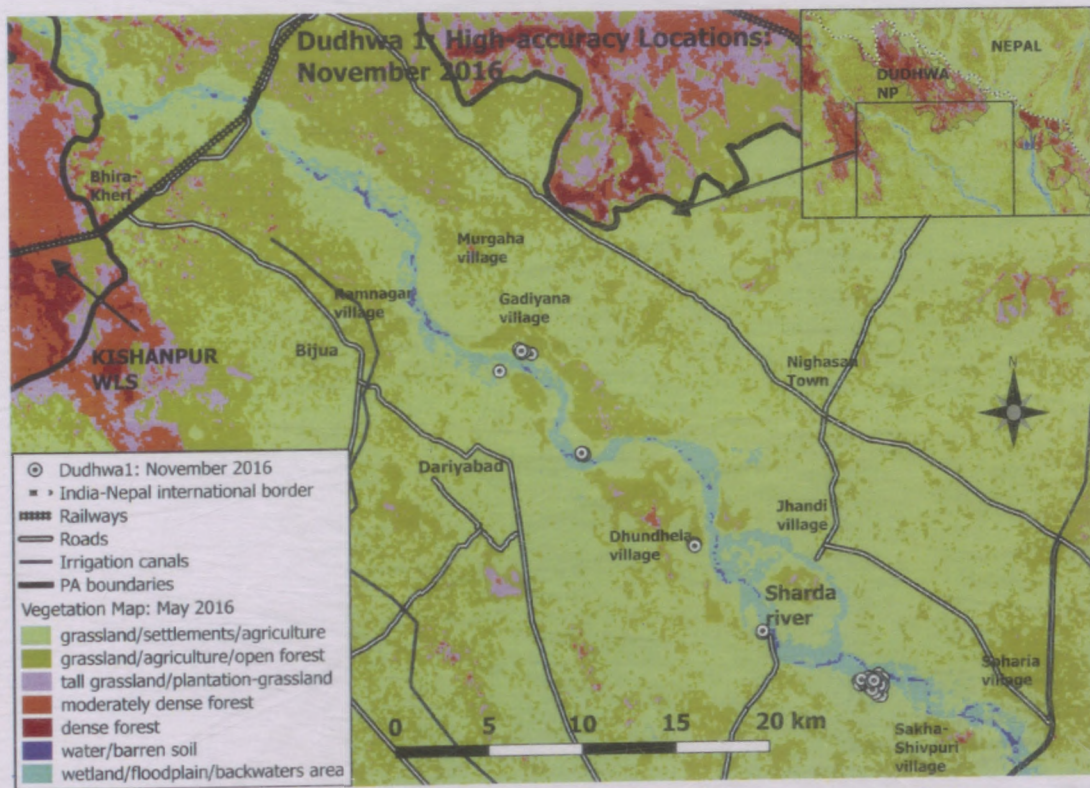
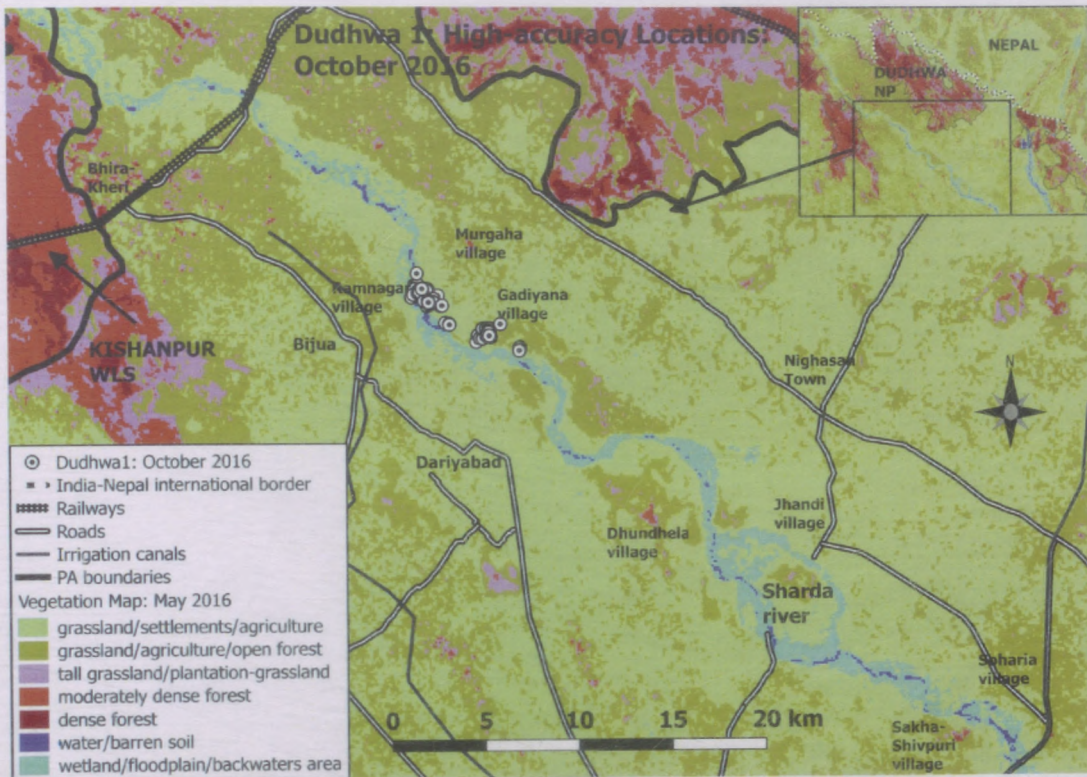


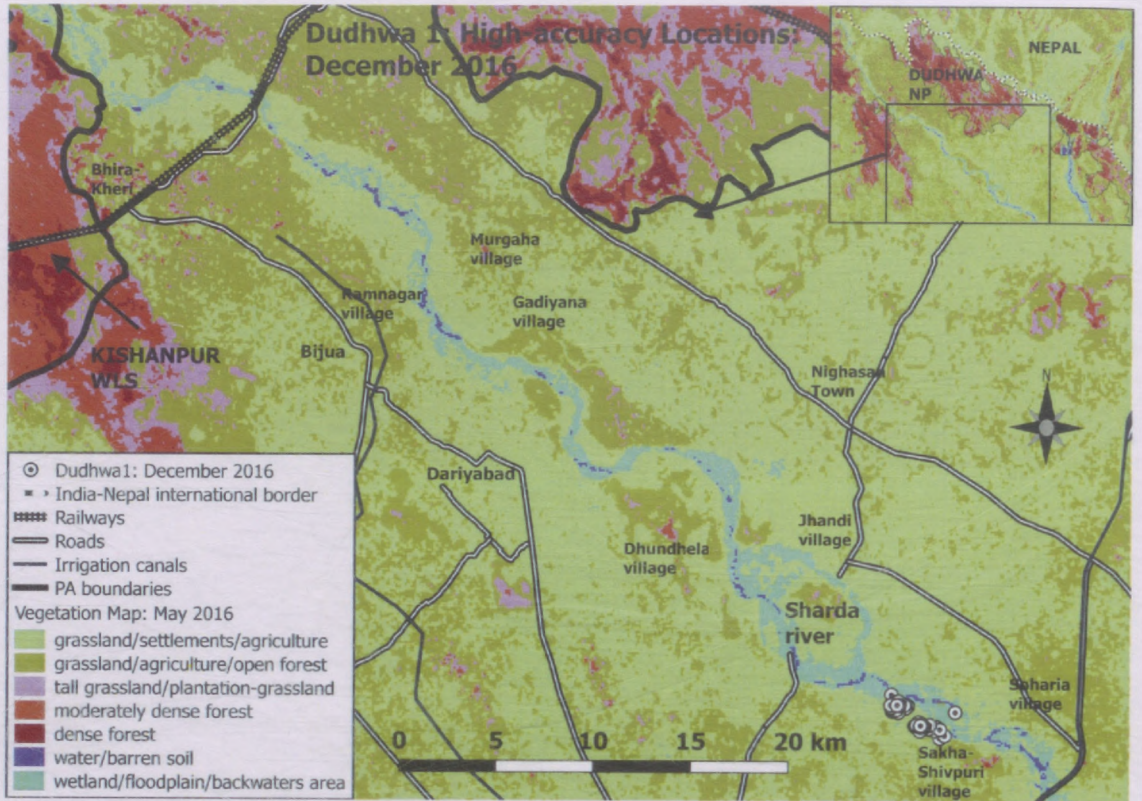




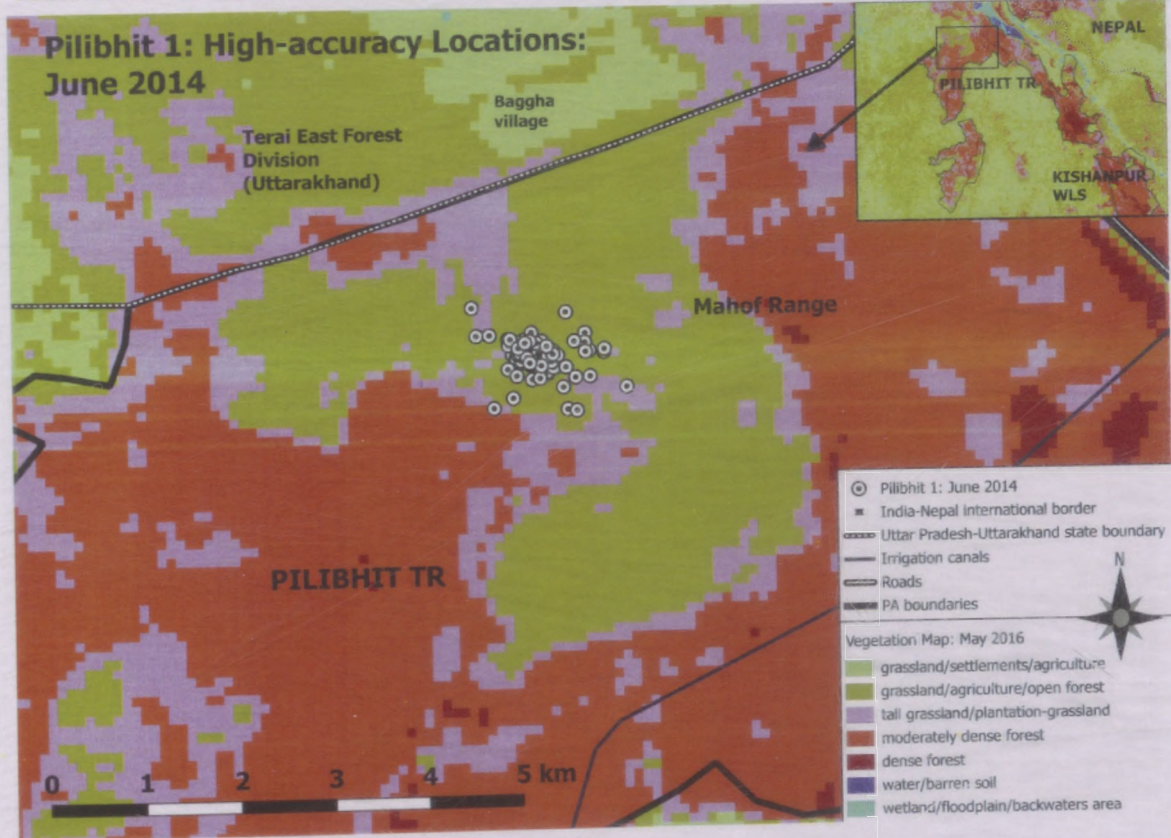
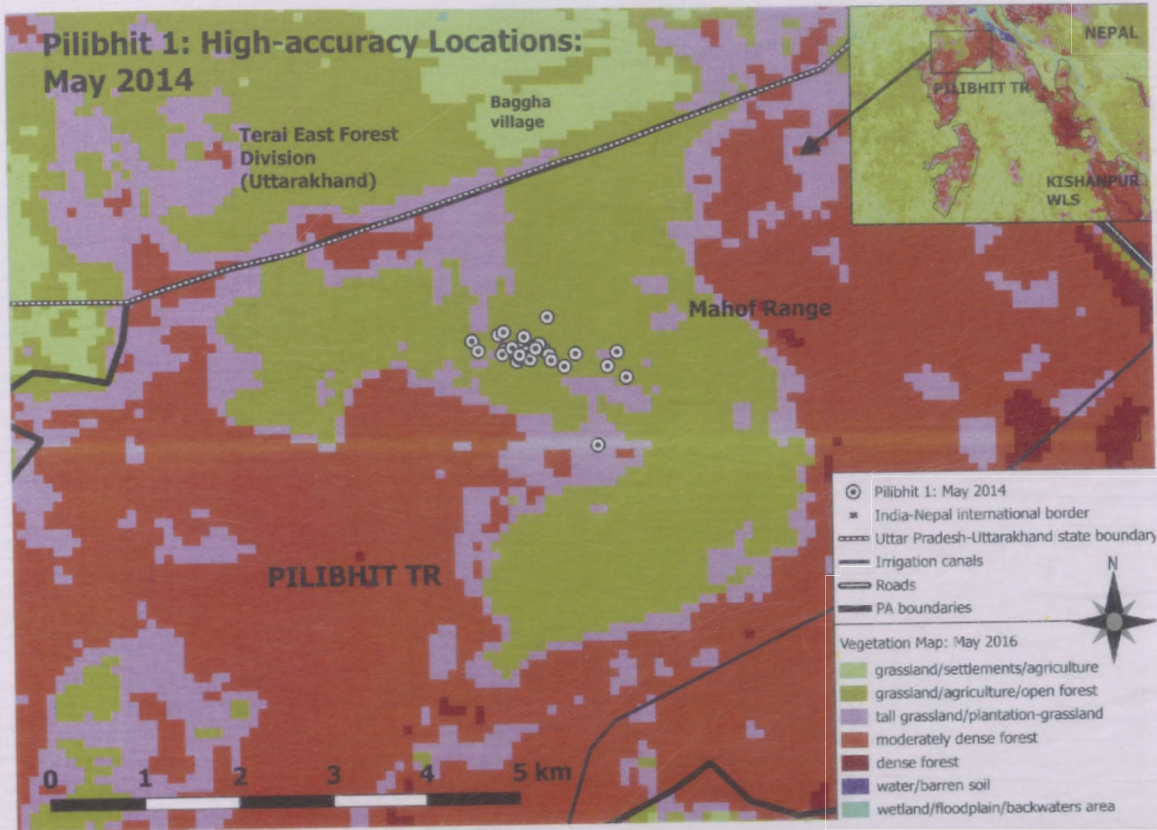


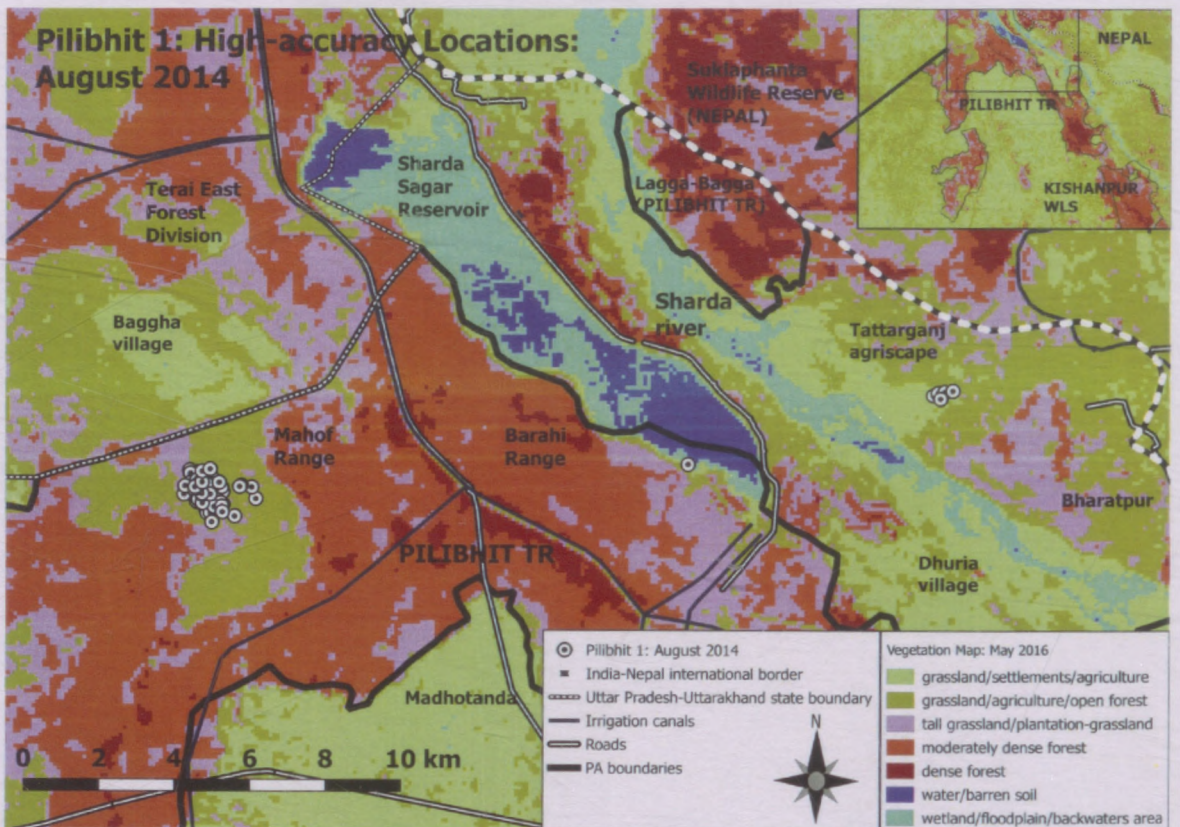
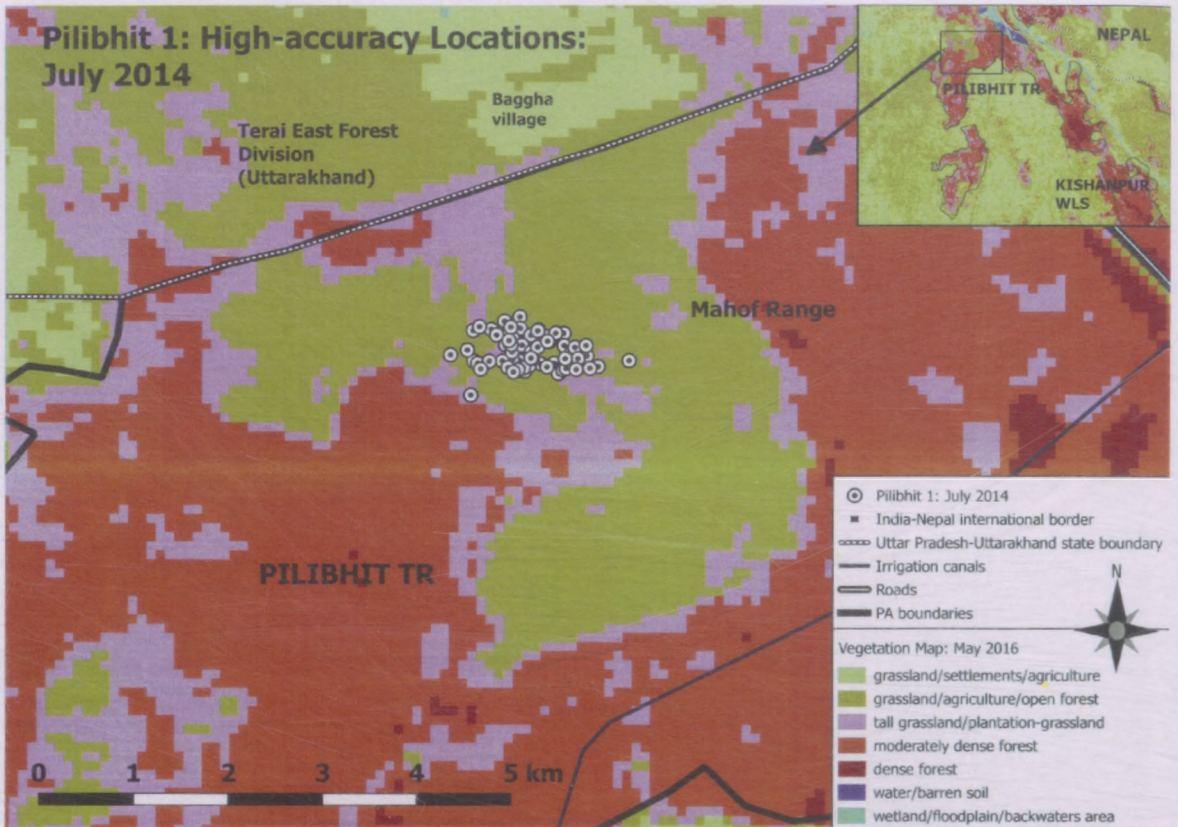


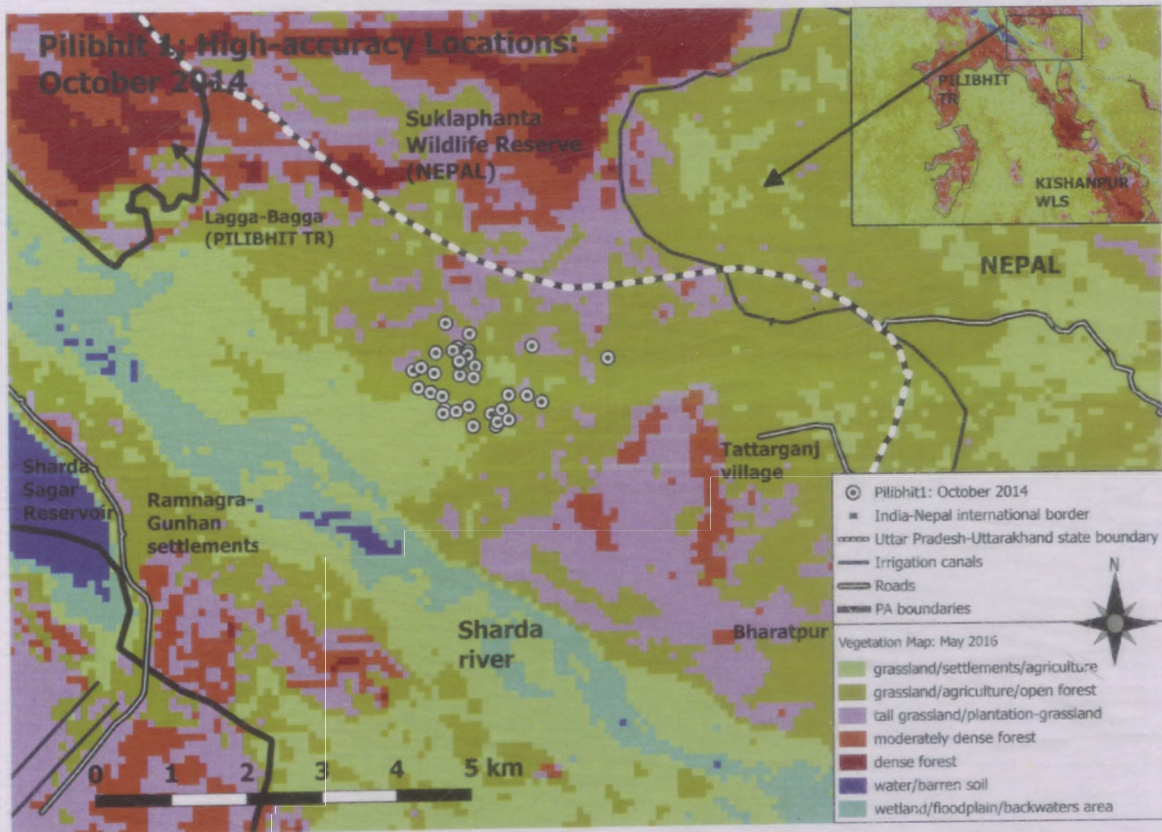
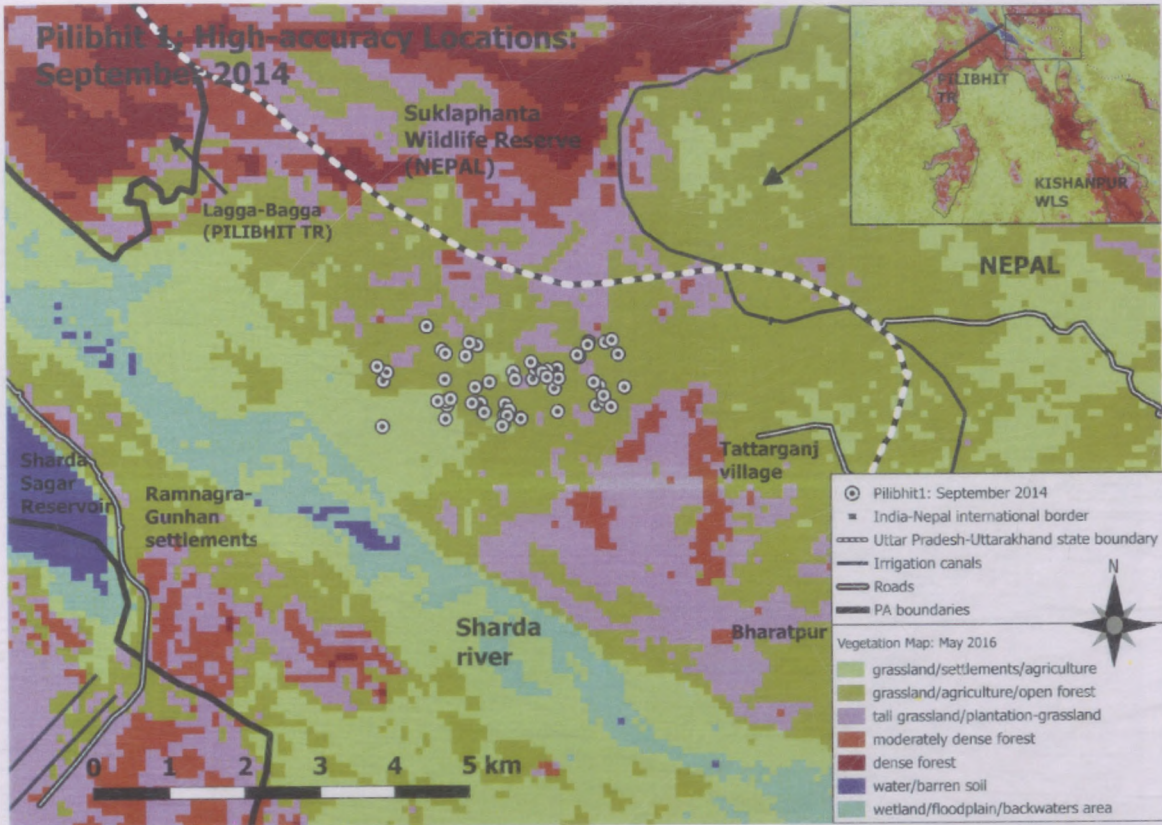


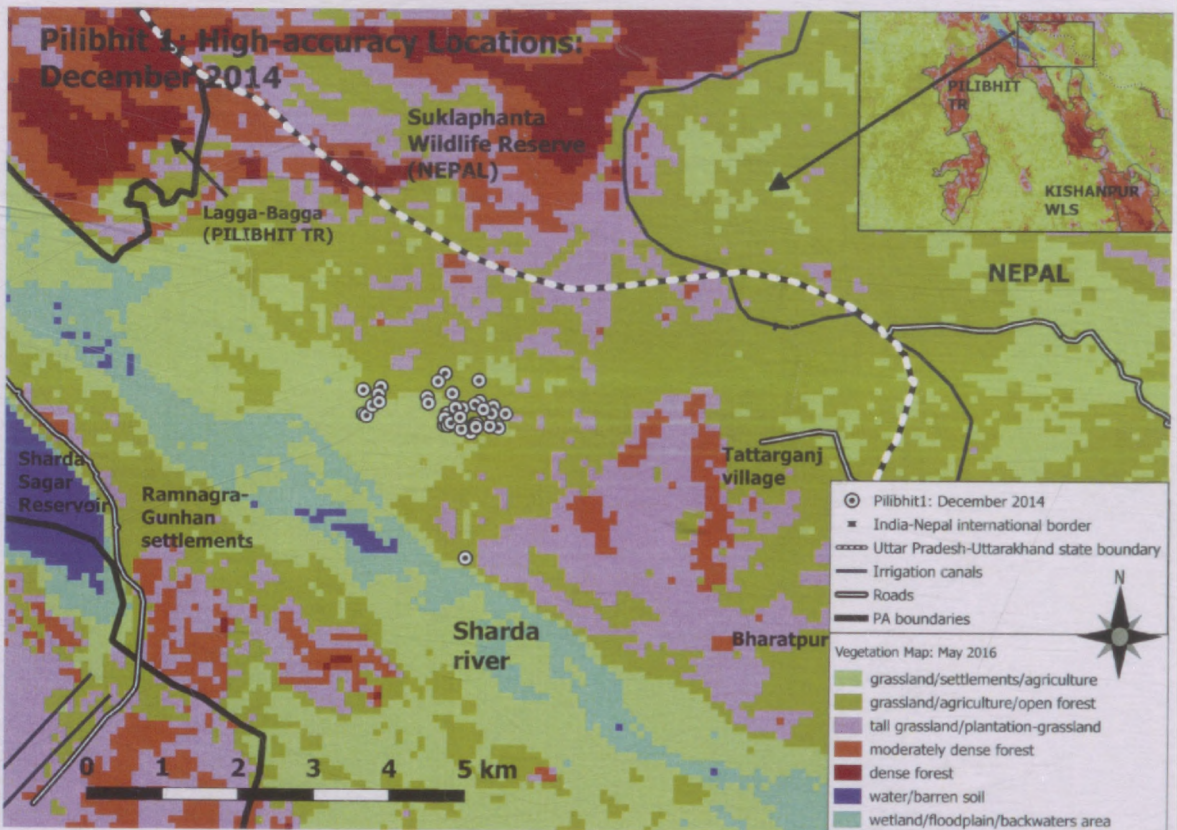
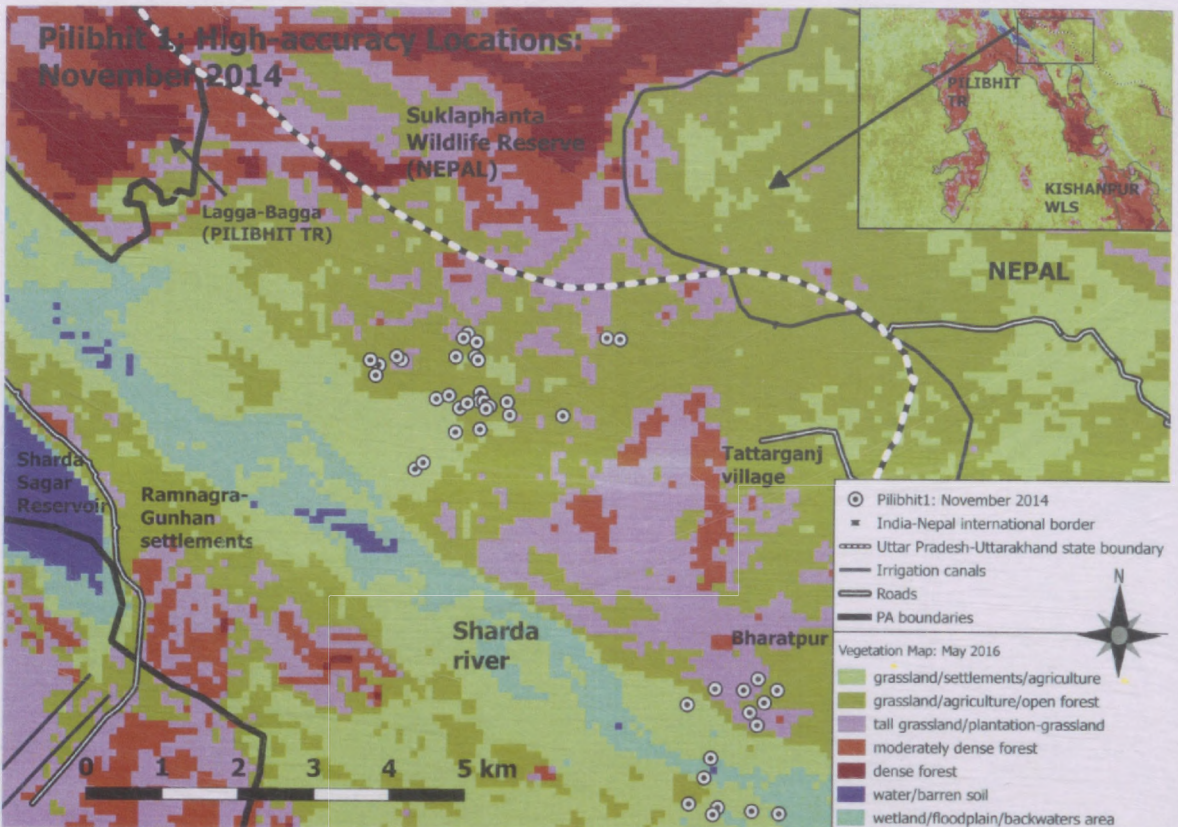


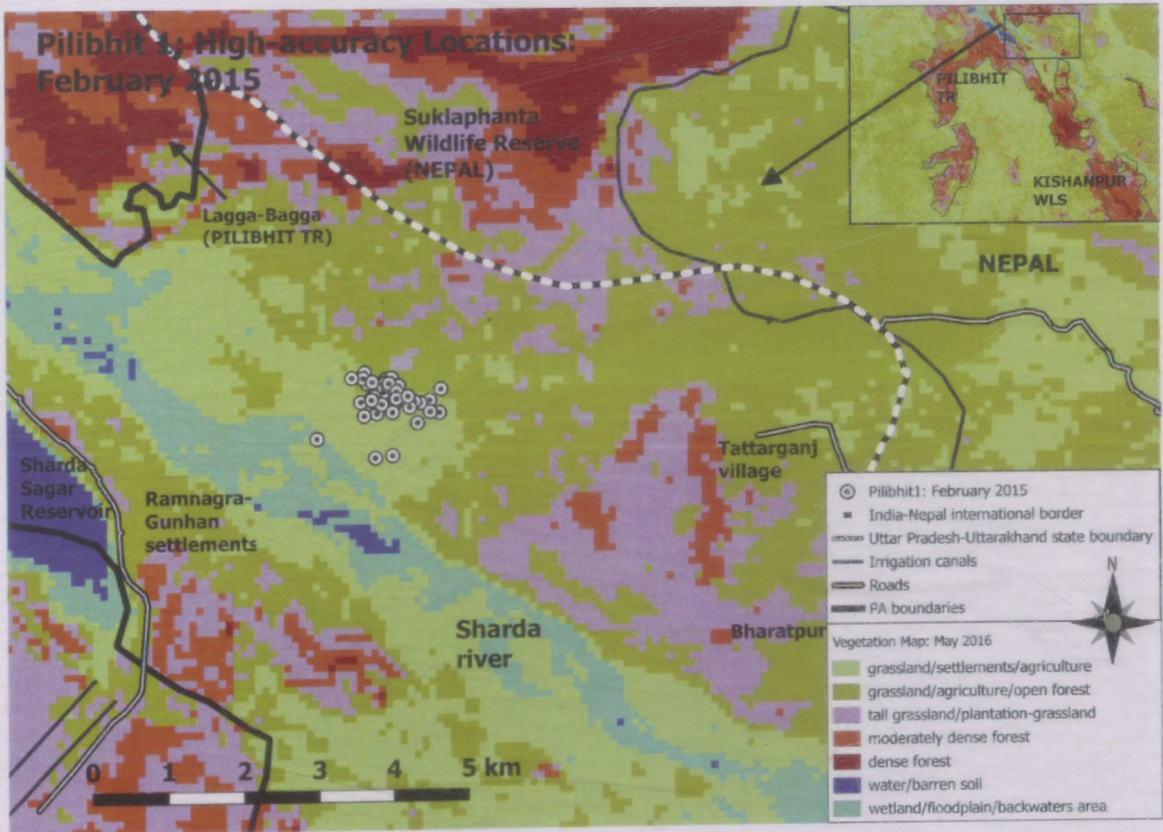
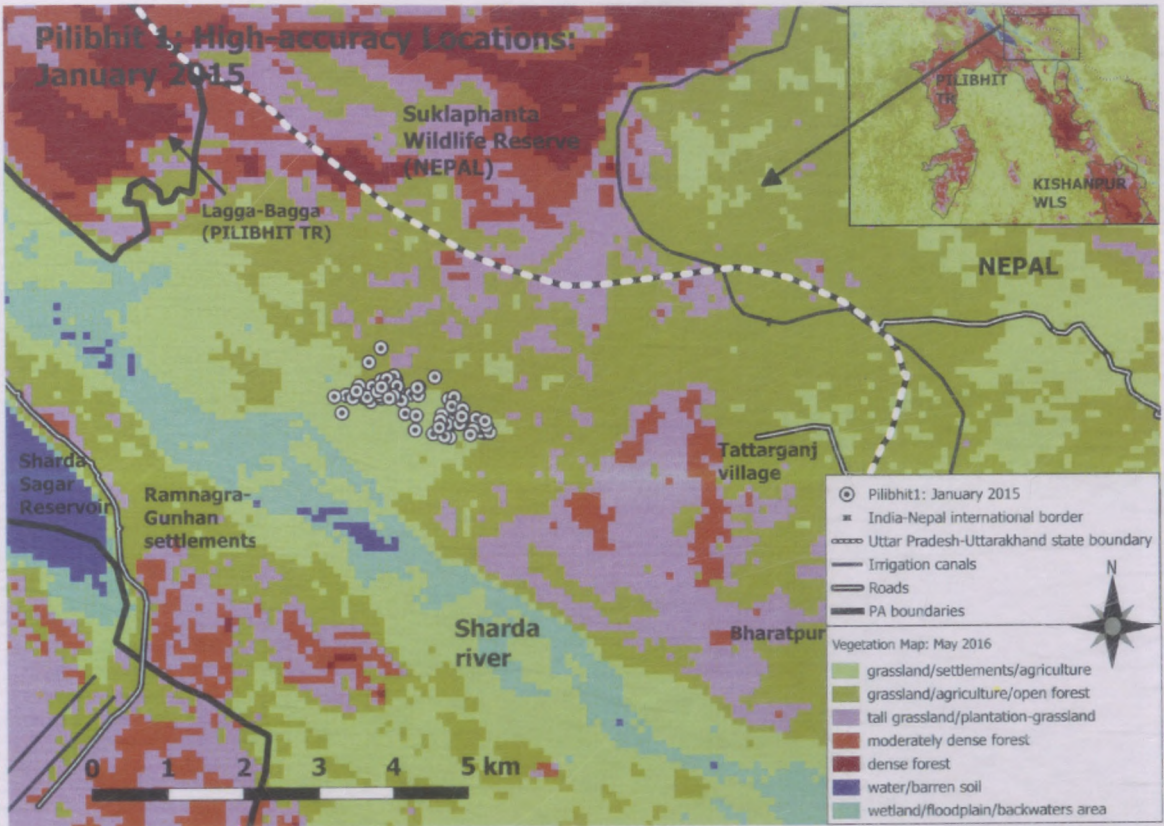
Month-wise movements of bird 'Pilibhit 1' derived from high-accuracy locations during May 2014 to December 2016

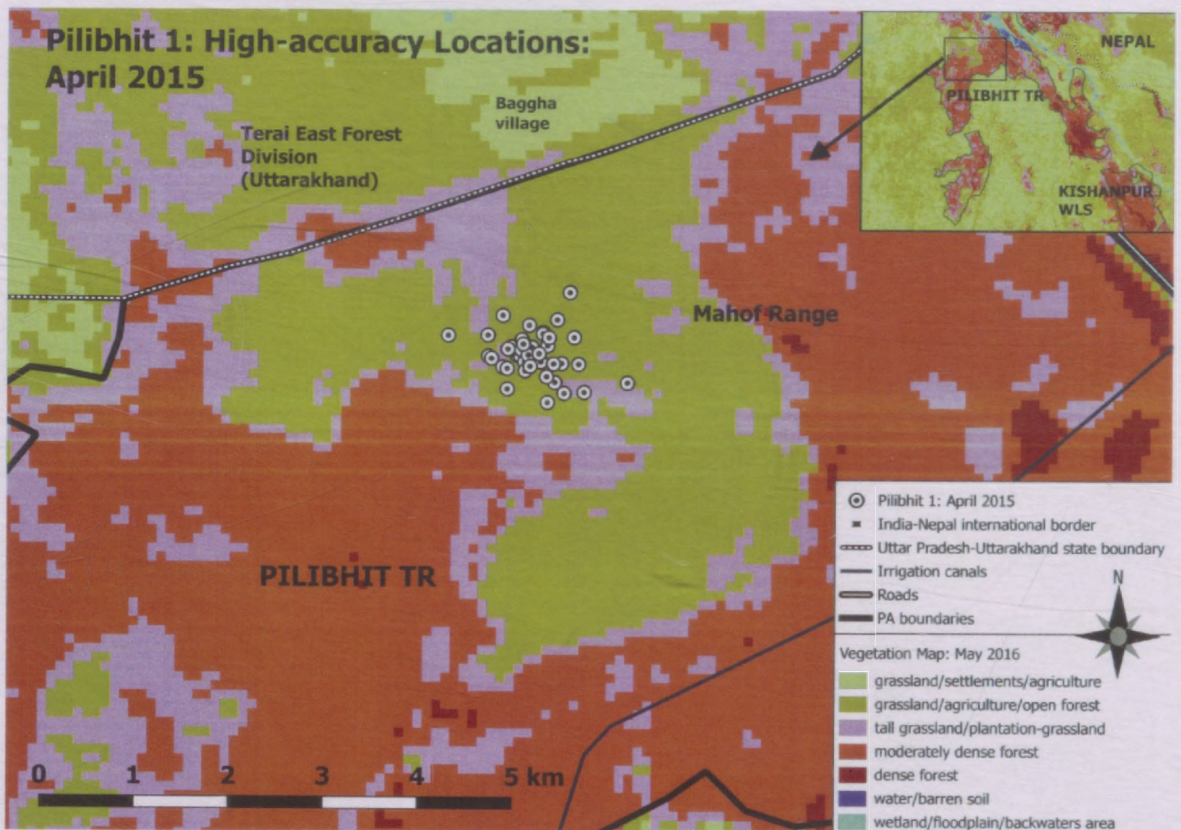
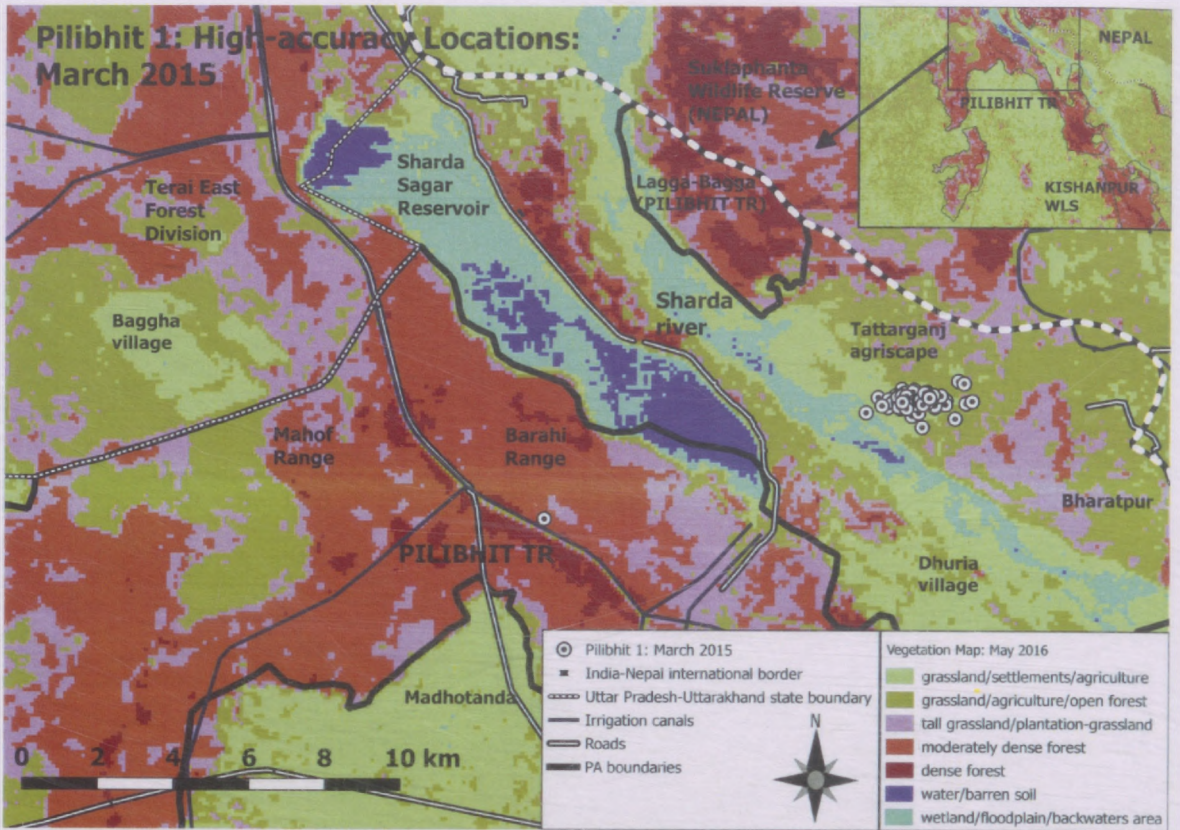


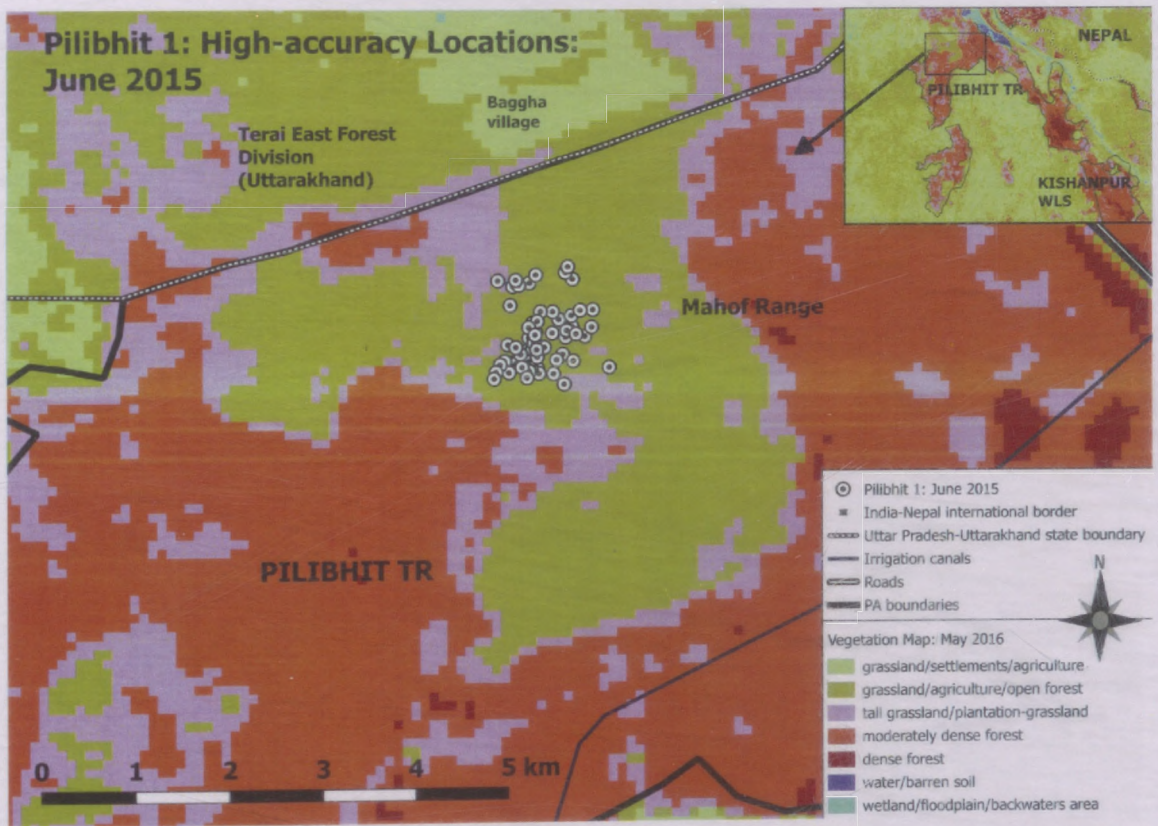
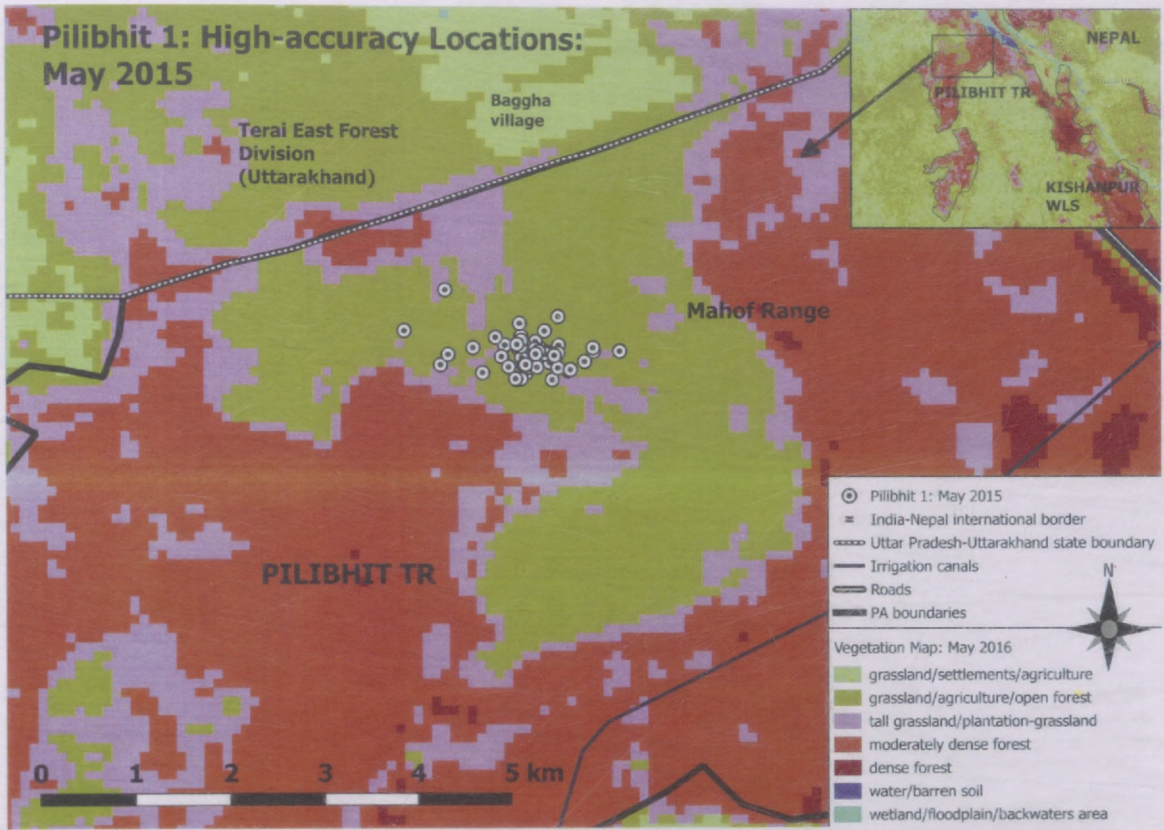


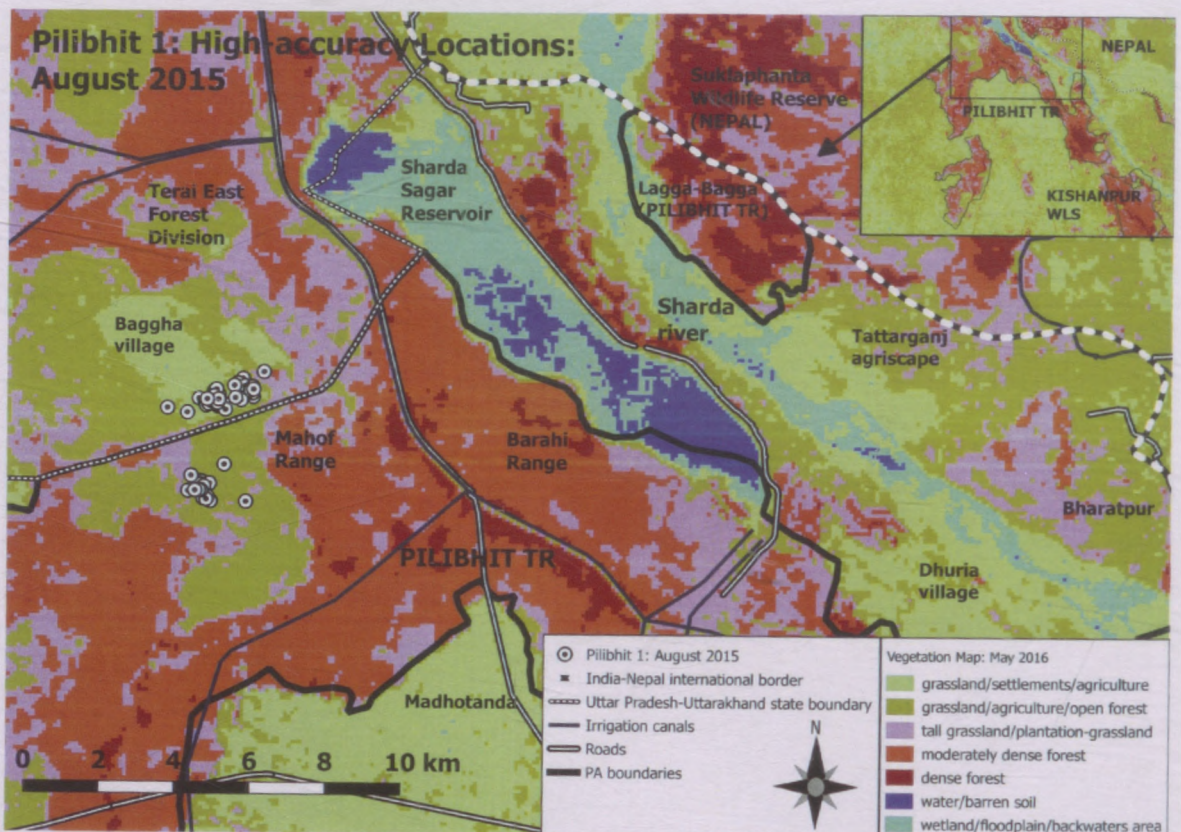
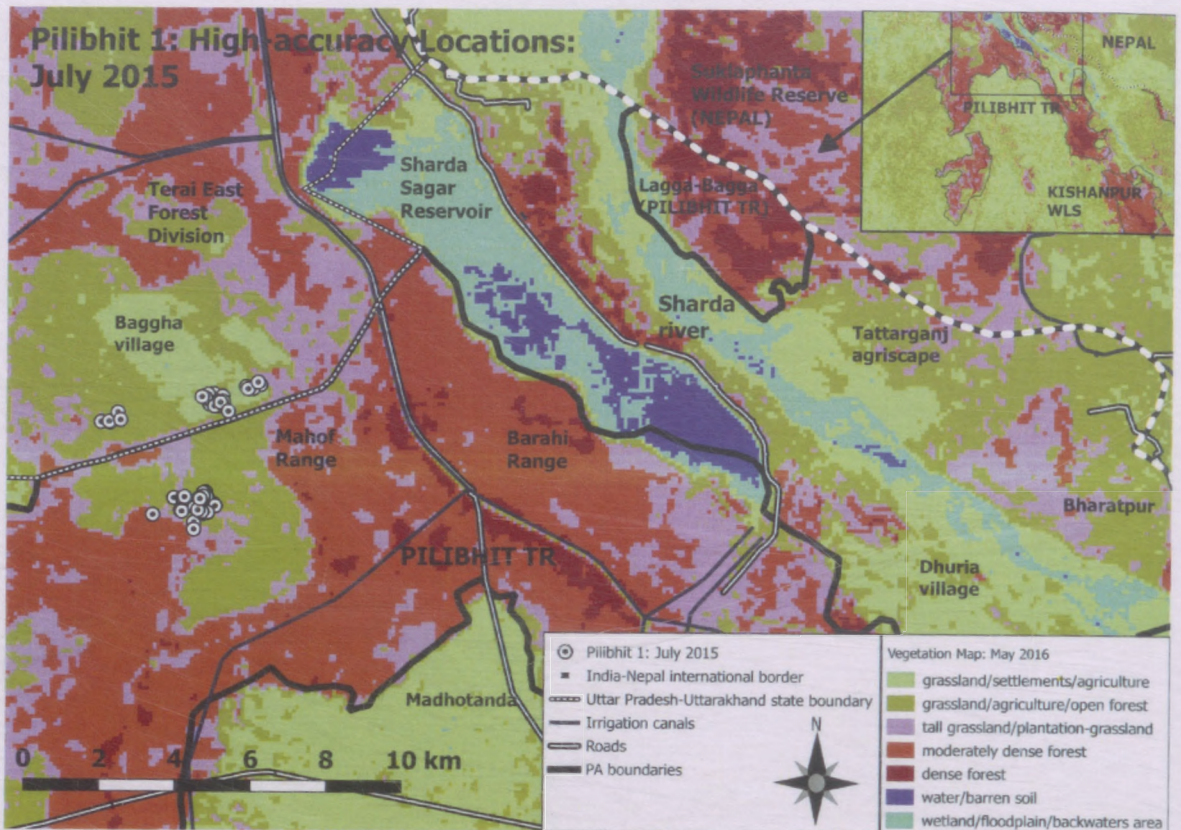


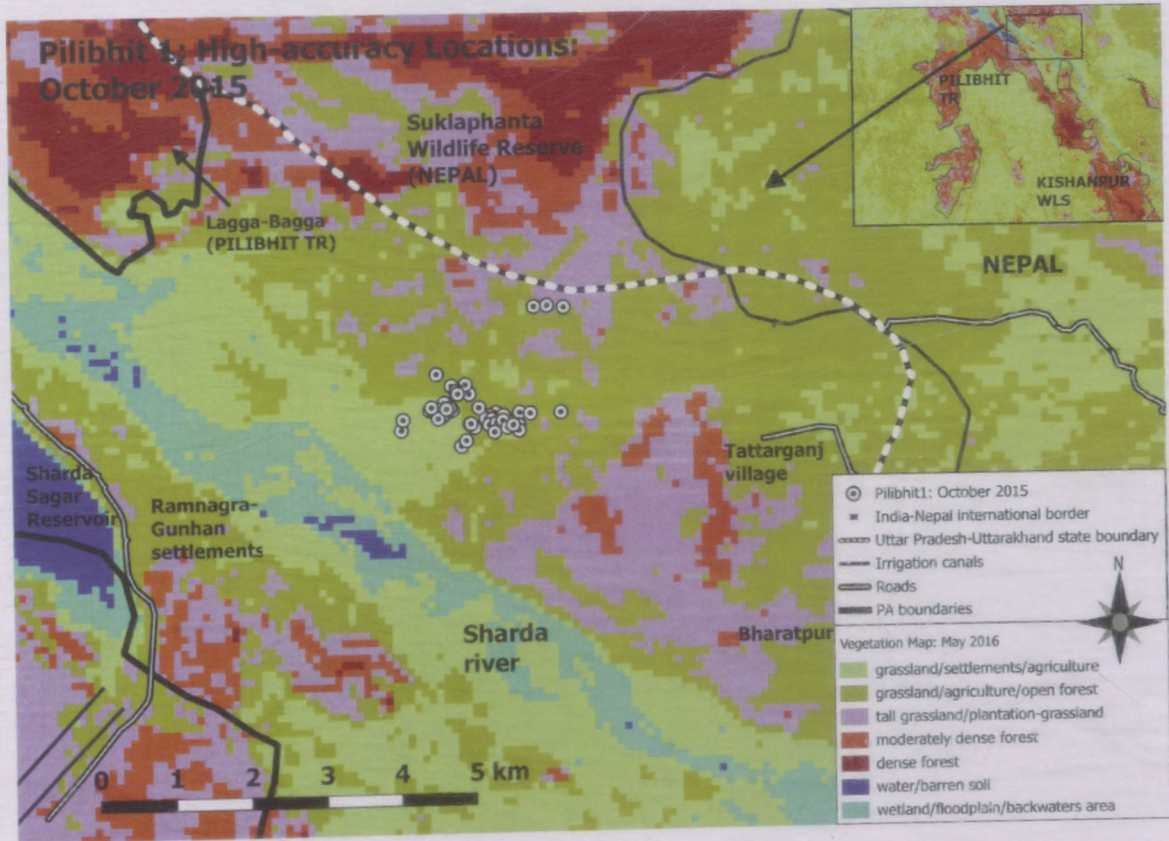
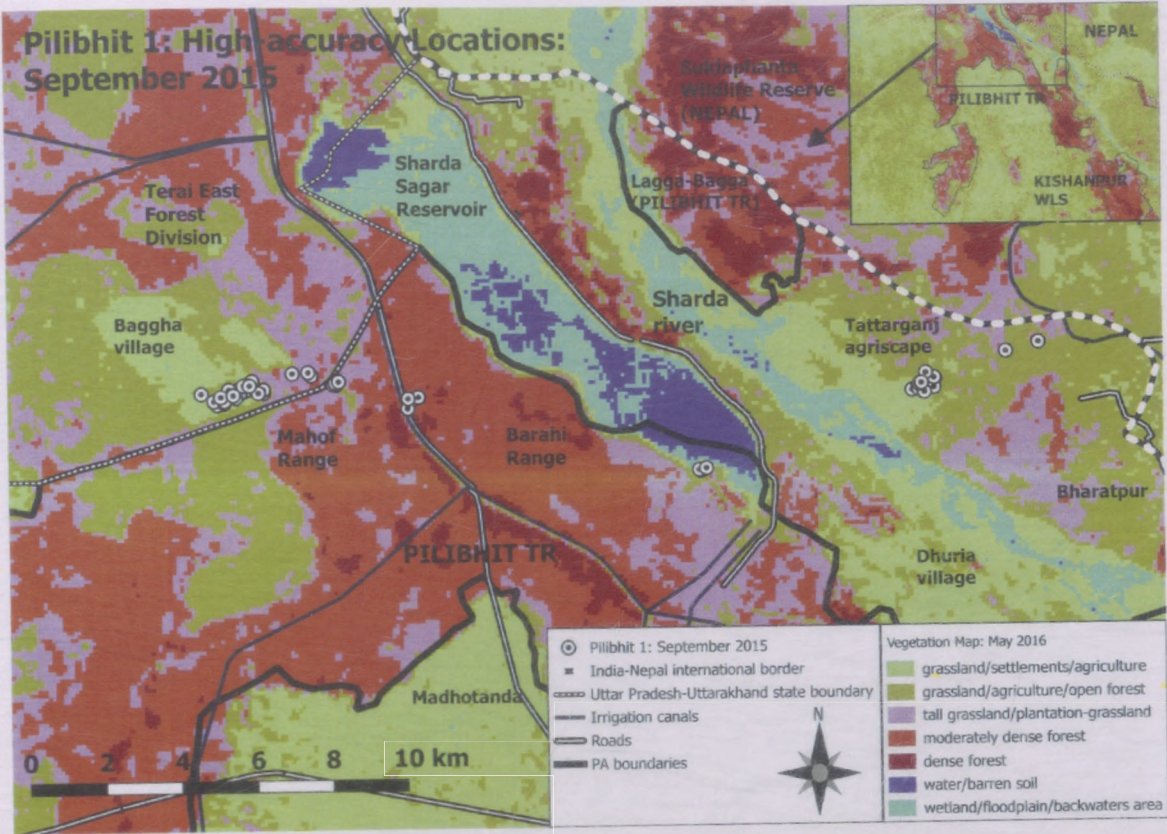


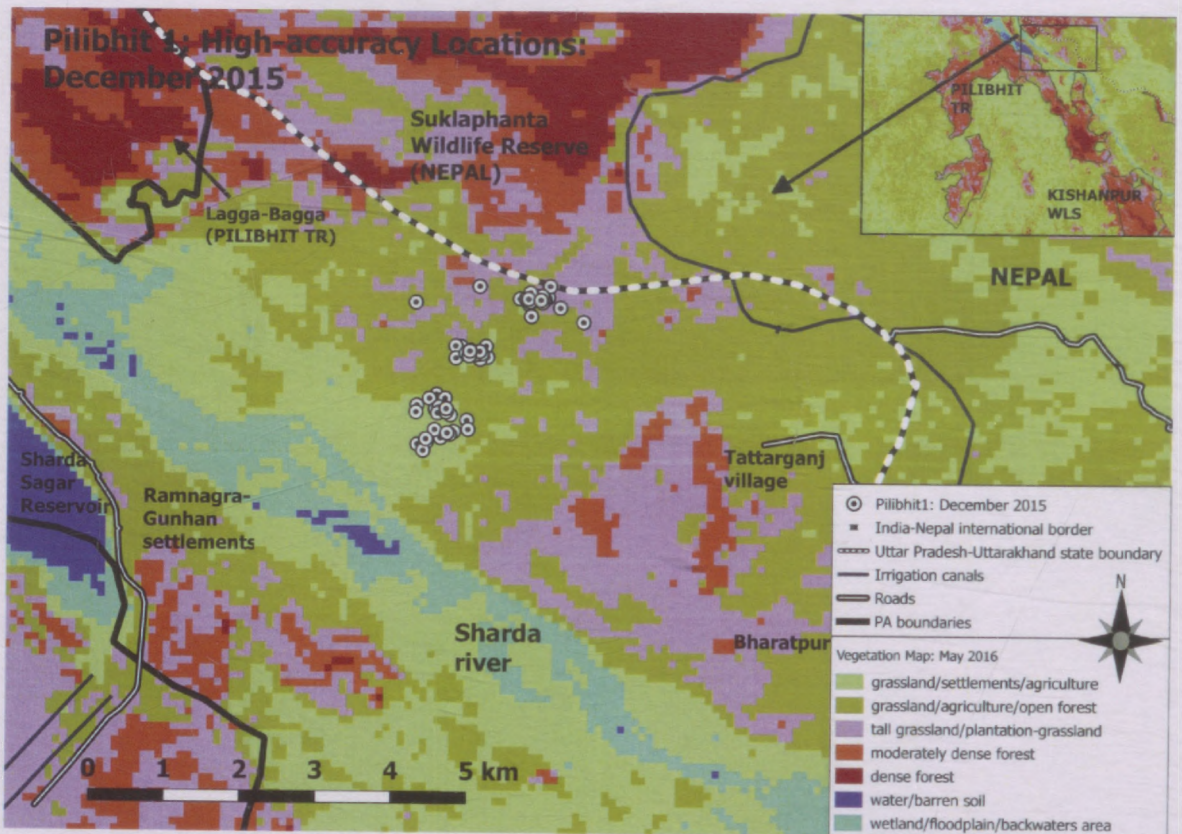
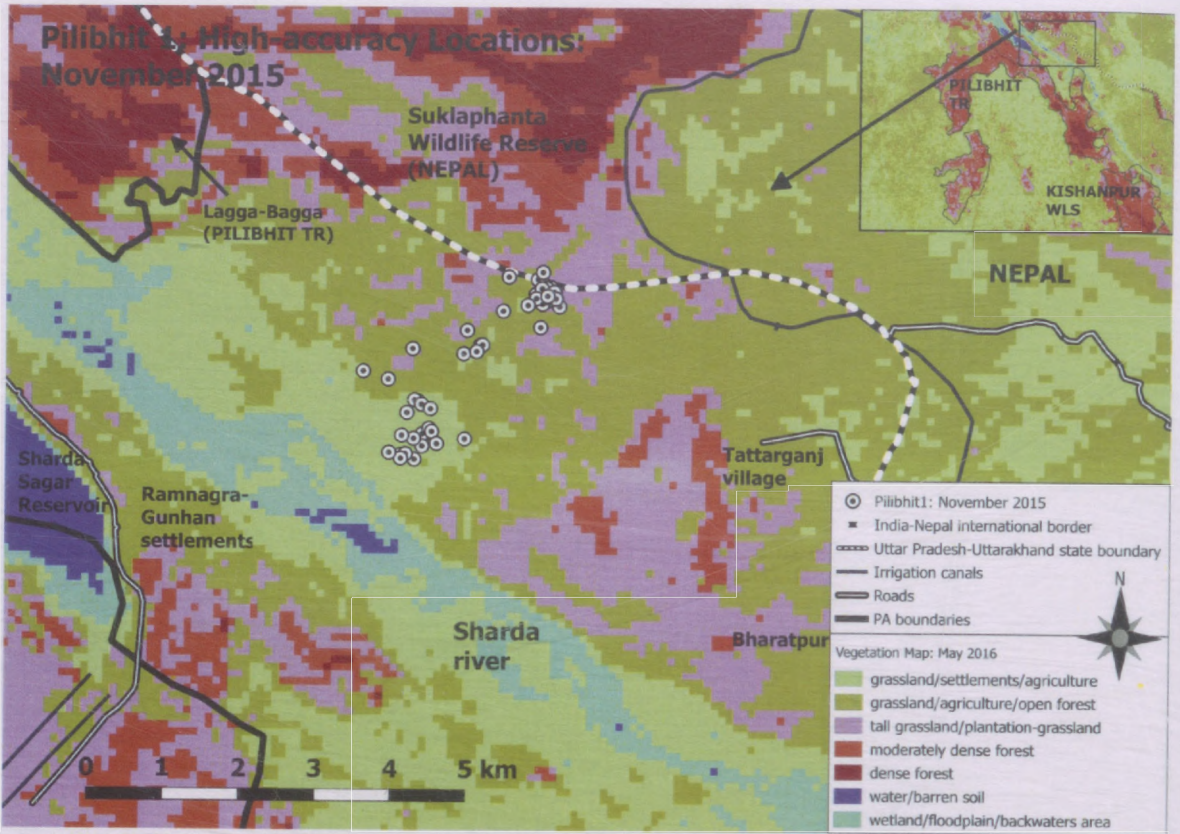


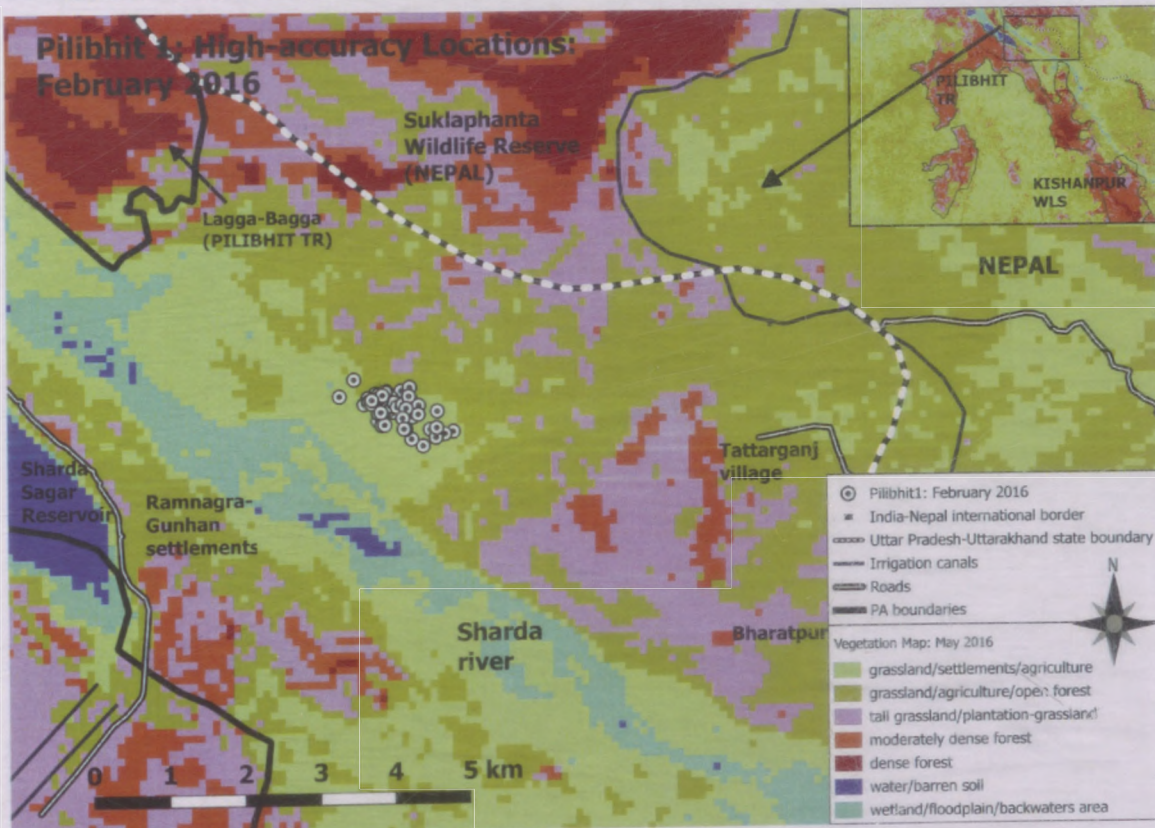
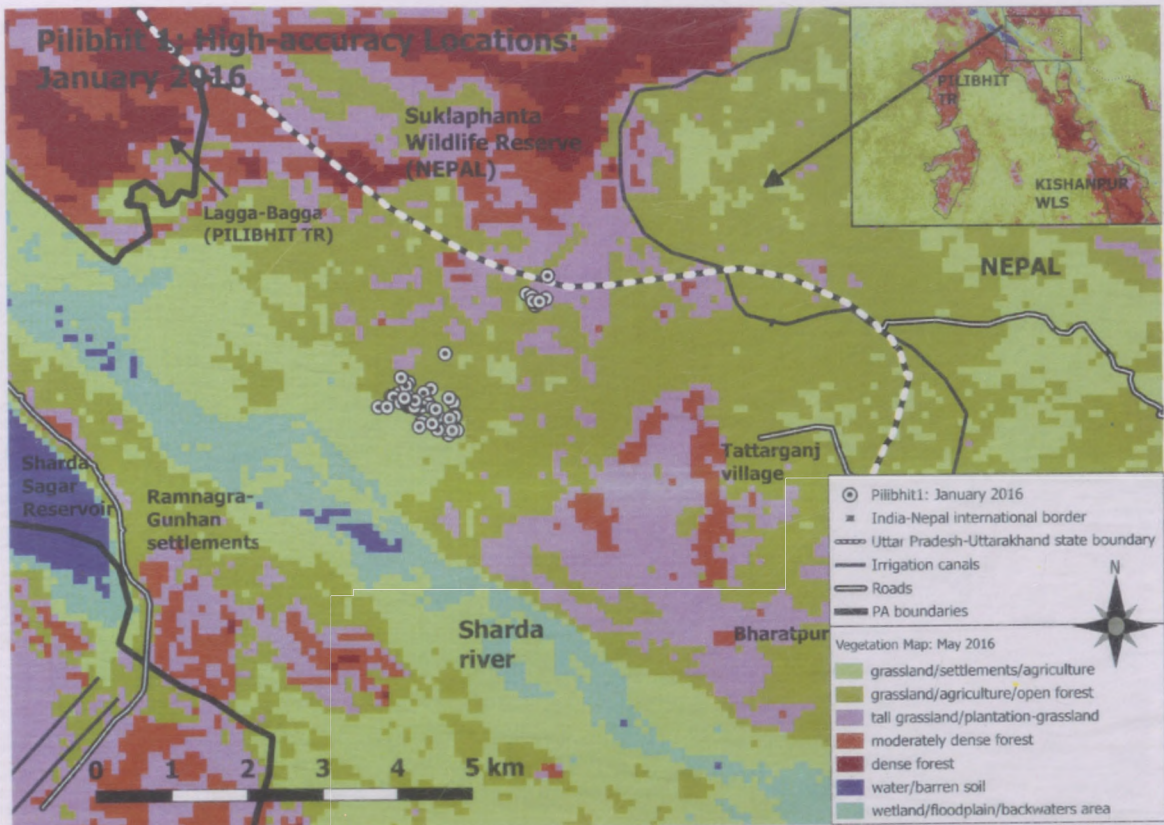


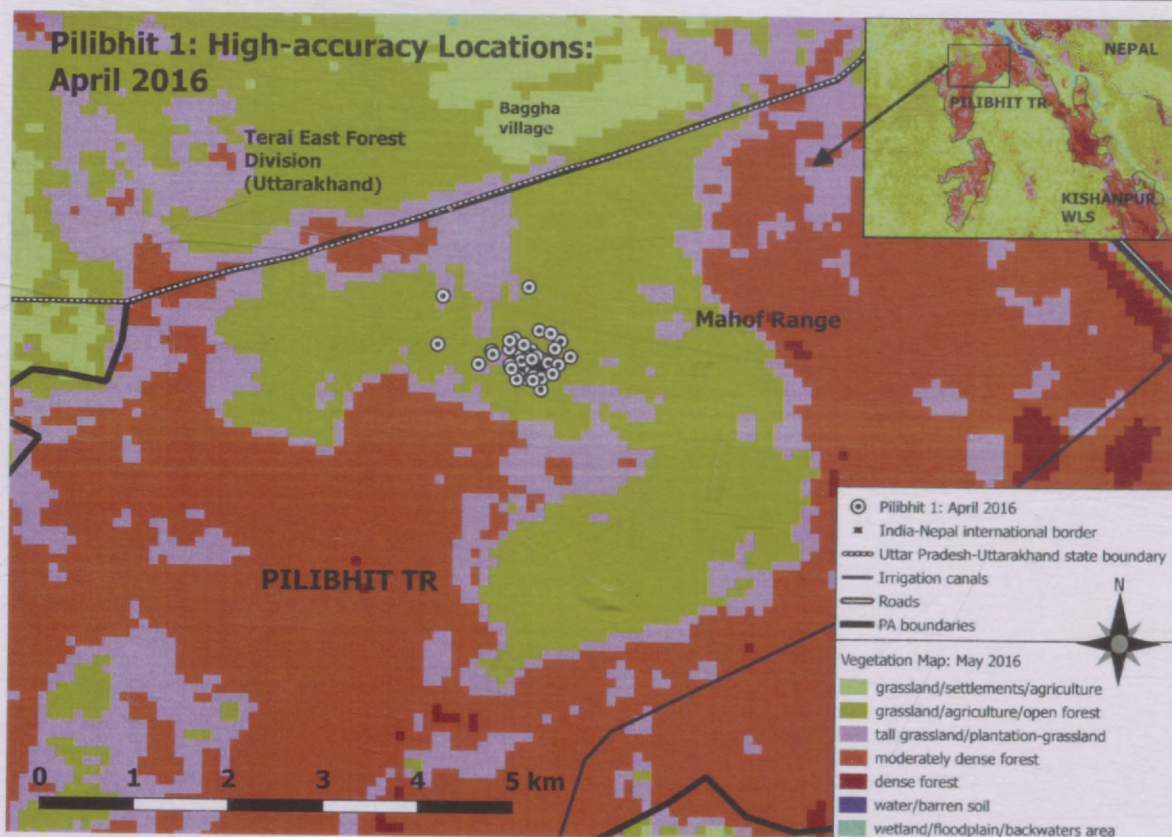
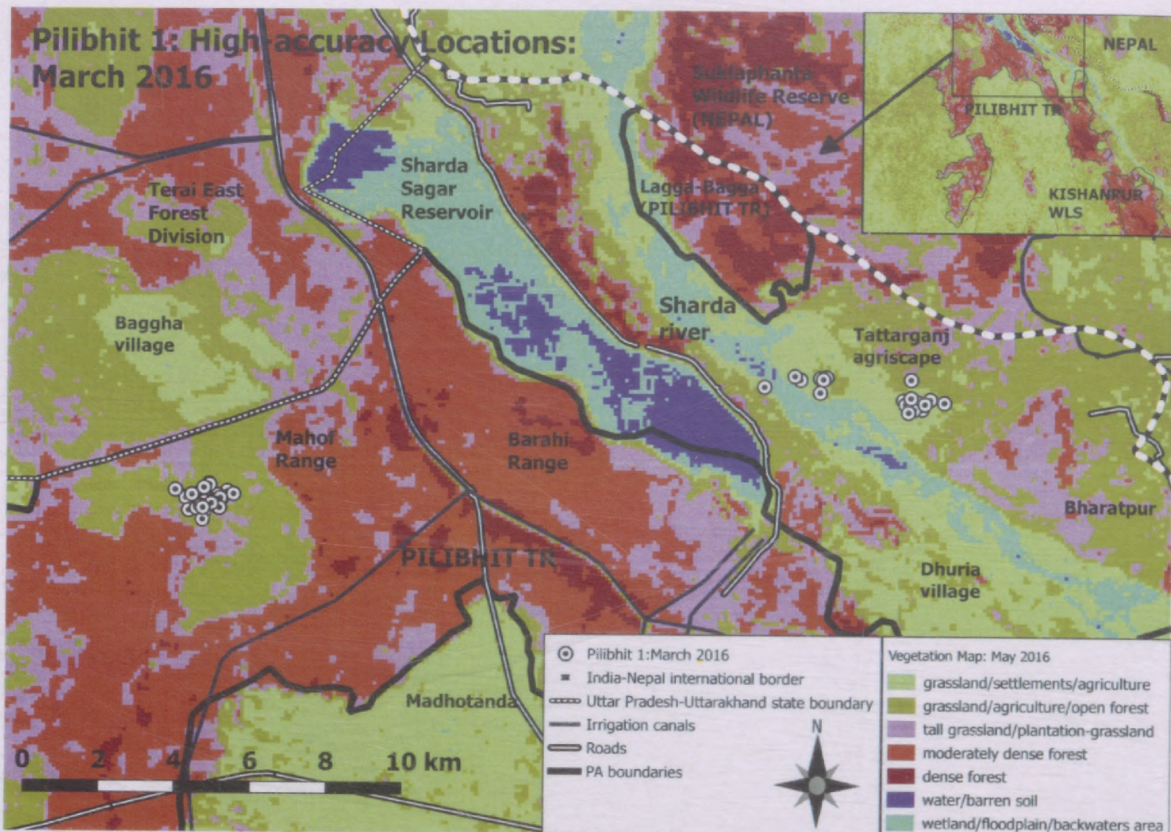


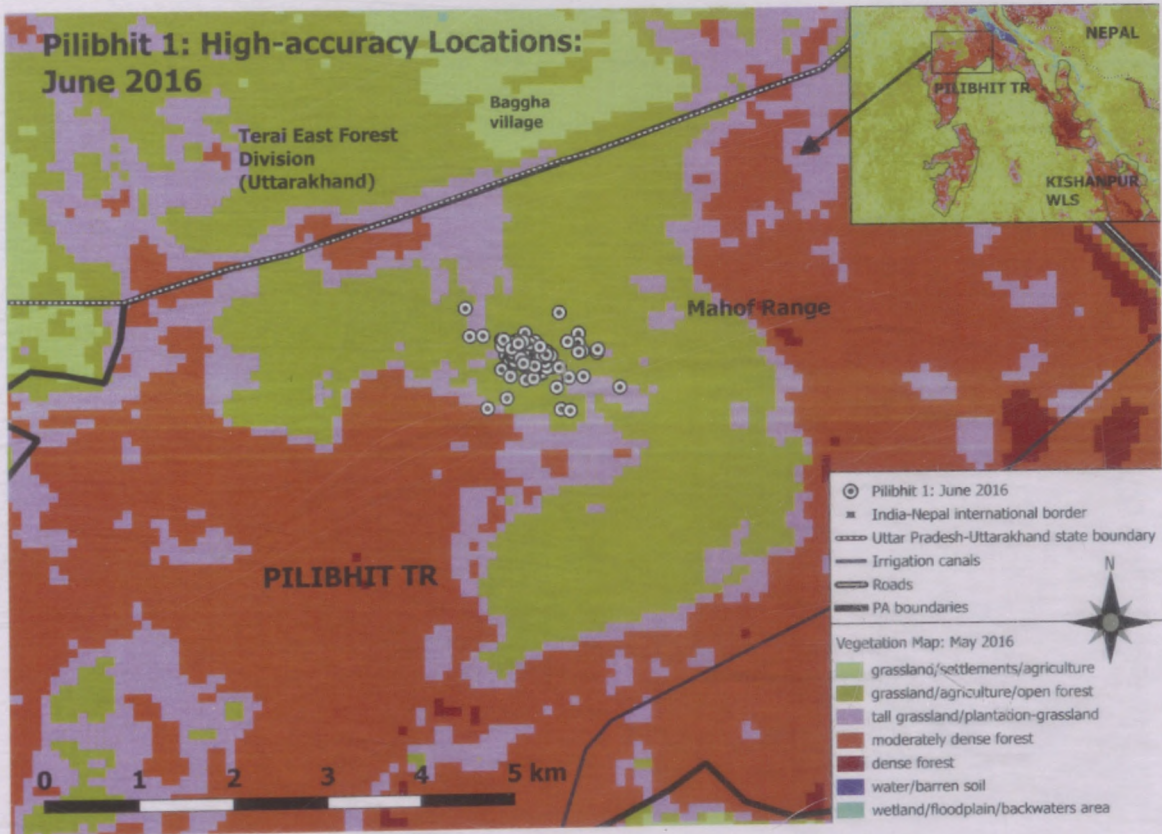
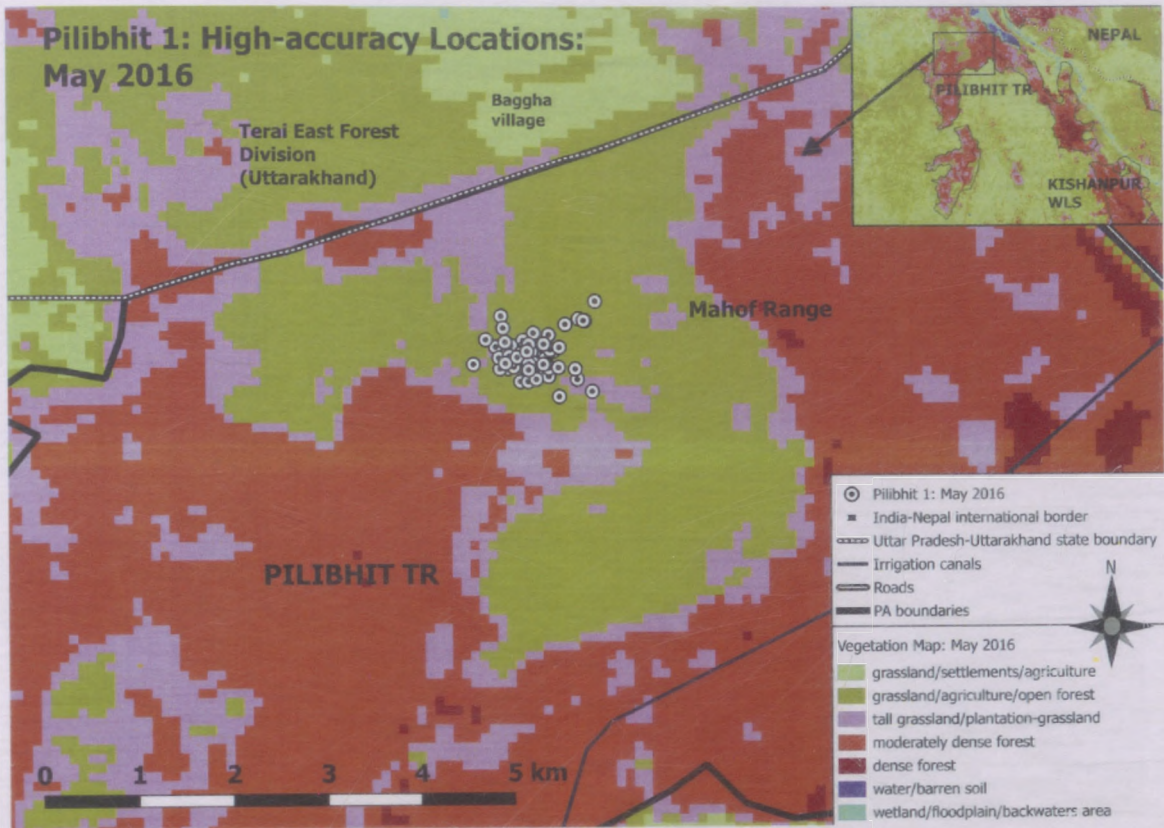


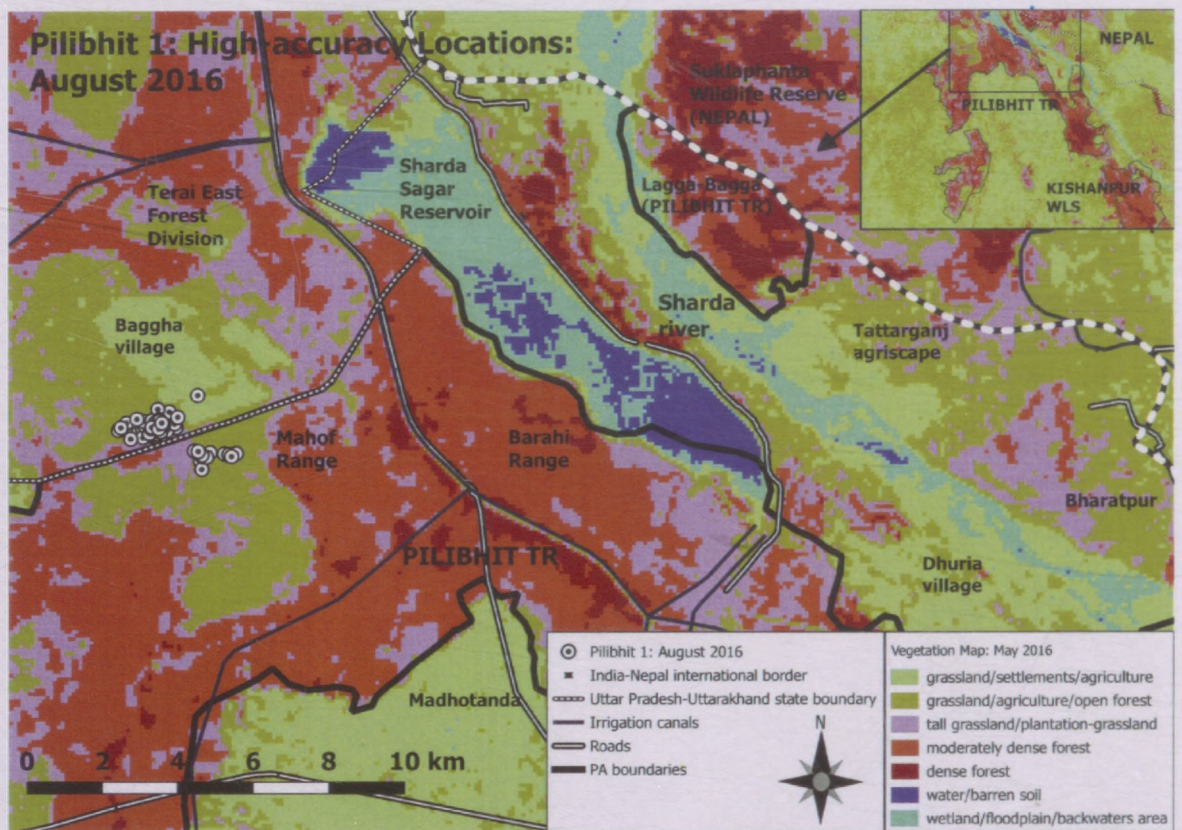
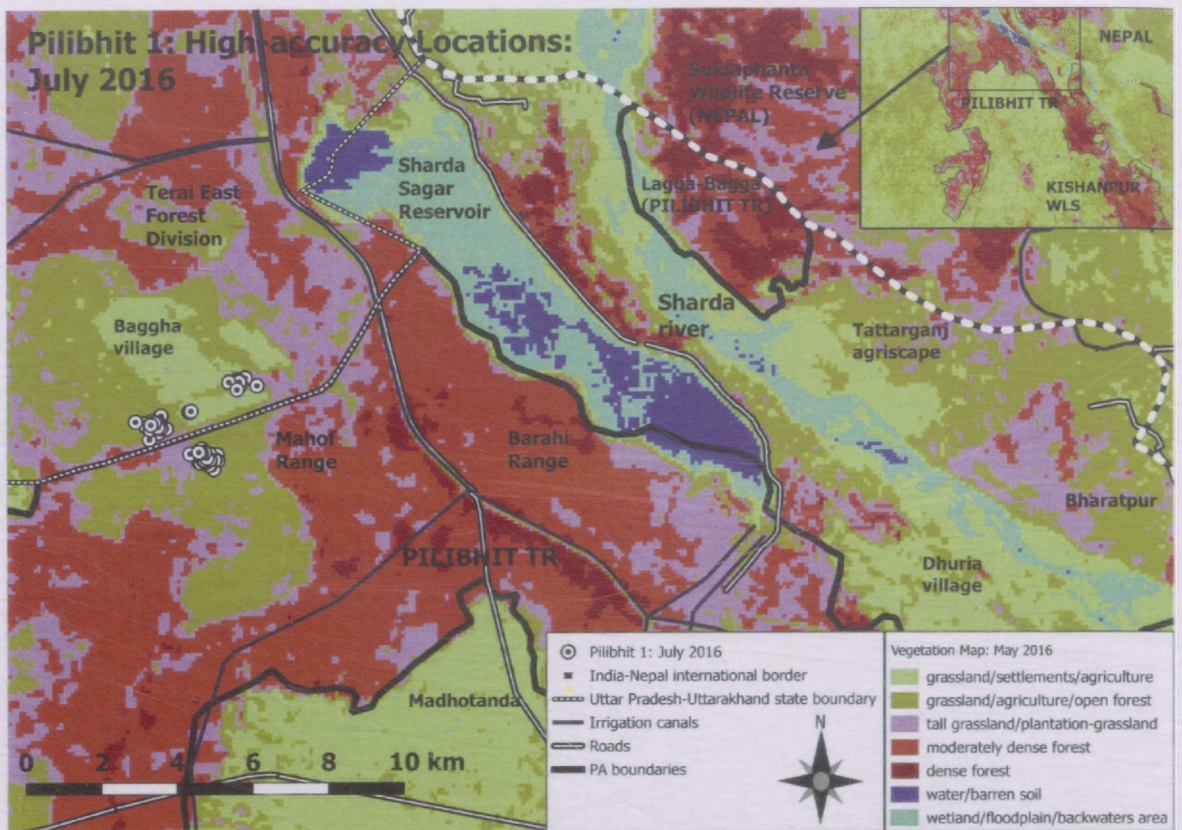


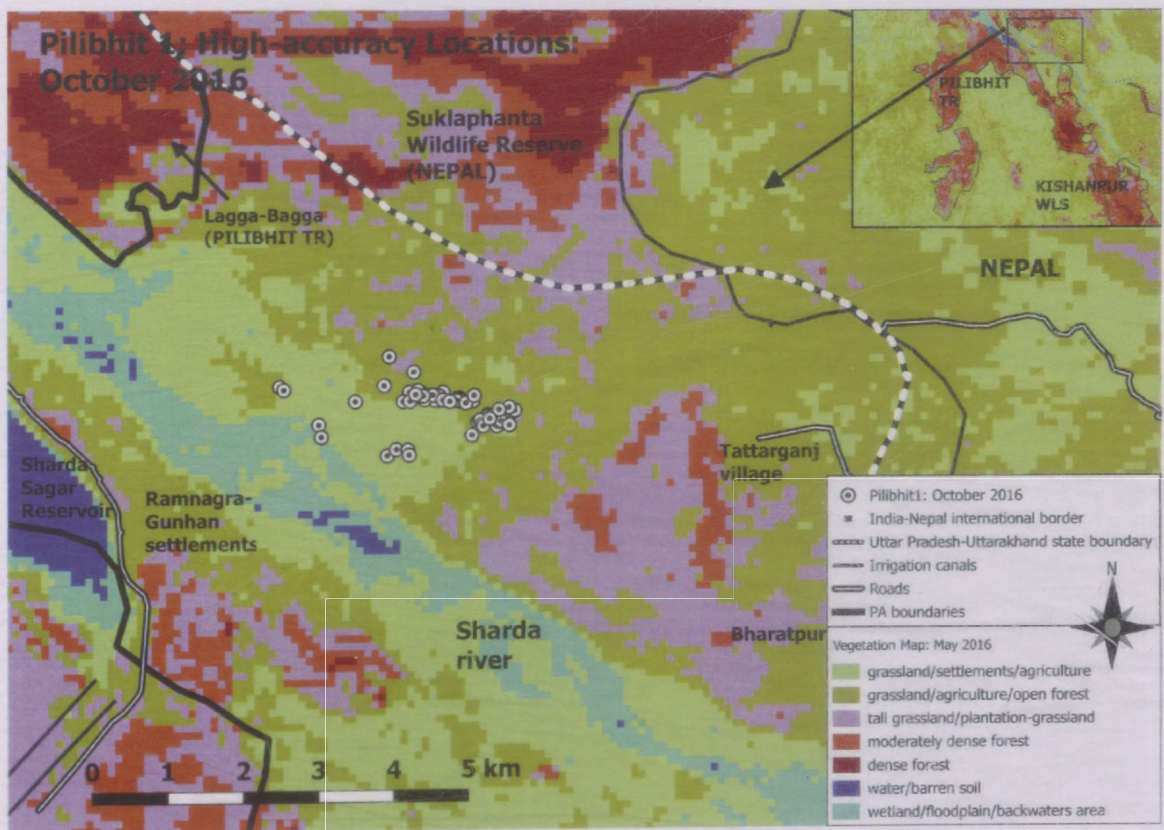
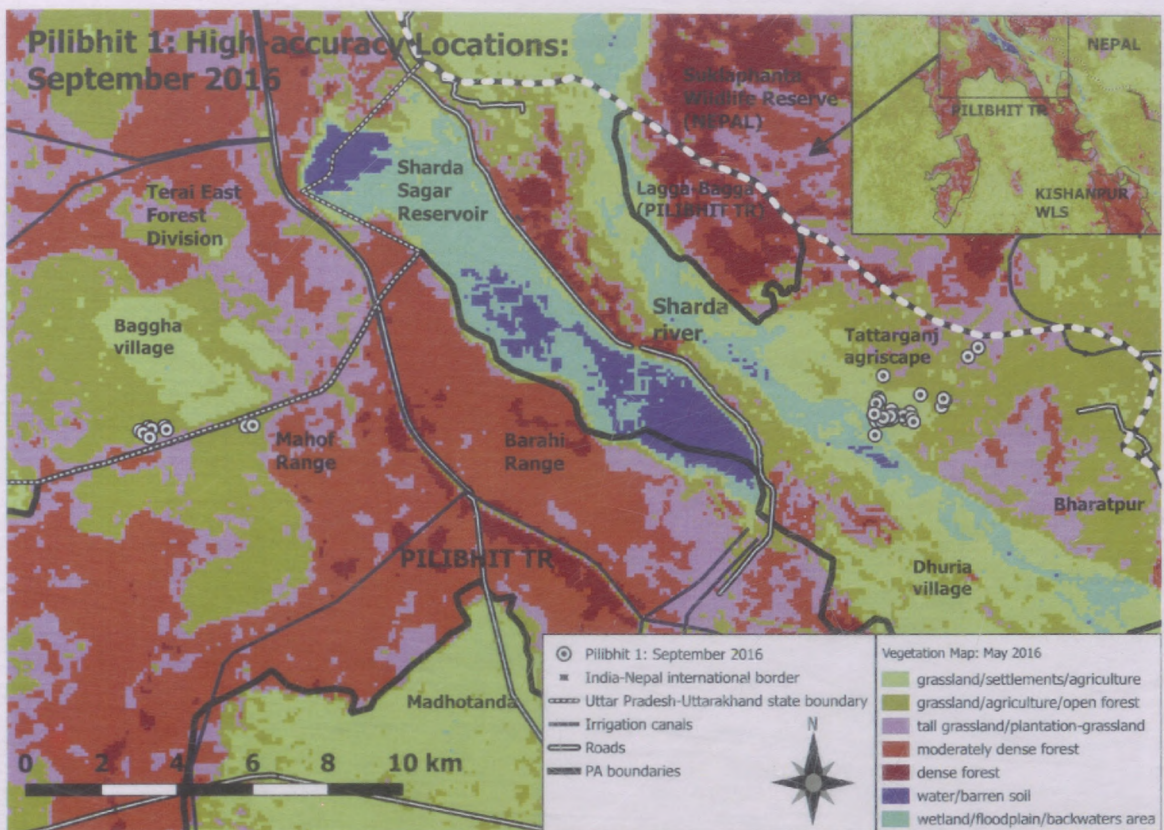


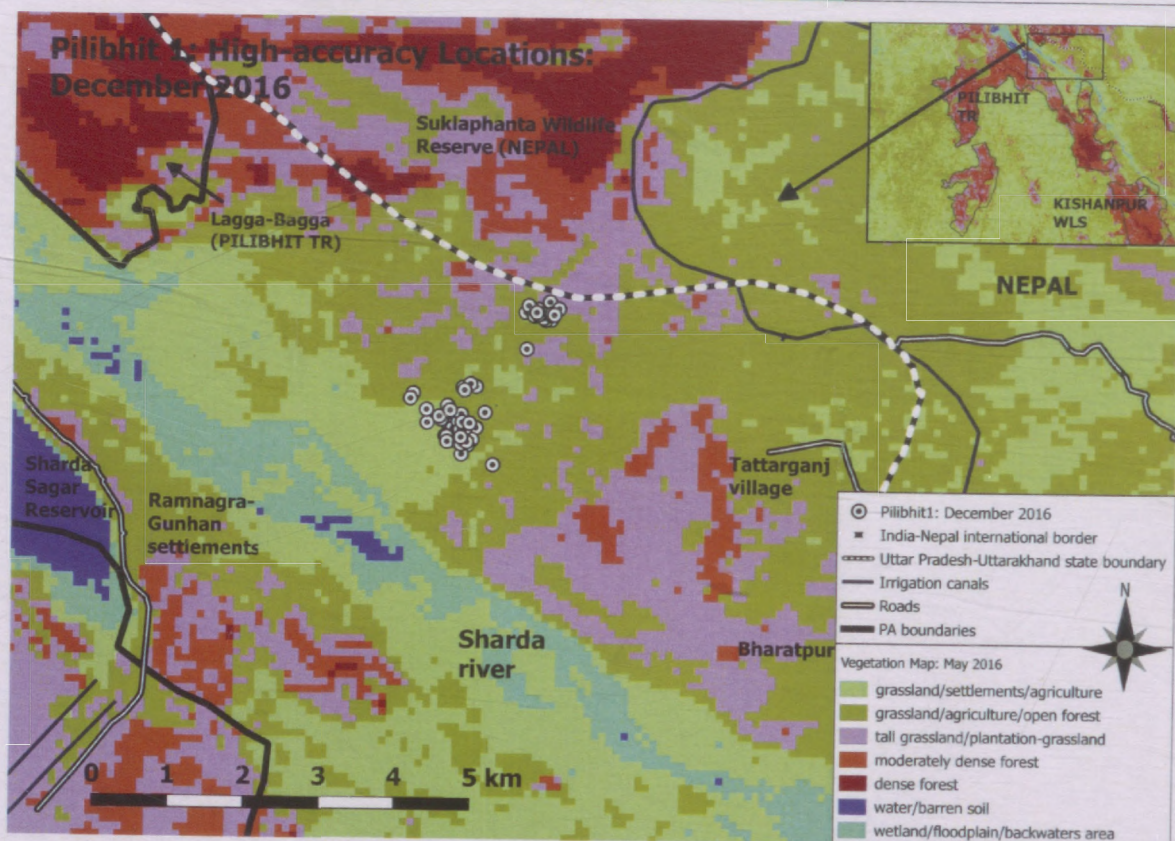
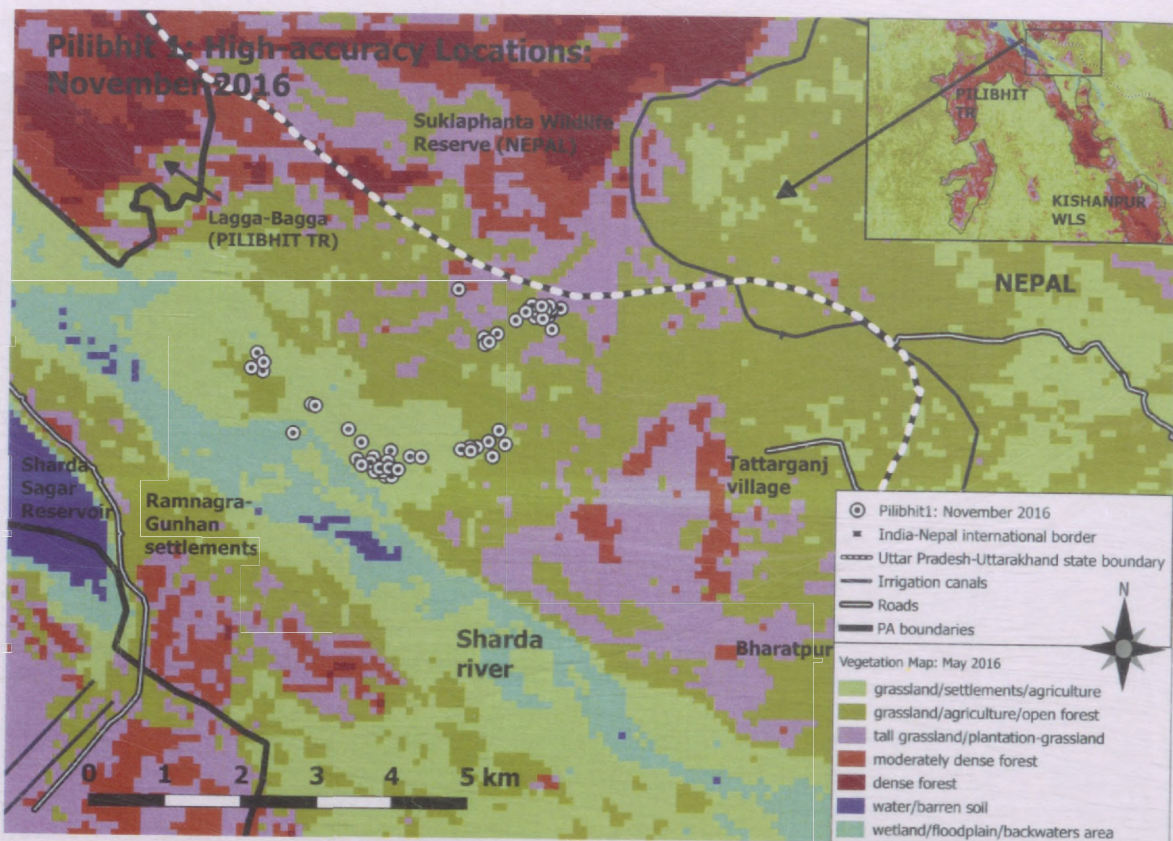




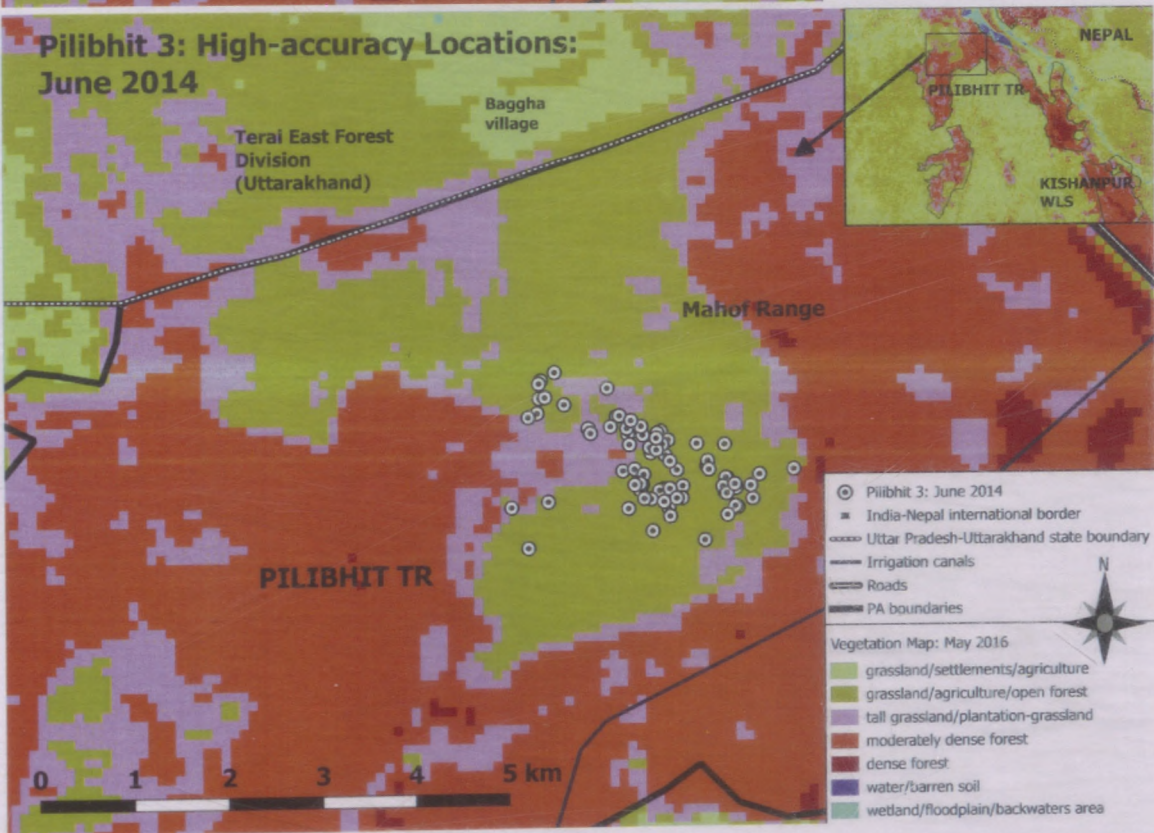
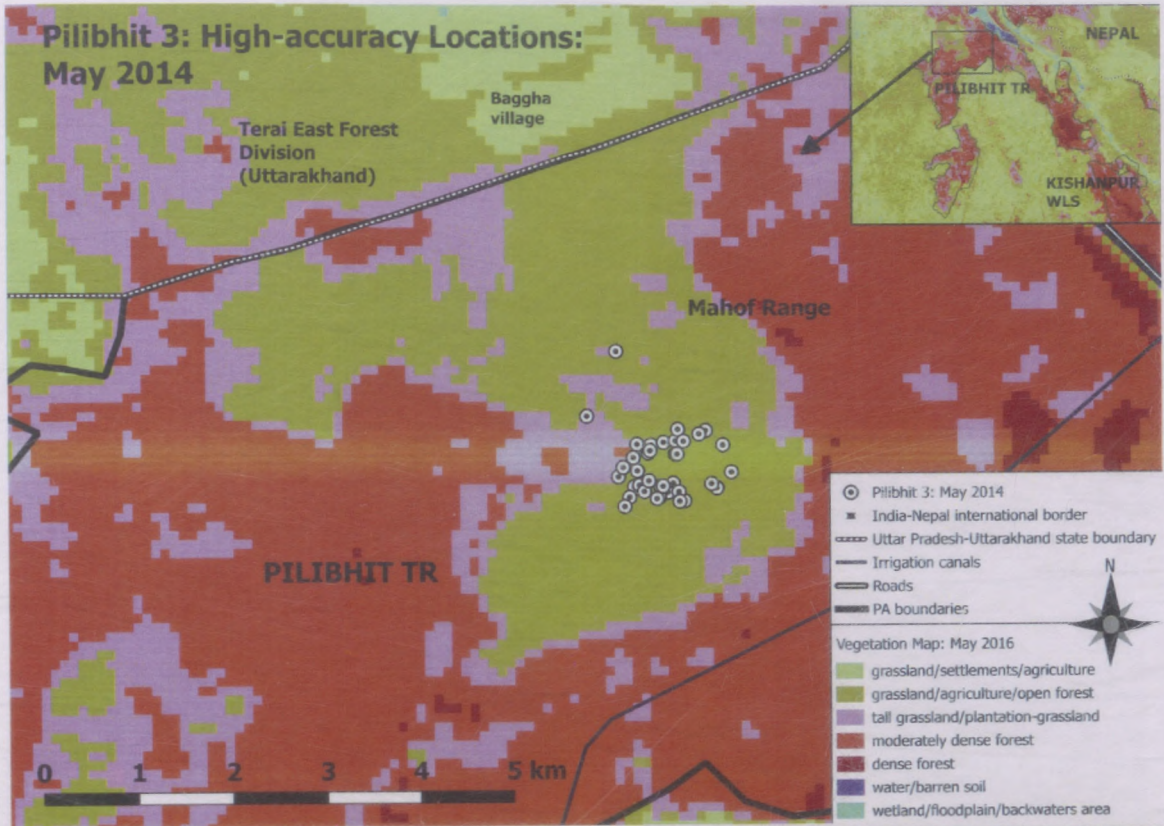


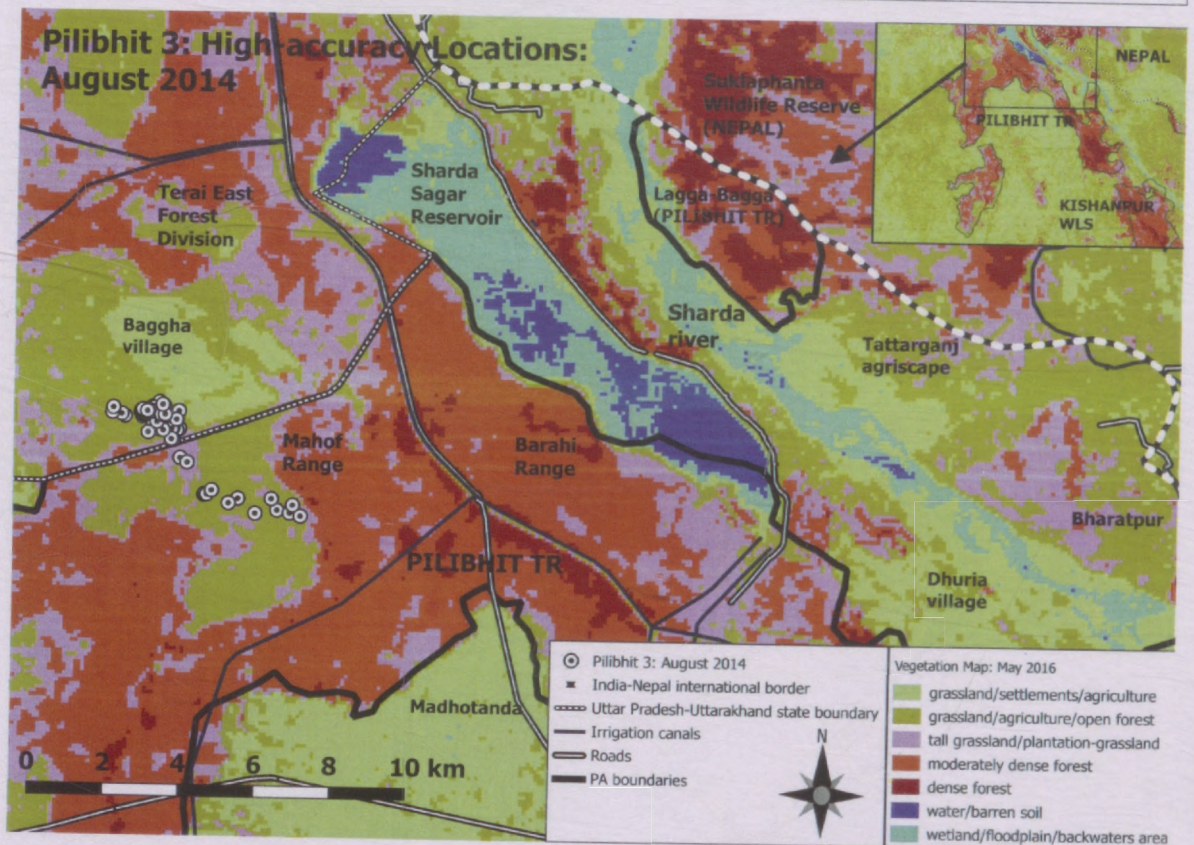
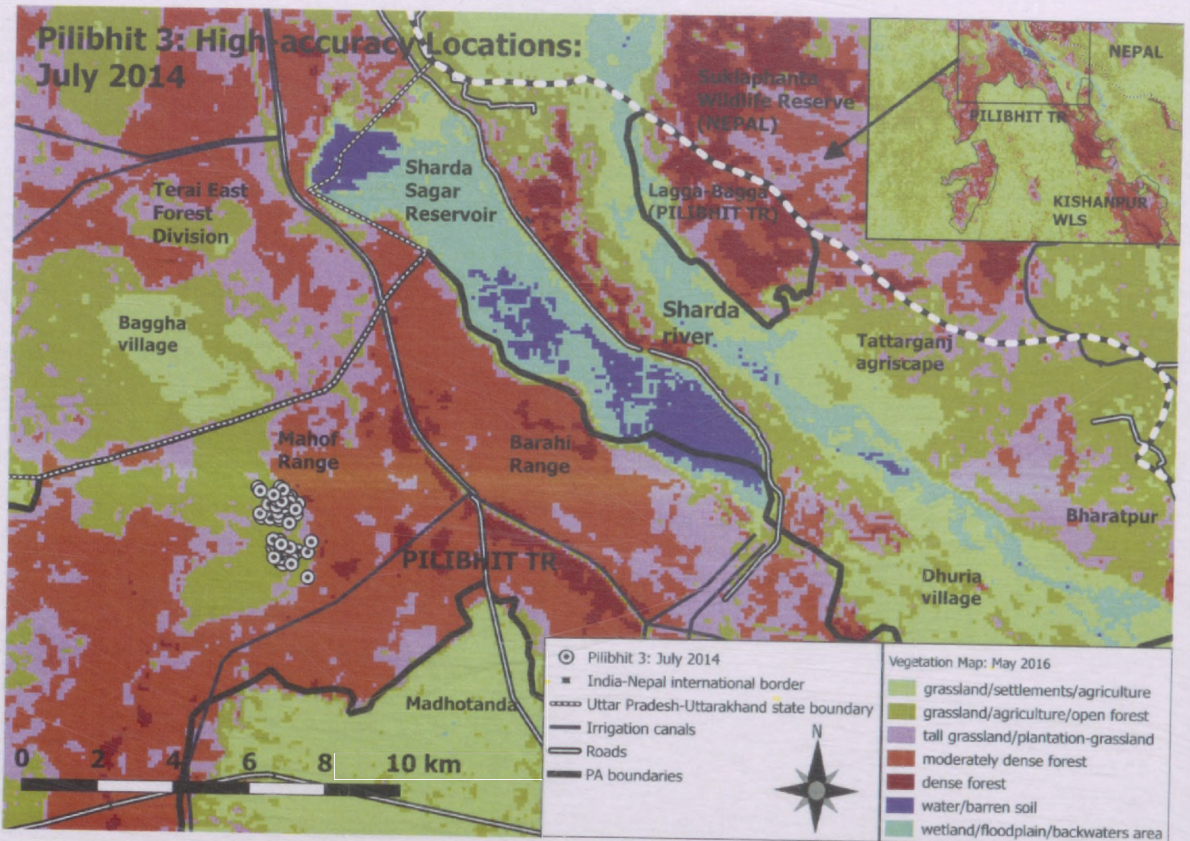


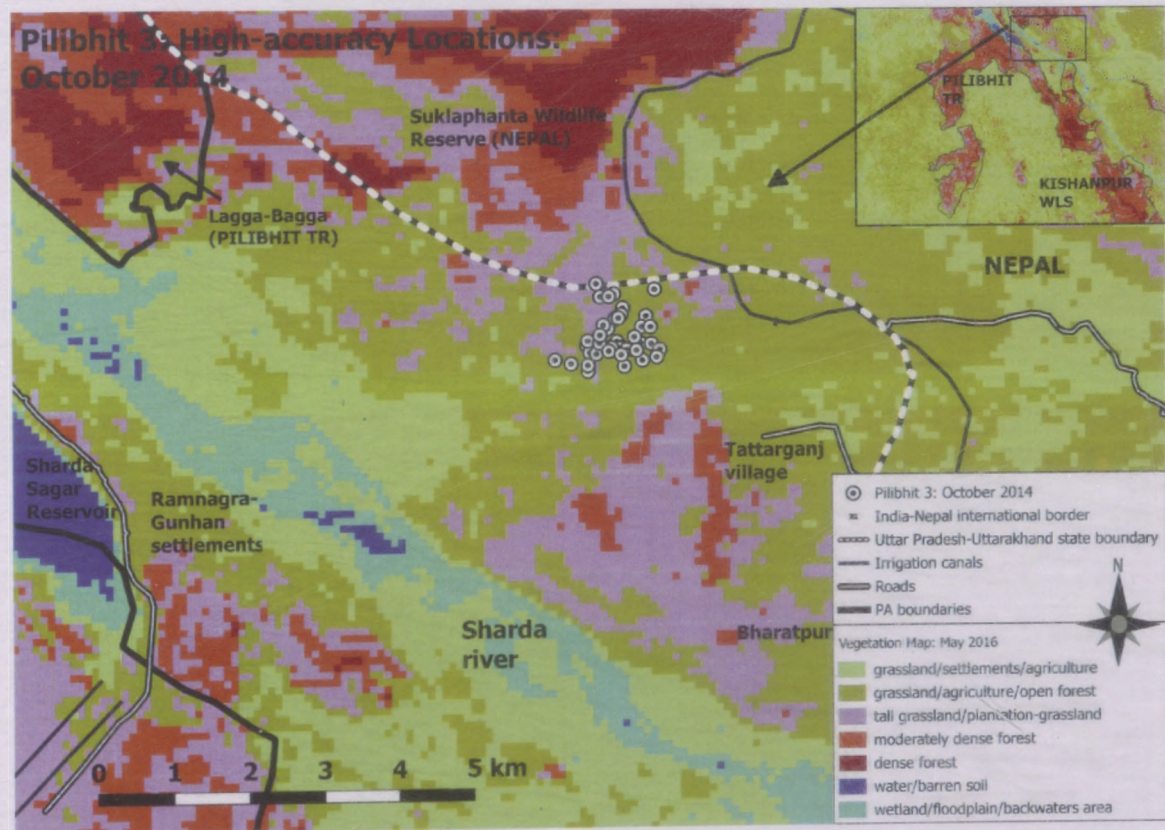
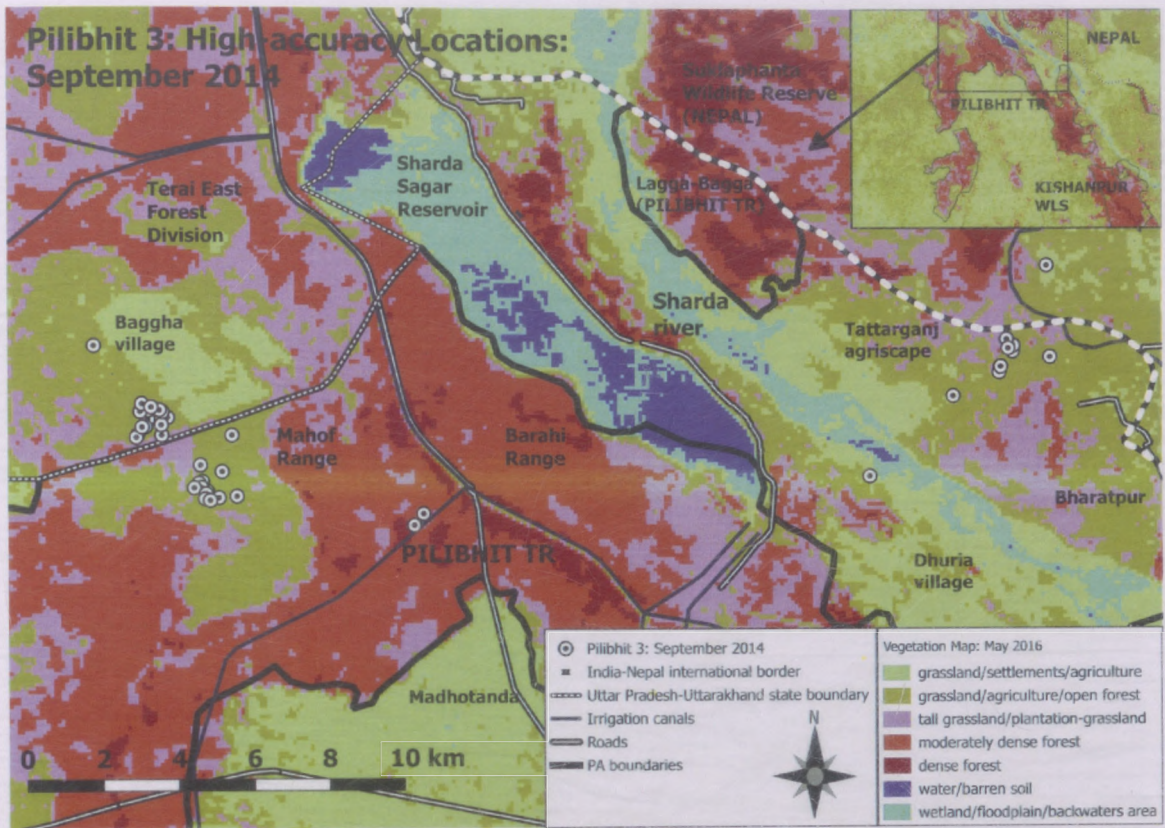


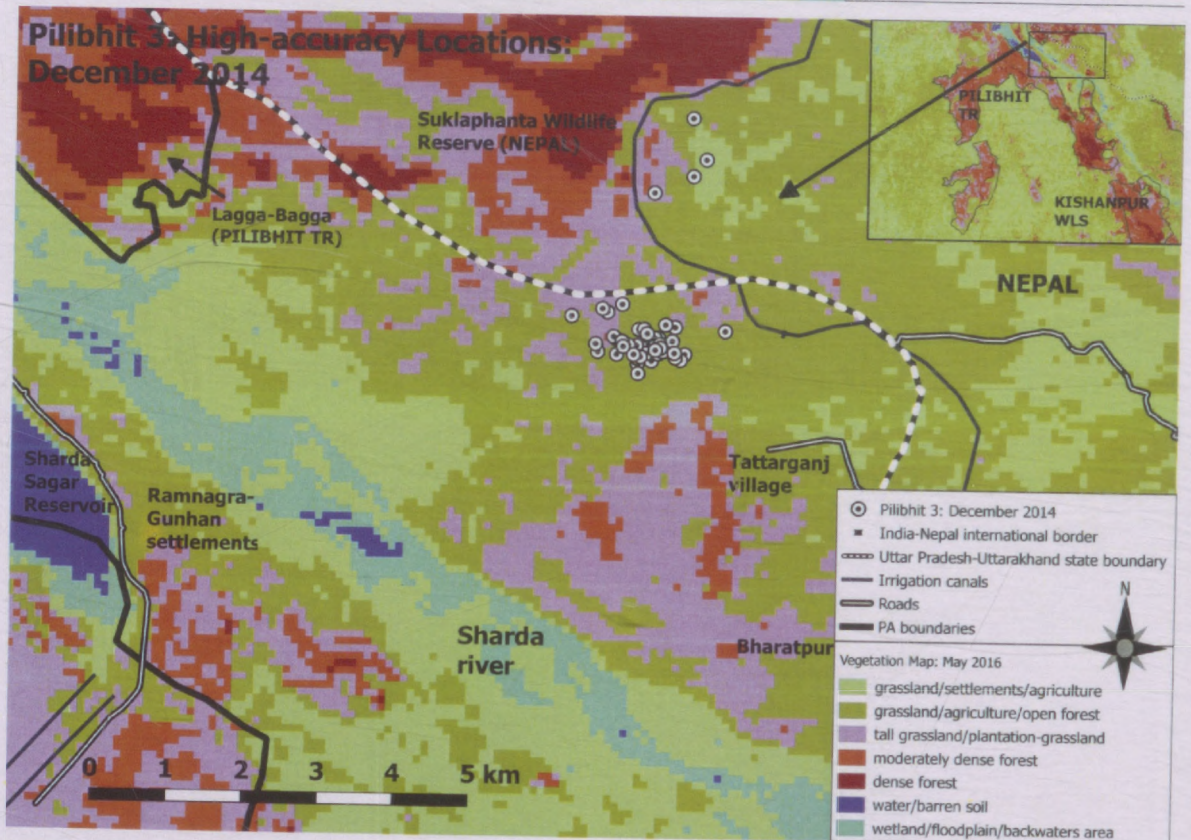
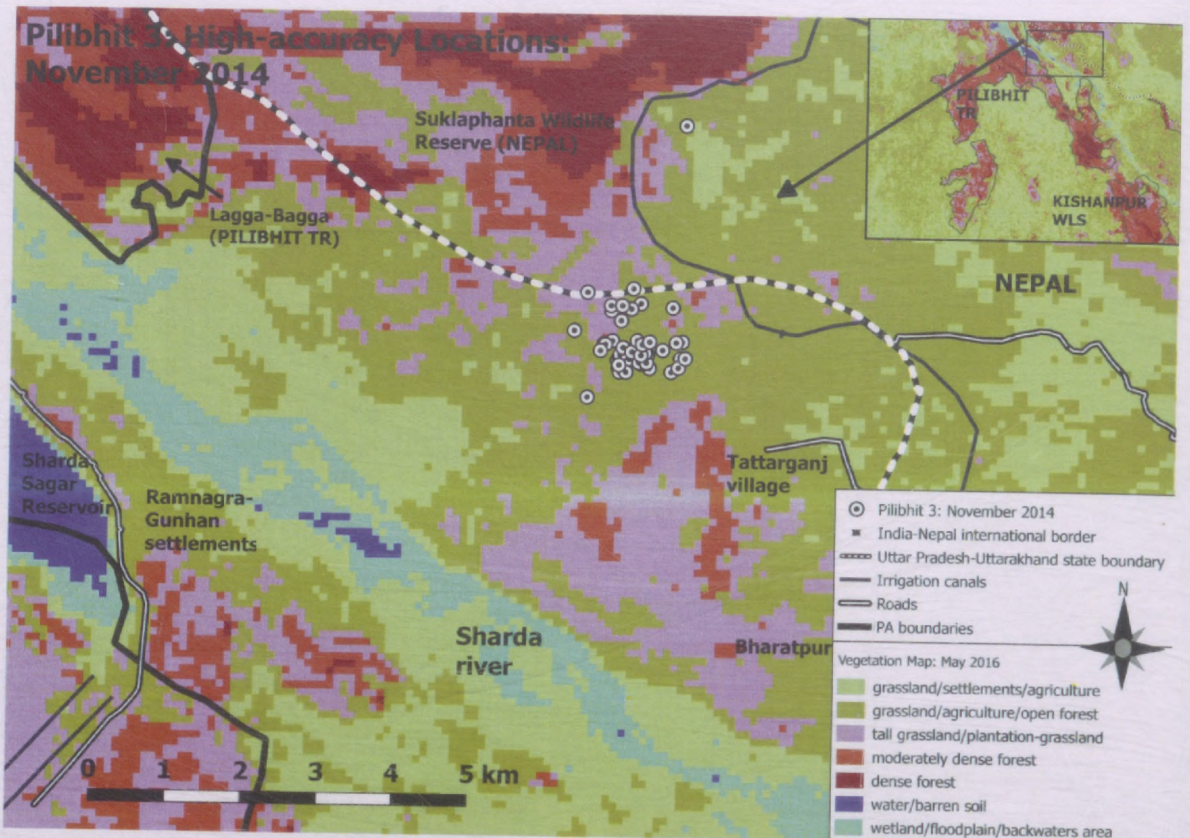


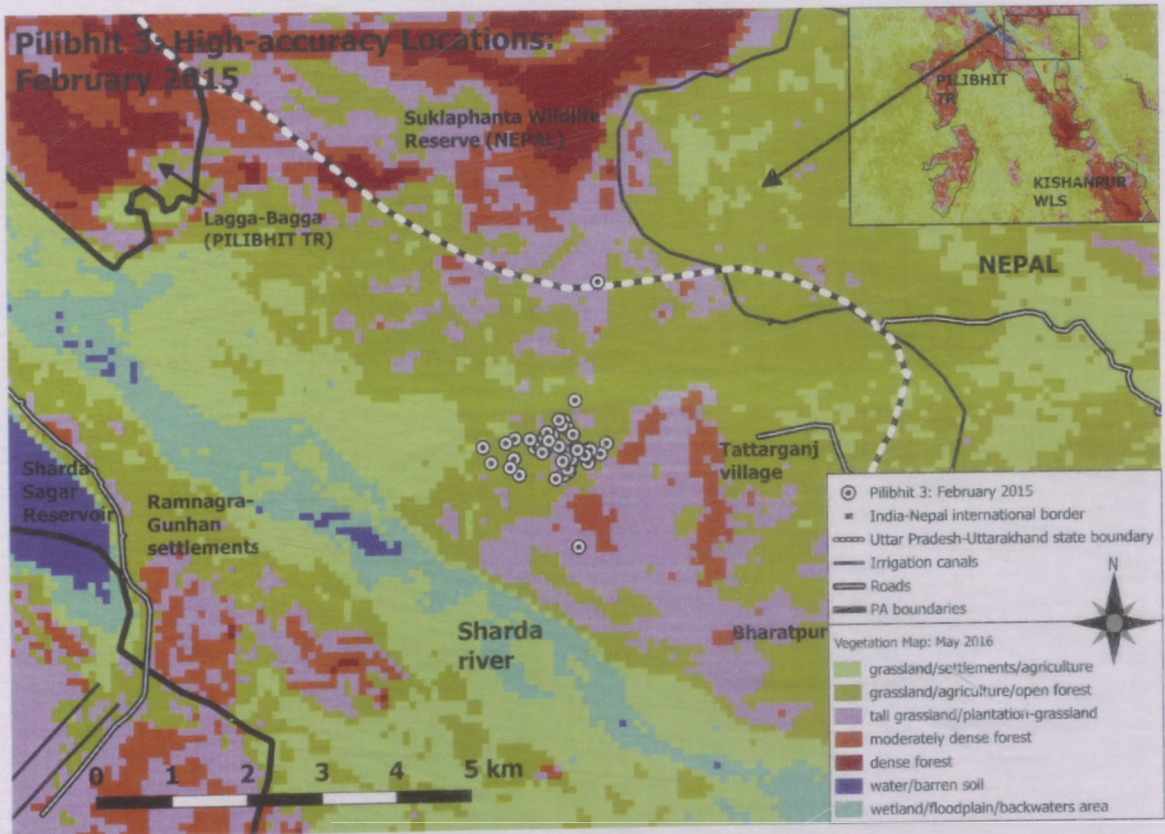
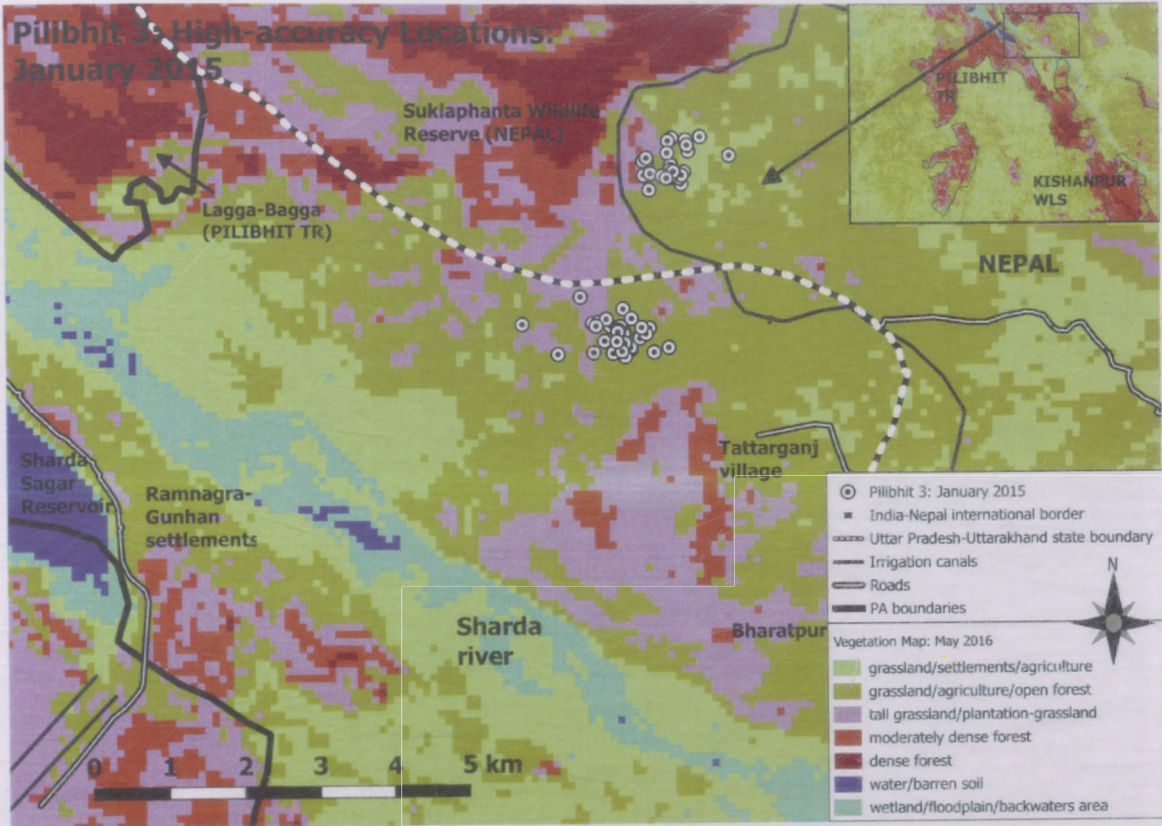
Month-wise movements of bird 'Pilibhit 3' derived from high-accuracy locations during May 2014 to December 2016

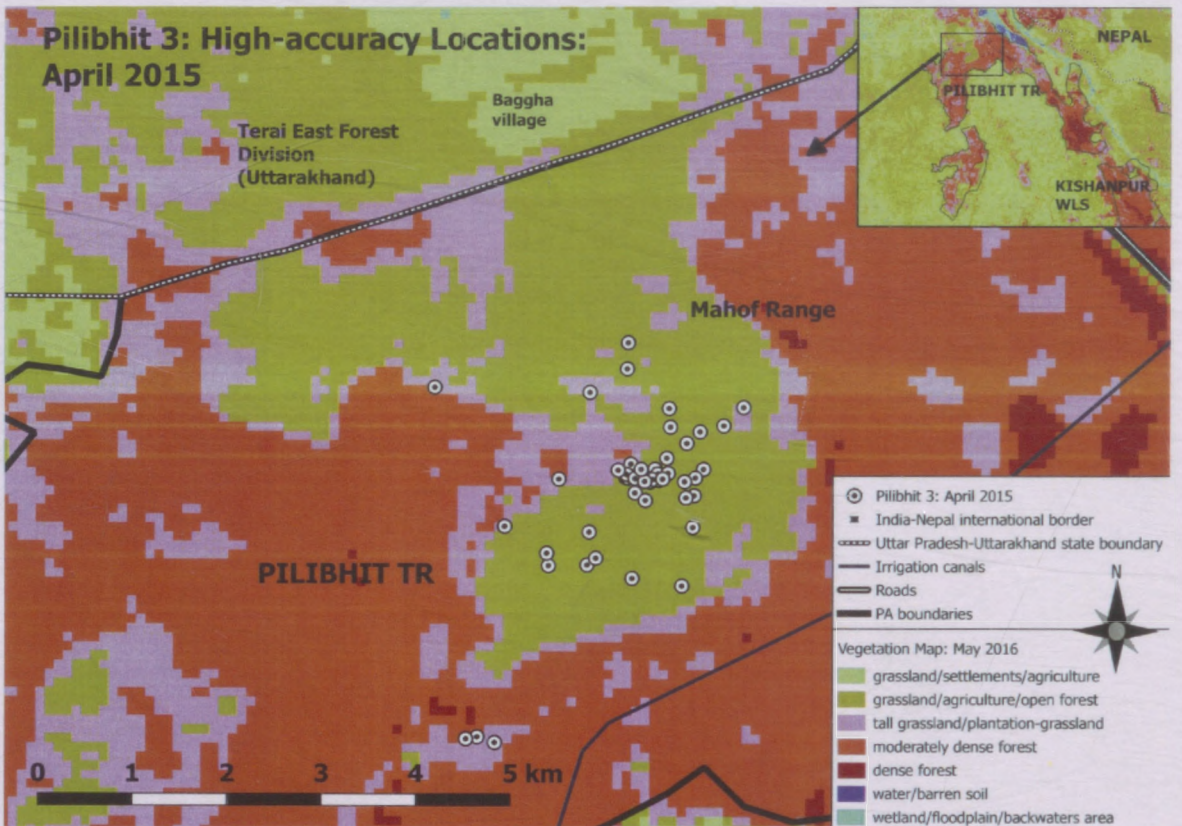
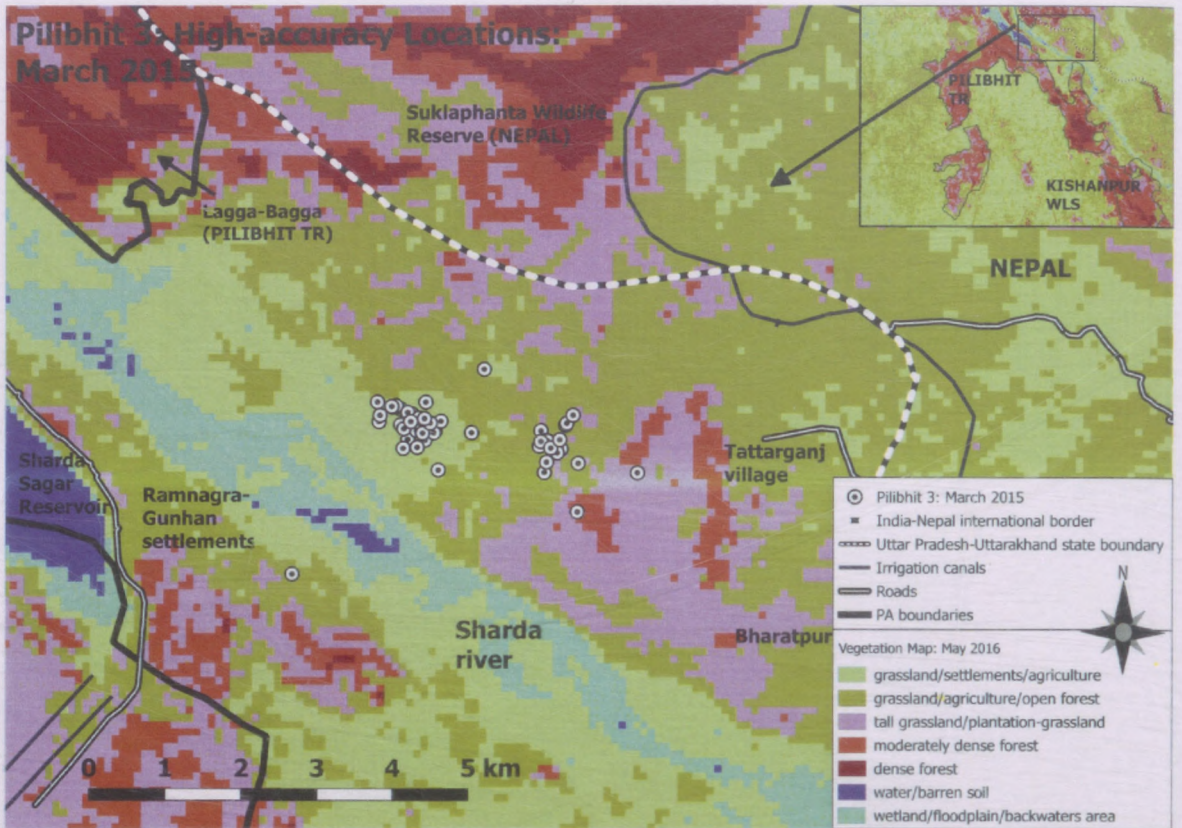


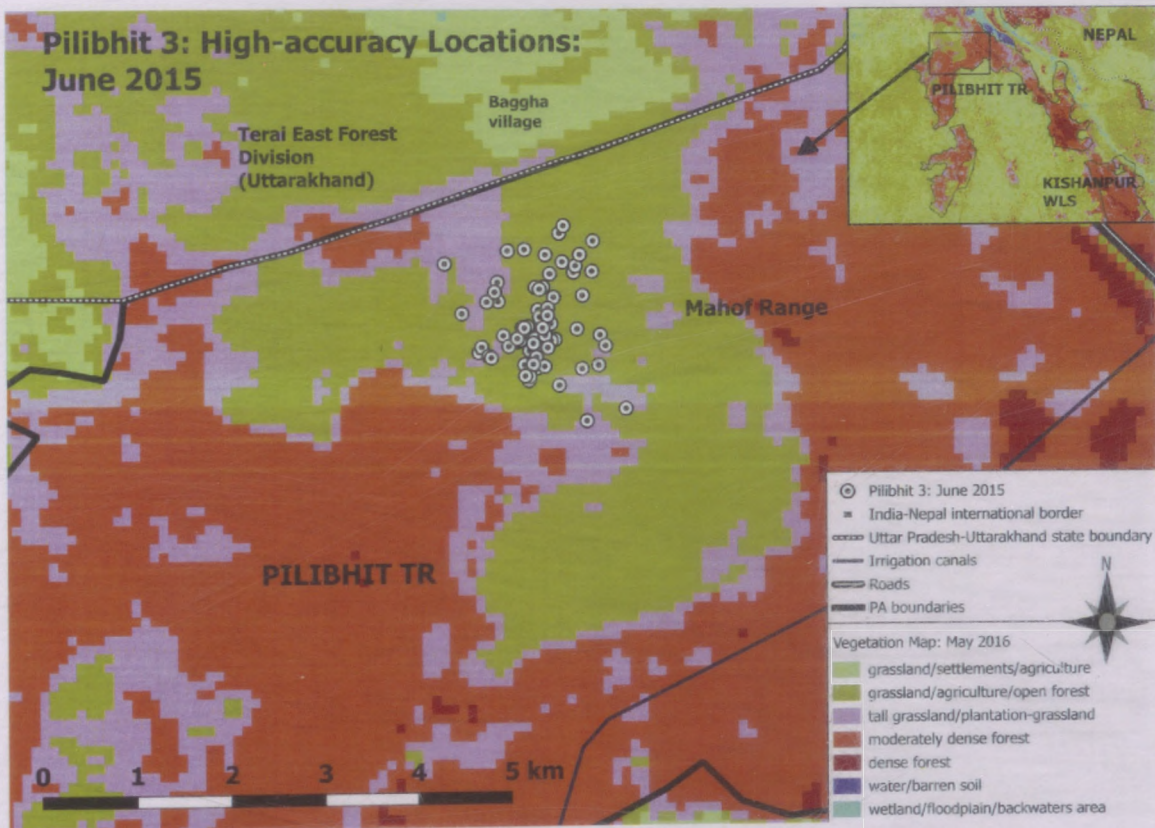
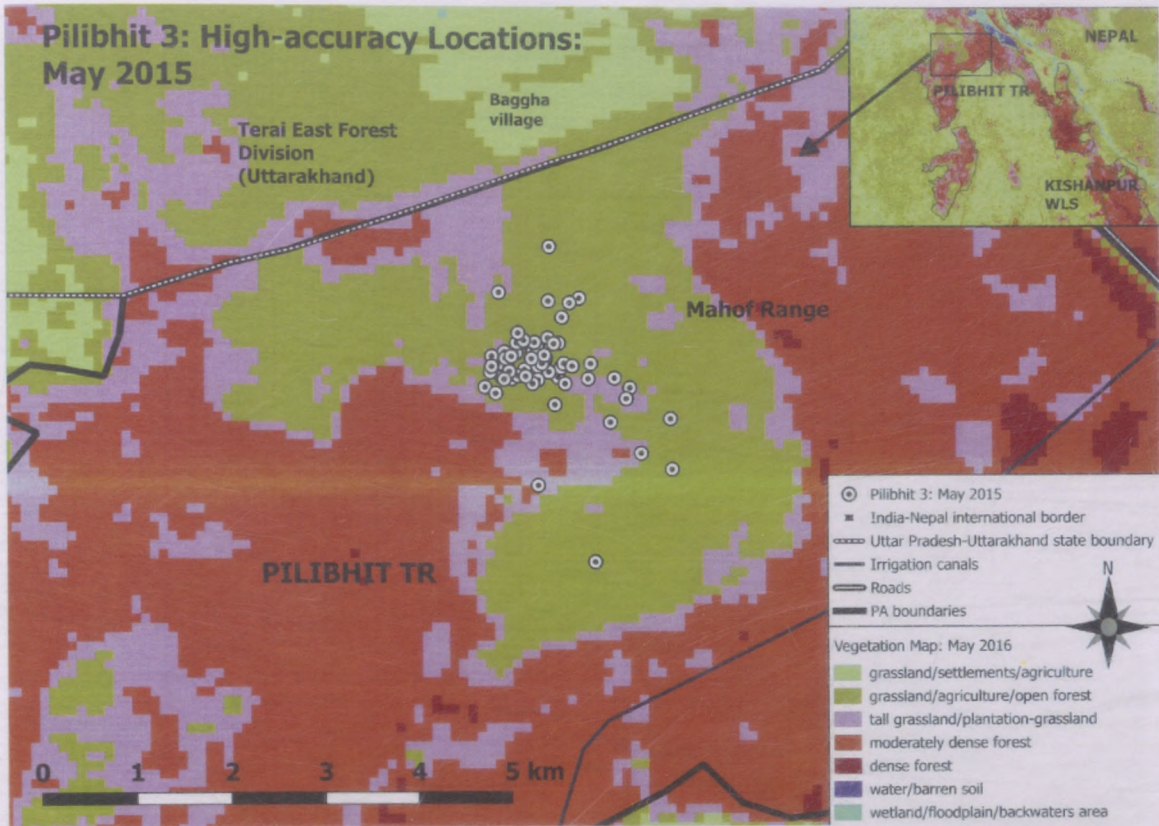


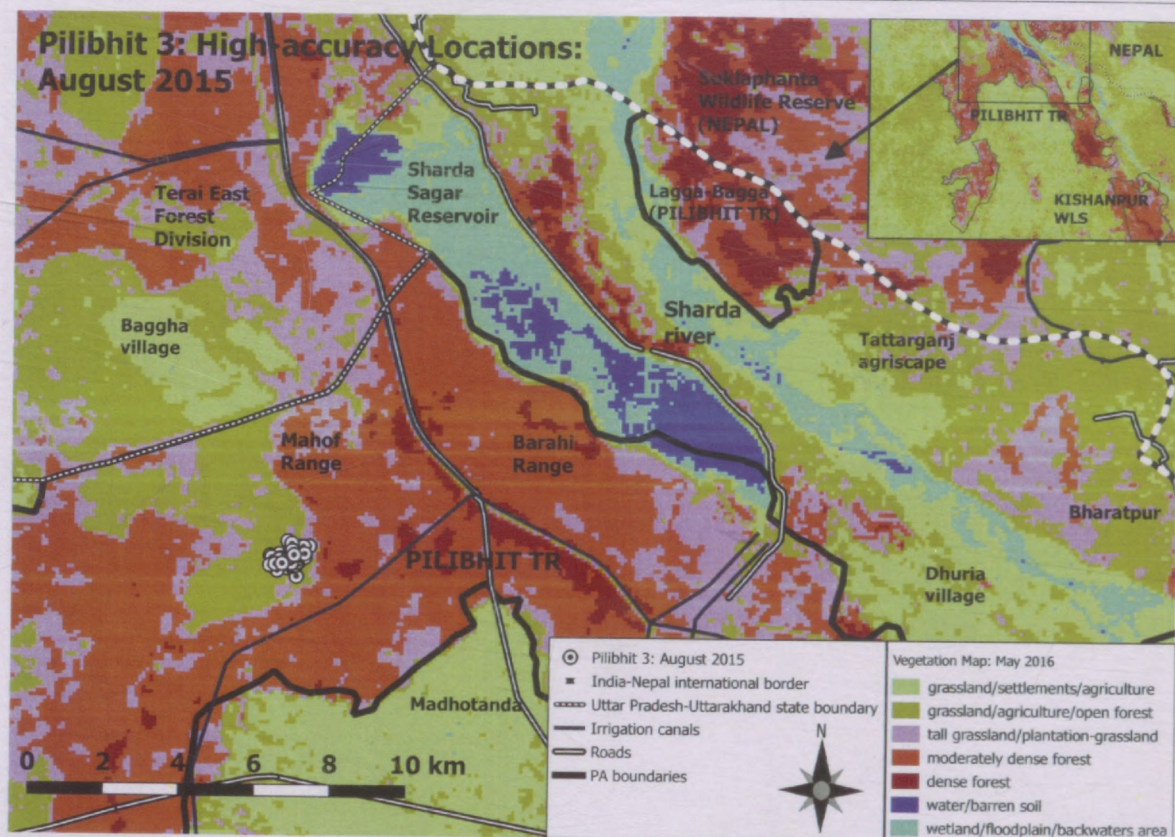
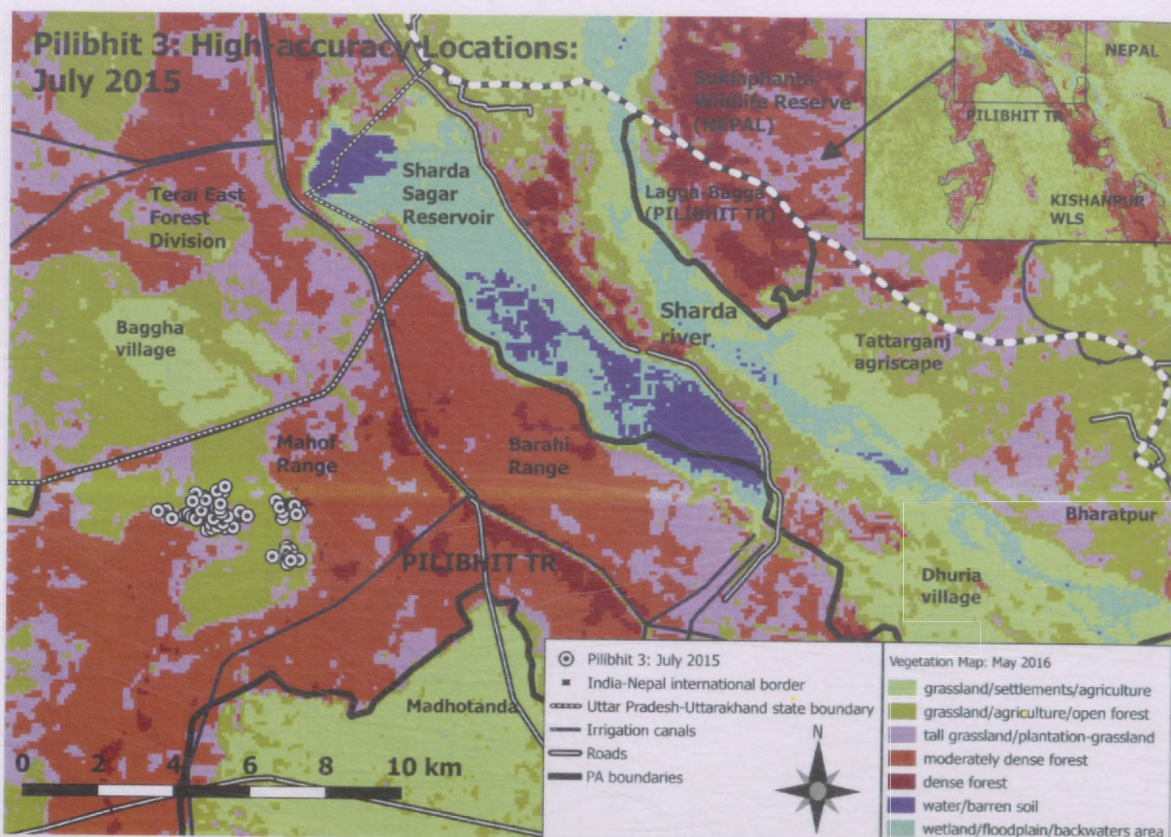


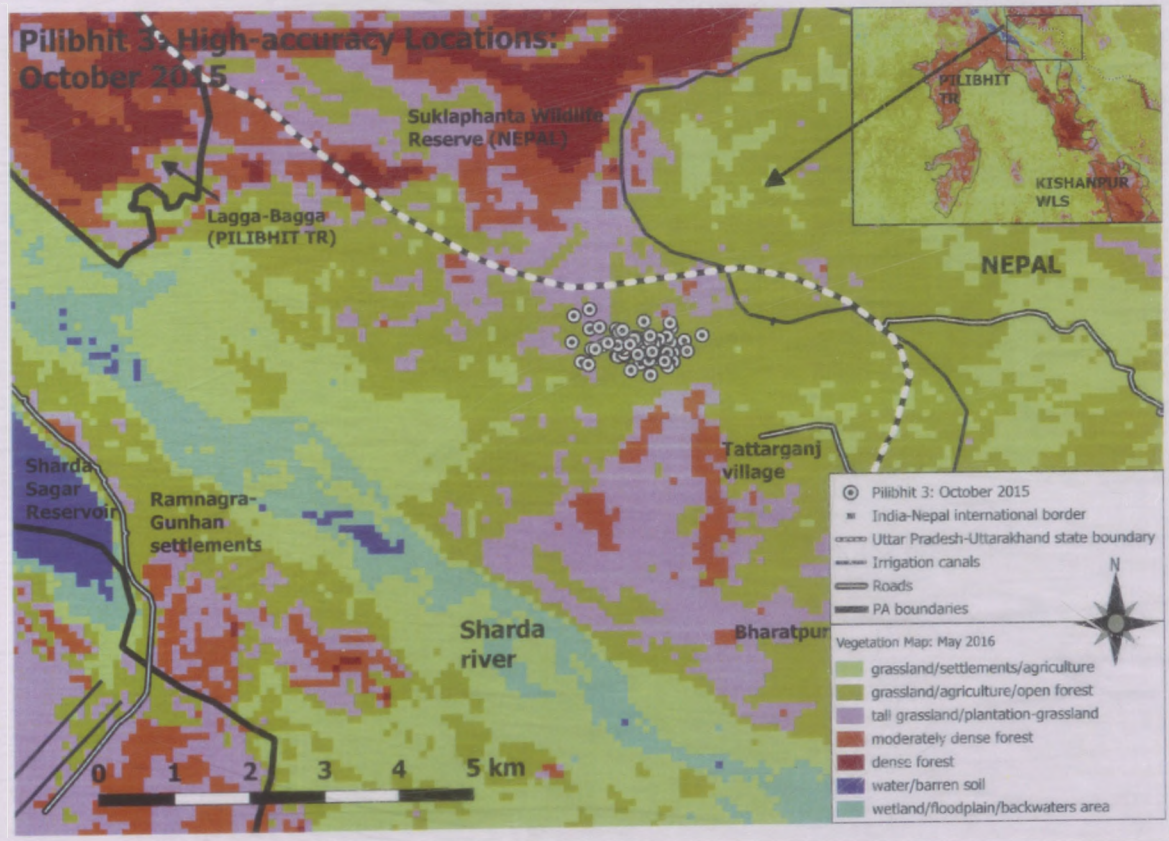
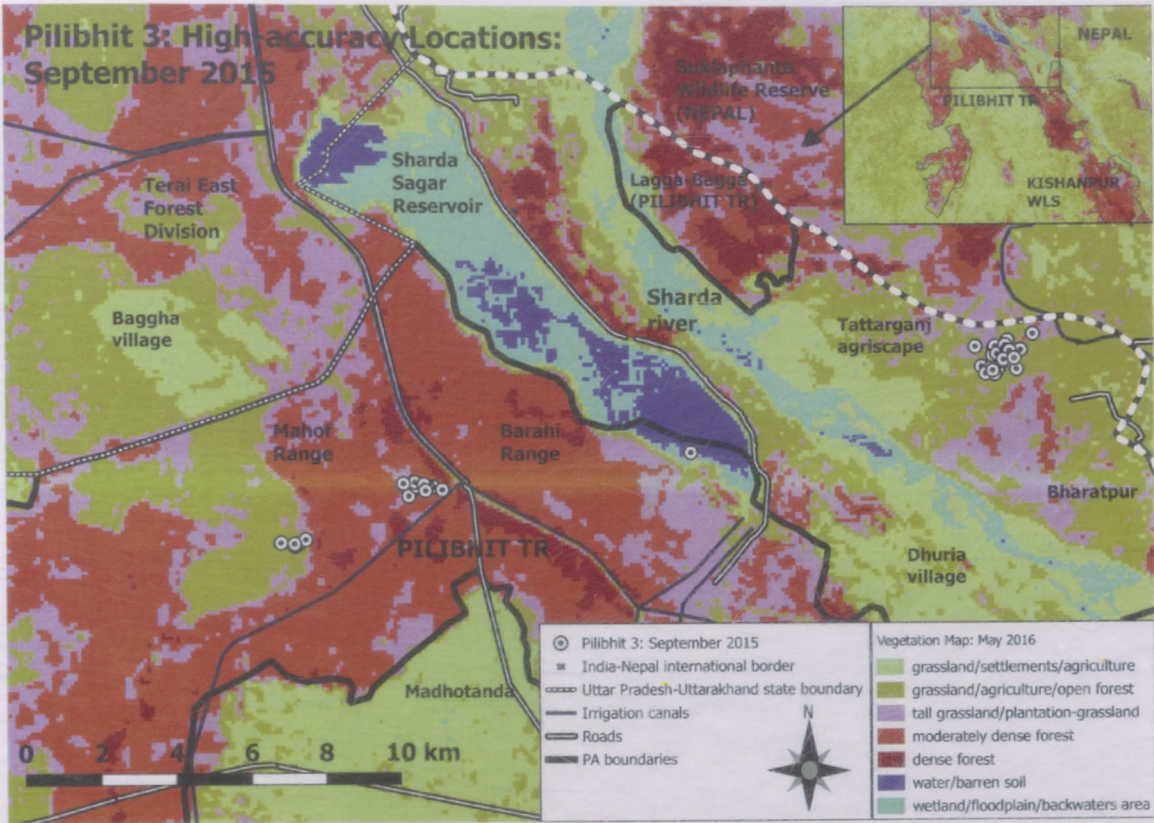


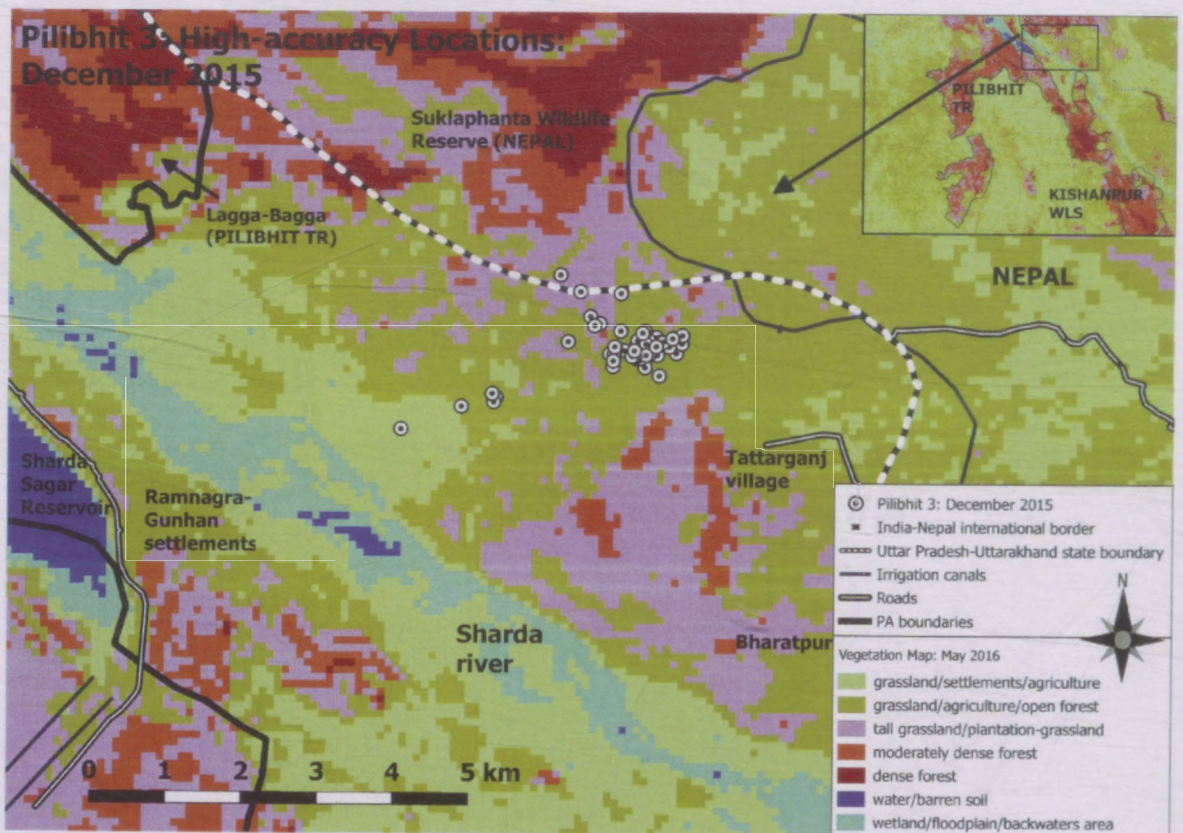
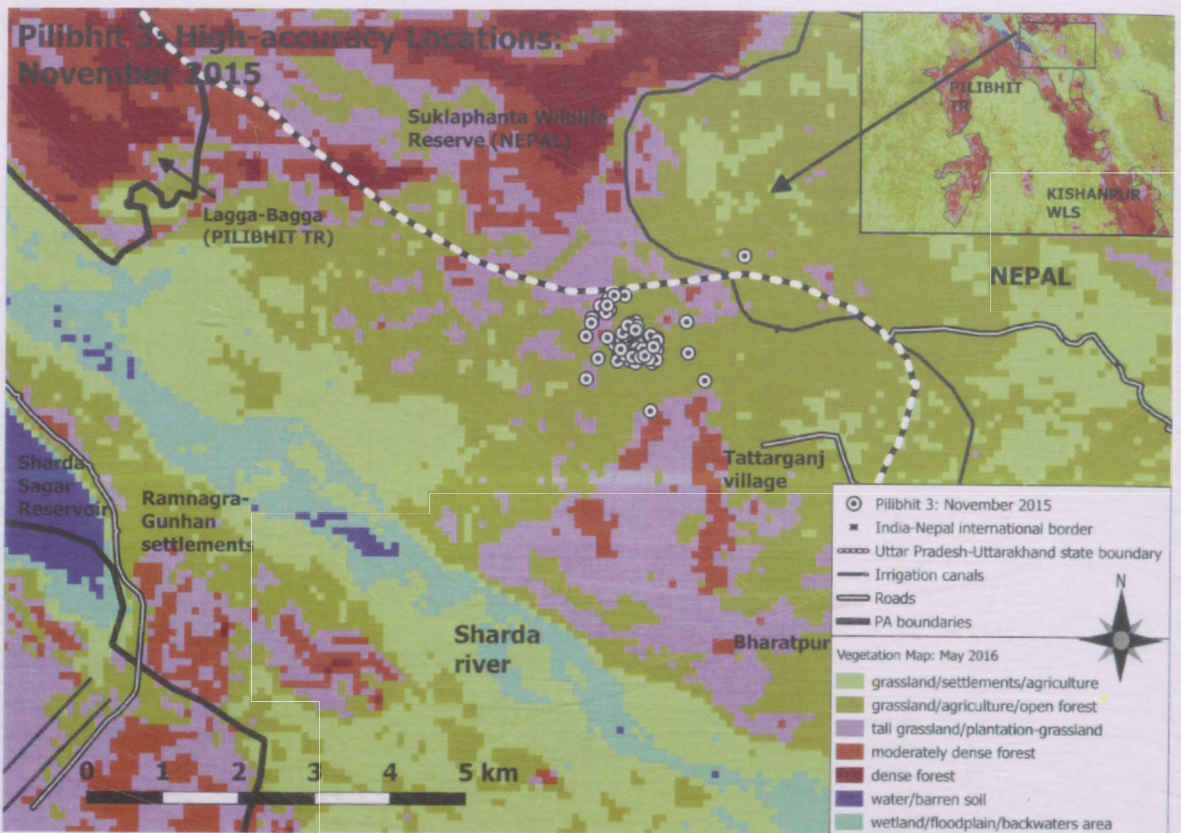


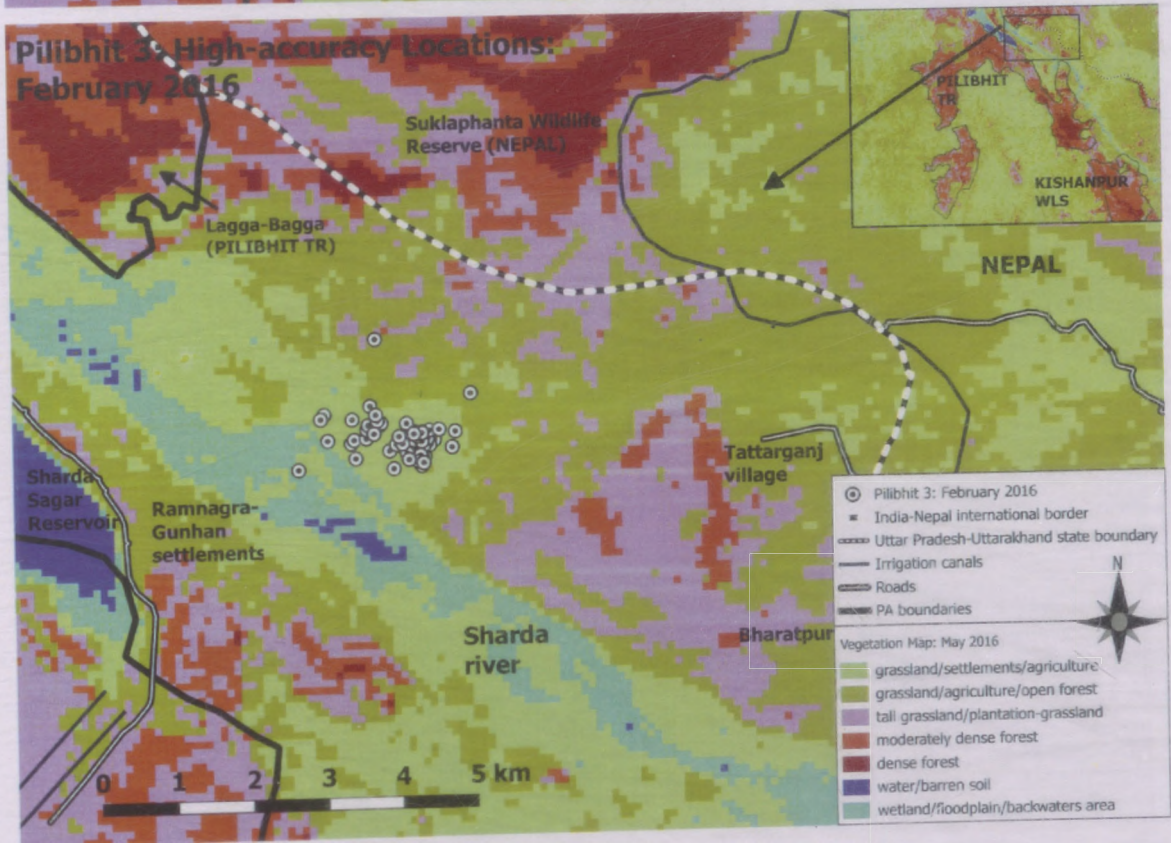
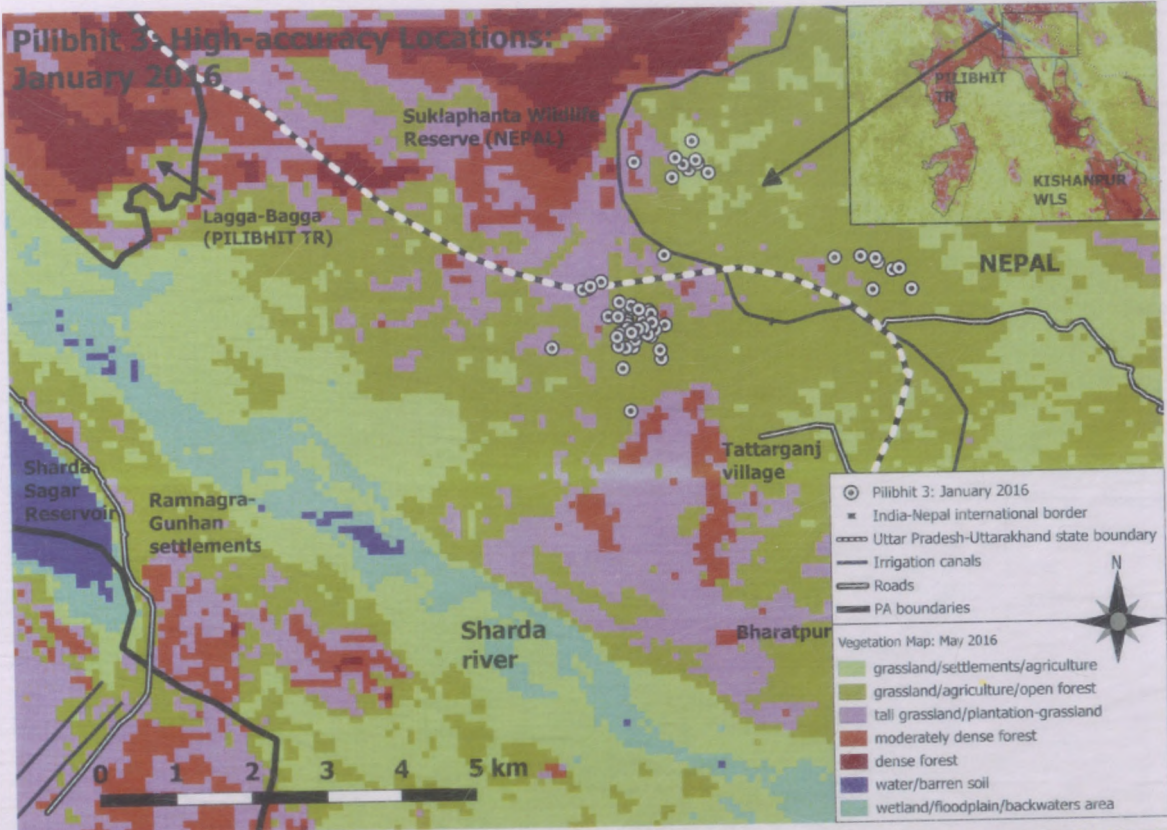


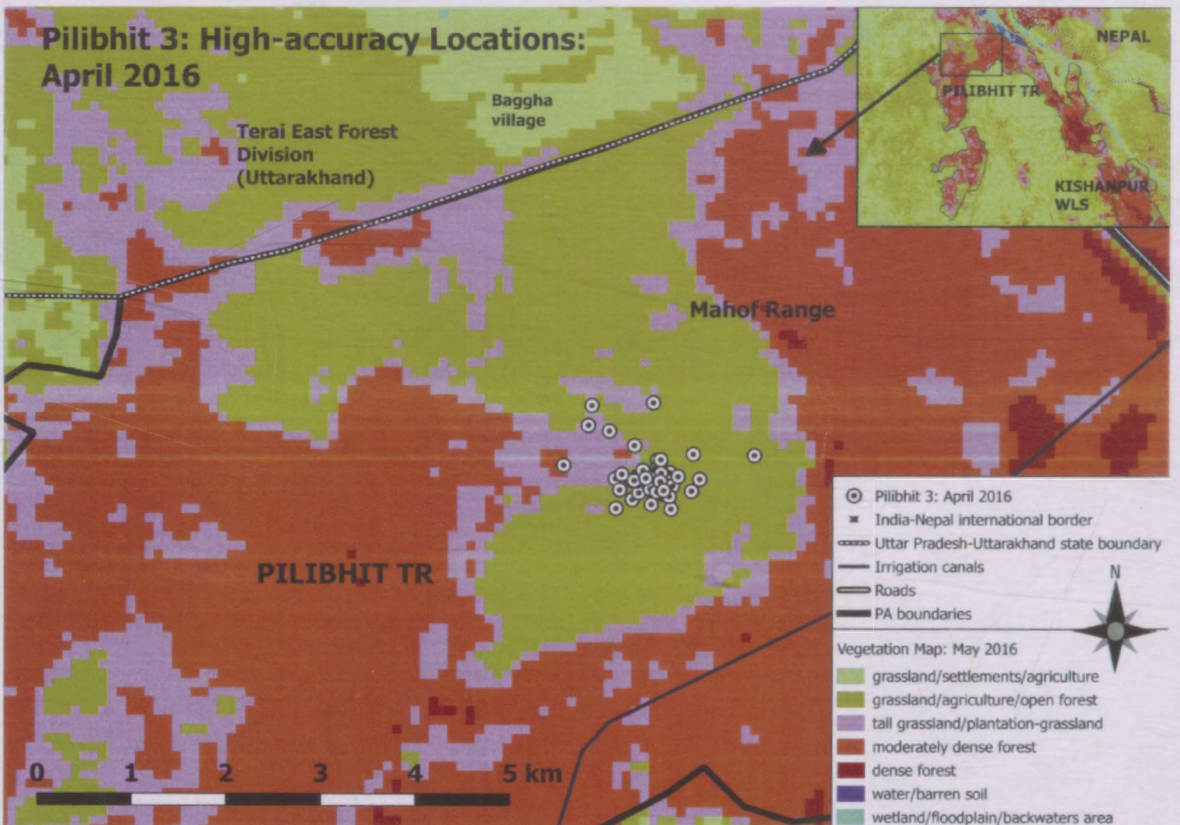
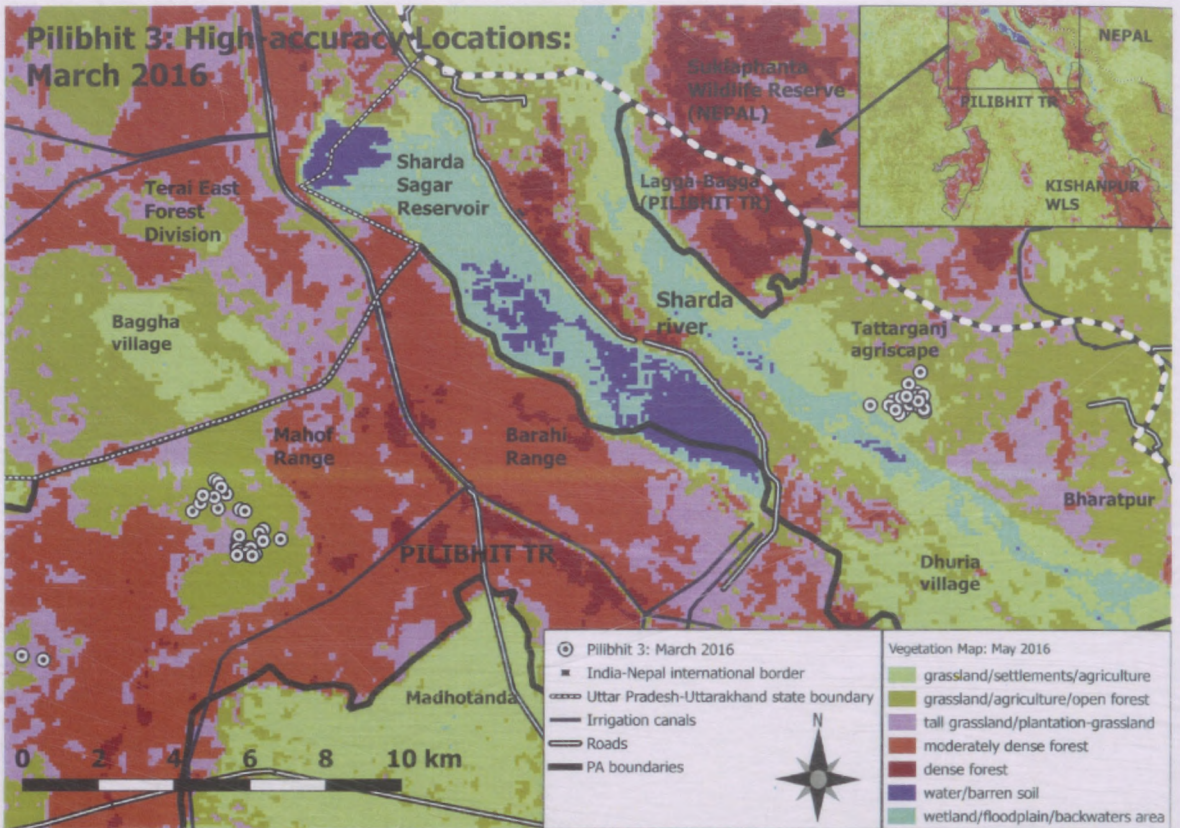


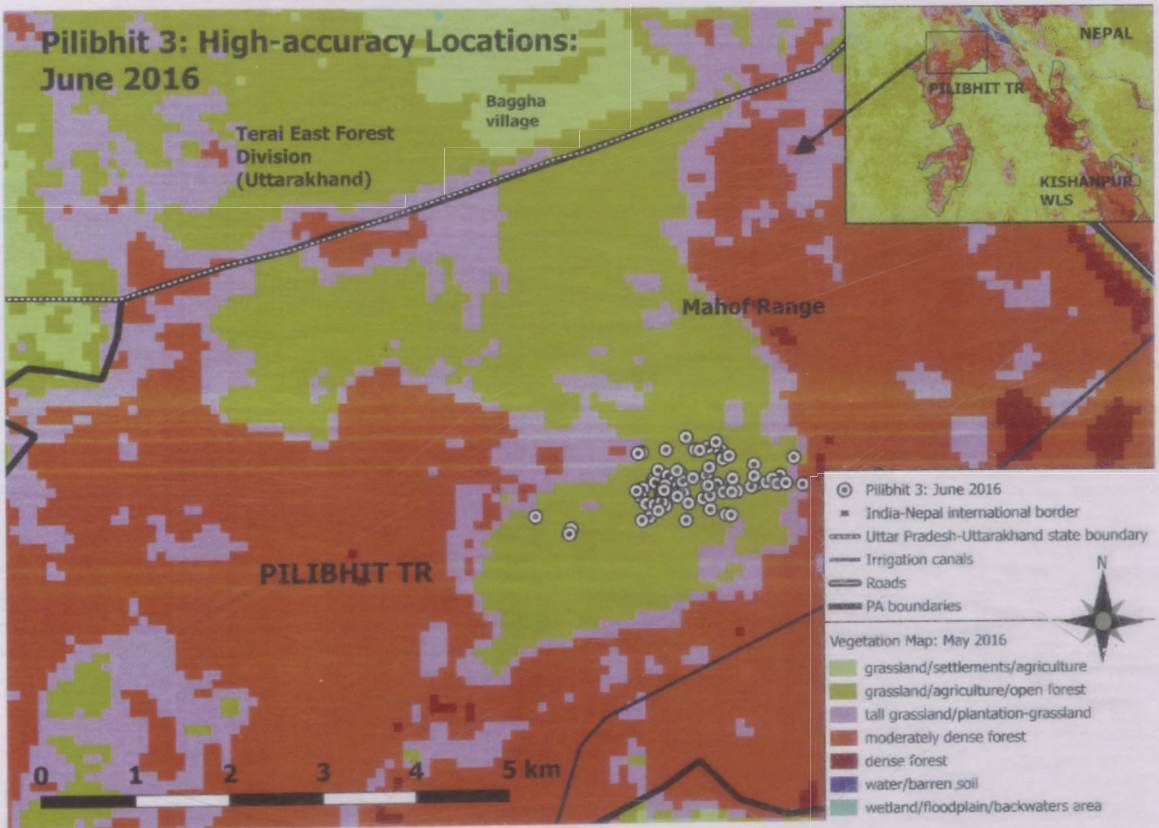
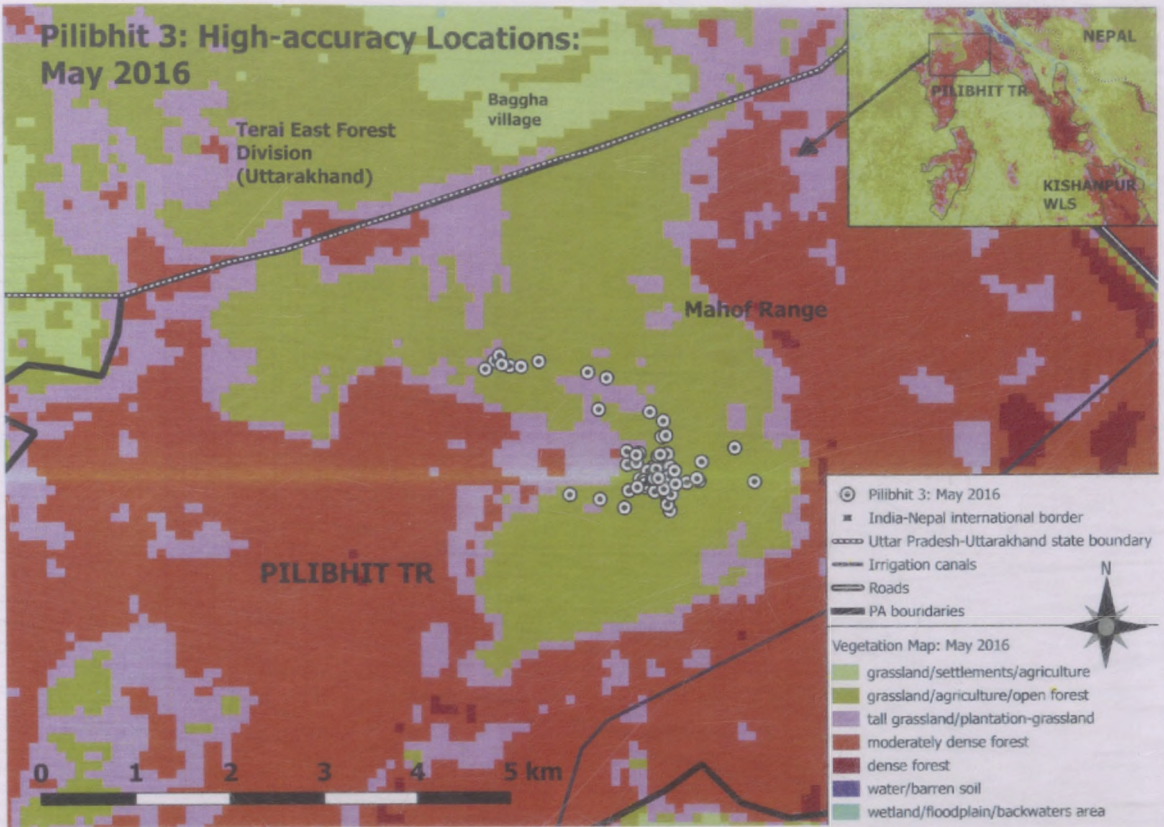


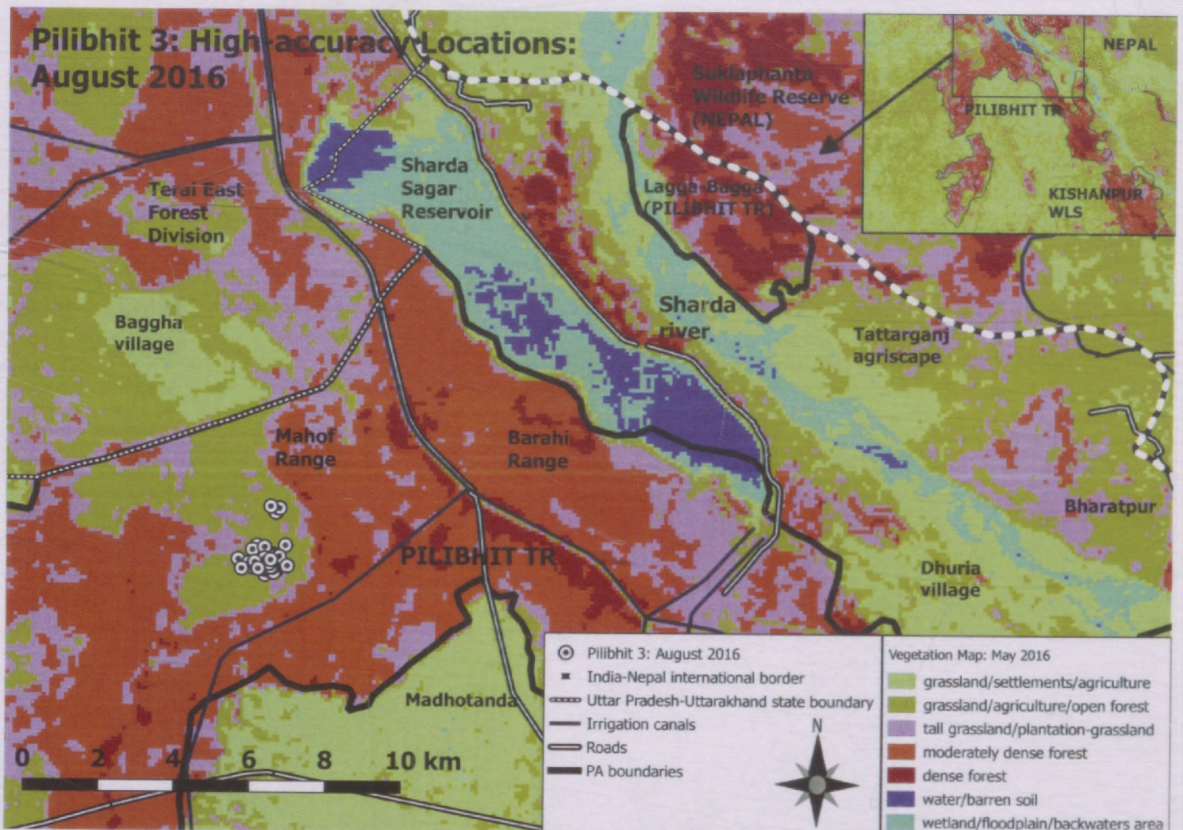
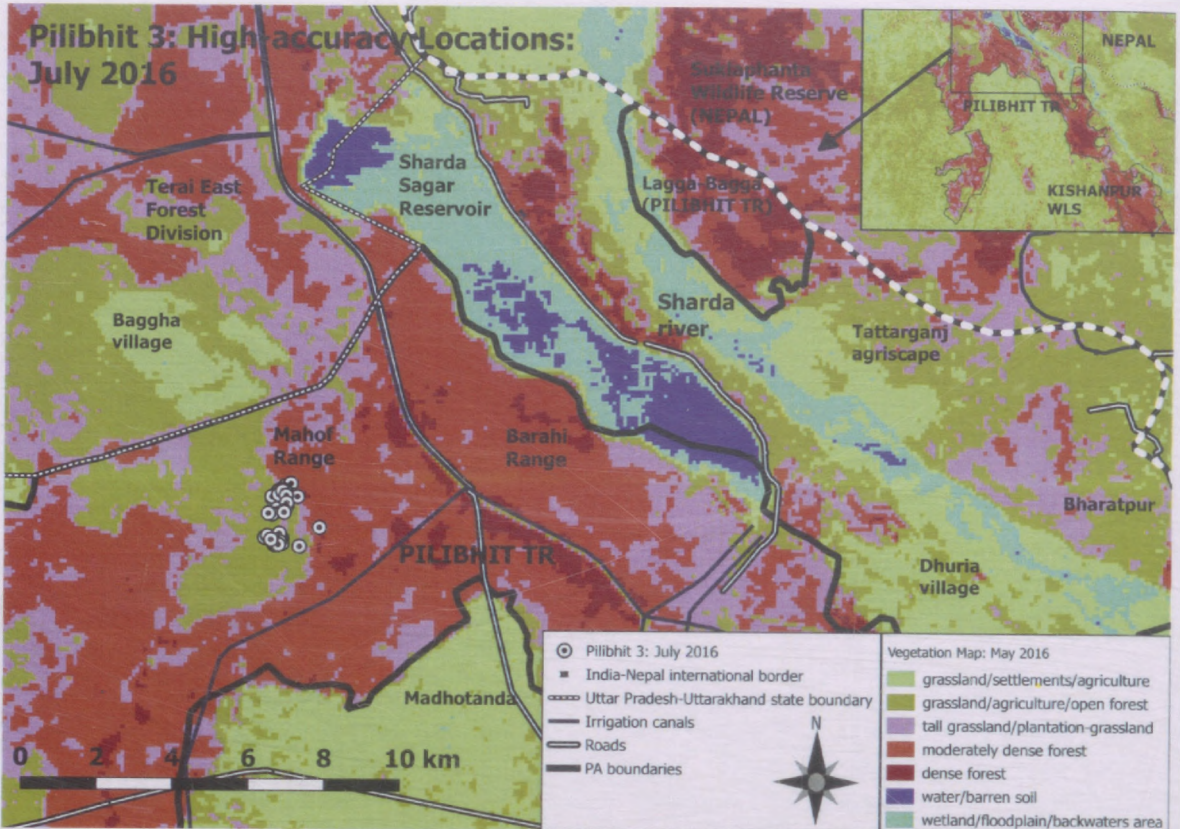


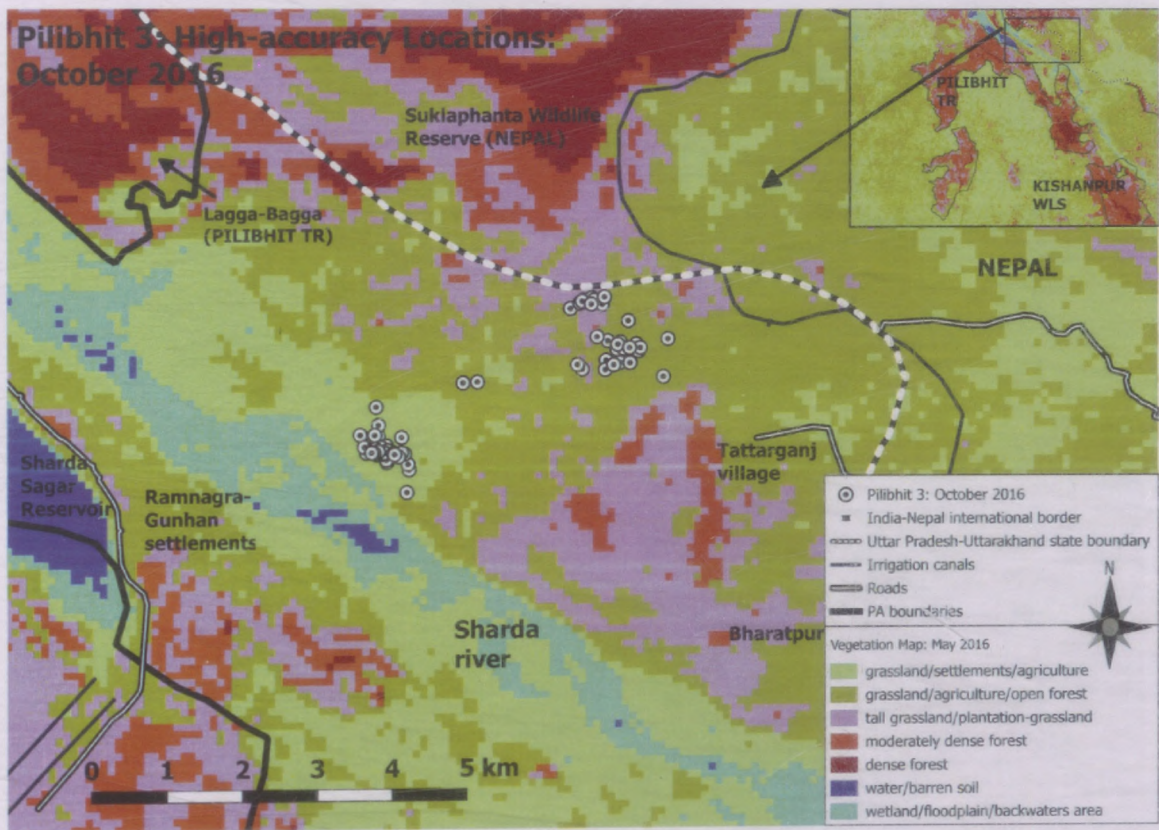
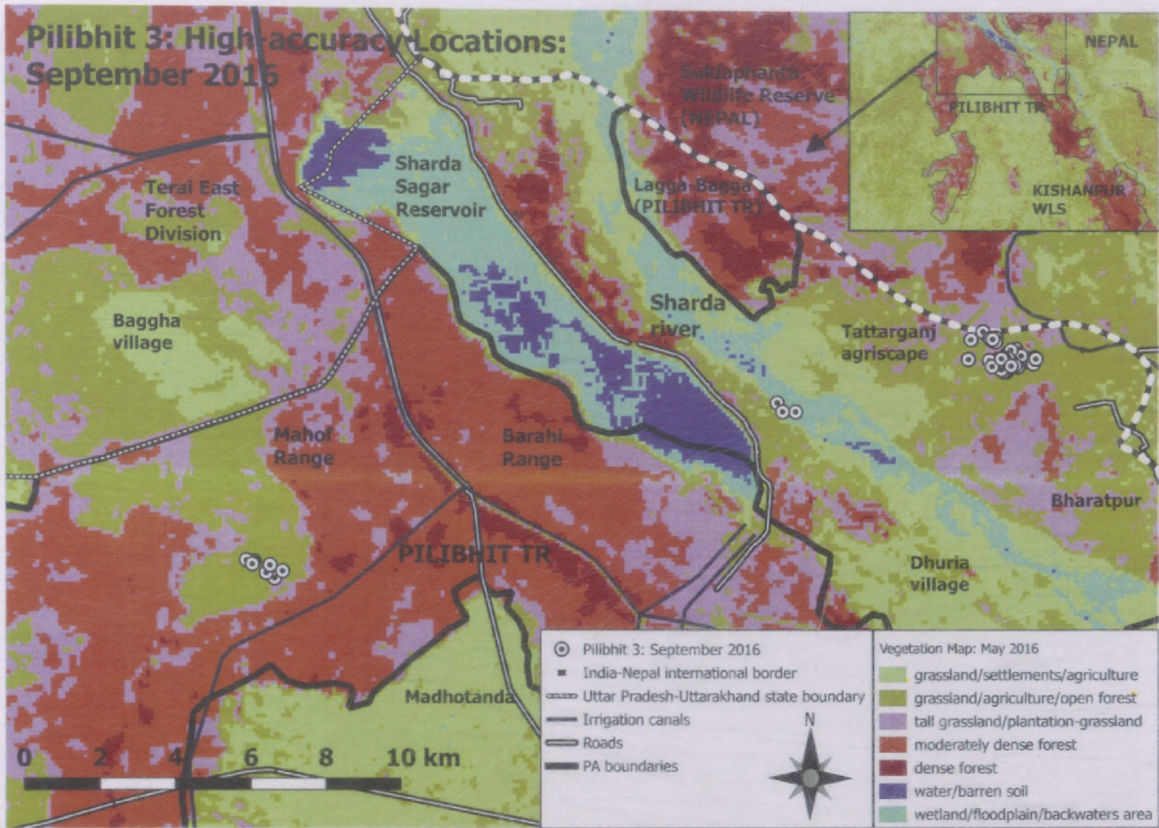


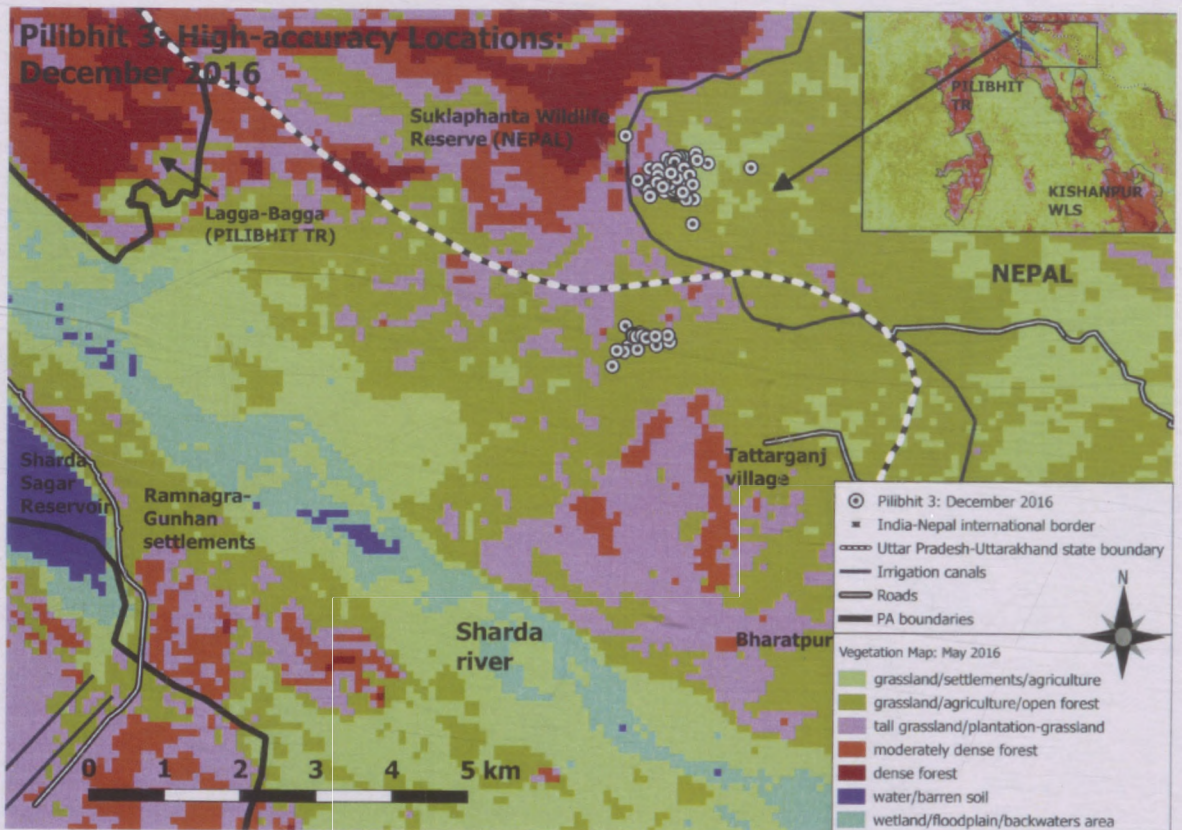
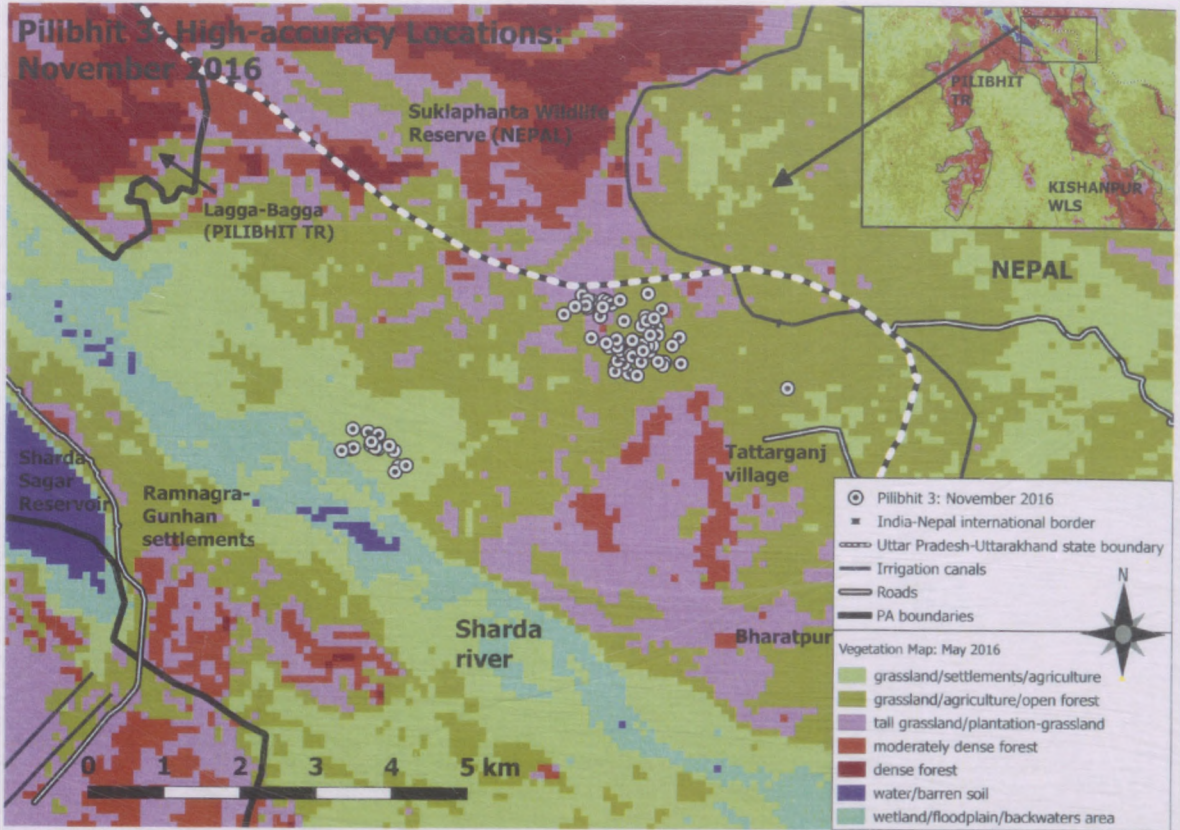












## APPENDIX II: Bengal Florican Detection Survey Proforma

### VISIT DETAILS (Bengal Florican observation surveys)

Observers		Date	Site / PA (write details)	
GPS N E	Point code	Wind None/Mild/Moderate/Strong	Cloud cover —/8	Air clarity Mist / Haze / Clear
Time start		Time end	Visit number 1          2          3	

#### Point information

Visibility (m)		Within 100m (Y/N)	
N	S	Grass cutting	Recent fire
NE	SW	People	Flooding
E	W	Vehicles	Other (e.g. raptors)
SE	NW	Grazing	
Vantage*:	Height:	Notes:	

\* whether observed from vehicle, *machaan*, tree or any other vantage point

#### Bengal Floricans seen

Bird #	Sex (M/F)	Activity when first seen <sup>1</sup>	All activities seen <sup>1</sup>	Distance from point (m)	Bearing (degrees from N)	Heard calling? (Y/N)
1						
2						
3						
4						
5						

<sup>1</sup> Display flight (D), Walking (W), Flying (F), Feeding (E), Other (O)

<b>Florican visibility on ground</b> Invisible when lands Head only Head and back Legs	<b>Notes / Any other important information</b>
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### APPENDIX III: Bengal Florican *Chapori* Survey Proforma

#### Visit Details (Bengal Florican surveys)

Observers/Surveyors:		Date:	Chapori name:	
			District:	
GPS N: E:	Chapori area (approx)	Soil: (Sandy/Loamy)	Cloud cover:  —/8	Air clarity: Mist / Haze / Clear
Time start:	Time end:		Visit number: 1            2	

Point information (place from where Bengal Florican presence/absence was being determined):

Visibility (metres)		Within 200m radius	
N:	S:	Grass cutting:	Grass burning:
E:	W:	People:	Flooding:
Vantage*:	Height:	Vehicles:	Other (e.g. raptors)
Average vegetation height (estimate visually): 0-0.75 metre 0.75-1.5 metre 1.5+ metre	Species :	Grazing Number of livestock (locals' report): Number of livestock seen: Number of <i>khuttis</i> :	Trees 0-2 metres: 2-5 metres: 5 metres and above:
Vegetation density: (dense, medium, sparse)	Proportion of tall grass patch:	Remarks/Notes:	

\* whether observed from *machaan*, tree or any other vantage point

#### Bengal Floricans Observation:

Bird #	Time	Sex (M/F)	Activity when first seen <sup>1</sup>	All activities seen <sup>1</sup>	Distance from point (m)	Bearing (degrees from N)	Heard calling? (Y/N)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							

<sup>1</sup> Display flight (D), Walking (W), Flying (F), Feeding (E), Other (O)



LILADHAR (SONU)



Female Bengal Florican

### **BNHS Mission**

**Conservation of nature, primarily biological  
diversity through action based on research,  
education and public awareness.**



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