MAPPING
LANDUSE/LANDCOVER PATTERNS IN
ARAVALLIS
HARYANA WITH REFERENCE TO STATUS OF KEY WILDLIFE SPECIES

MAY 2017

Further Contact:

Dr. Bilal Habib
Department of Animal Ecology & Conservation Biology
Wildlife Institute of India, Chandrabani
Dehradun, India 248 001
Tell: 00 91 135 2646283
Fax: 00 91 135 2640117
E-mail; bh@wii.gov.in

Cover Photograph: *John Pheasant*
Design & Layout: *Bilal Habib*

Citation: *Habib, B., Talukdar G., Jain, P. and Bhasin A. (2017): Mapping landuse/landcover patterns in Aravallis Haryana with special reference to key wildlife species. Project Completion Report. Wildlife Institute of India, Dehradun and Haryana Forest Department. Pp 97.*

Project Completion Report

MAPPING LANDUSE/LANDCOVER PATTERNS IN ARAVALLIS HARYANA WITH REFERENCE TO STATUS OF KEY WILDLIFE SPECIES

Principal Investigators
Dr. Bilal Habib
Dr. Gautam Talukdar

Advisors
Dr. Amarinder Kaur, PCCF/MD, HFDC
Dr. P. P. Bhojvaid, PCCF Haryana
Mr. G. K. Ahuja, PCCF (Wildlife) Haryana
Mr. M. D. Sinha, CF (South), Gurgaon
Dr. V. B. Mathur, Director, WII
Dr. G. S. Rawat, Dean WII

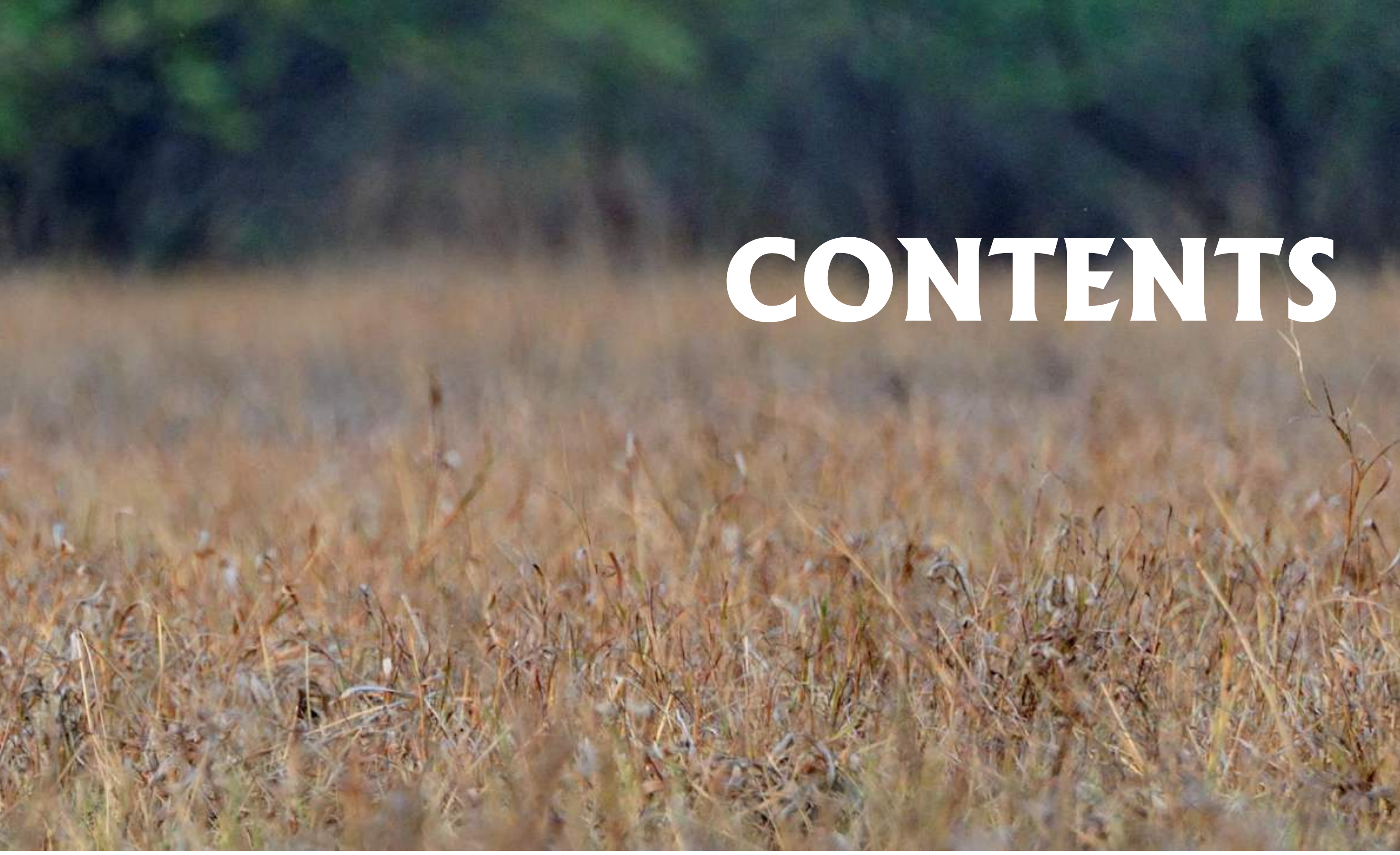
Researchers
Paridhi Jain
Anchal Bhasin

May, 2017

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

MAPPING

LANDUSE/LANDCOVER PATTERNS IN ARAVALLIS, HARYANA WITH REFERENCE TO STATUS OF KEY WILDLIFE SPECIES



📷Hari Somashekhar

CONTENTS

Executive Summary

The oldest mountain range on earth, Aravallis hills of India, are the prominent landforms shaping the west-Indian climate and biodiversity. Aravallis with its lush green forests used to act as green barrier and acted as an effective shield against desertification. It checked the spread of the Indian Desert (Thar) towards eastern Rajasthan, Indo Gangetic plains, Haryana and Western UP. The forests of Aravallis range in Haryana are now the most degraded forests in India, most of the indigenous plant species have disappeared. The rapid deforestation and developmental activities are destroying the unique landscape that requires immediate conservation attention. These vulnerable areas are biologically rich and support several unique elements of flora and fauna. Hence proper assessment and monitoring is necessary for restoration of the biological diversity because lack of ecological information leads to mismanagement. This is the first study in terms of detailed ecological information within this landscape that provides baseline ecological information, mainly on its mammalian status and distribution to identify priority based conservation regions.

Opportunistic camera trapping, sign surveys and line transects were conducted in 51 sites of Aravallis hills that fall within five forest divisions (Gurgaon, Faridabad, Mewat, Mahendargarh and Rewari) of Haryana State, Priority conservation areas for species were identified on the basis of occupancy estimates and kernel density (intensity of use). Area under different Landuse/landcover (LULC 2016) categories was estimated for all priority conservation areas. The kernel density maps were divided into core zone, buffer zone and transition zone.

Surveys resulted in presence of 10 mammalian species namely Common Leopard, Striped Hyena, Golden Jackal, Grey Wolf, Indian Fox, Jungle Cat, Grey Mongoose, Small Indian Civet, Indian Crested Porcupine, Indian Hare, Wild Pig, Rhesus Macaque, Blue-bull (Nilgai) and Indian Gazelle (Chinkara). The occupancy of leopard was 0.60 ± 0.10, Hyena was 0.68 ± 0.06, Nilgai was 0.76 ± 0.06 and Porcupine was 0.87 ± 0.05. Jackal was the highest occurring carnivore species in the landscape. Nilgai was the highest occurring antelope in the landscape. The individual density/km^2 of Nilgai was 8.31 ± 2.69 and Grey francolin was 0.15 ± 0.0047. The Landuse/Landcover utilization pattern indicates that the occupancy estimates are higher in the areas where the habitat covariates such as shrub cover and tree cover are highest. Forest cover in the study area is very low and only exists in the form of two categories i.e. Open Forest and Scrub. A common trend of utilization of habitats scrub and open forest was observed. Conserving the remaining forest patches should be prioritized.

Highways passing through the wildlife habitats have adversely affected the fauna in these forests. Fast moving vehicles kill these animals when they are move across these road stretches. The Gurgaon Faridabad expressway is one such road in Aravallis. Tolerance by public for wildlife is decreasing and several examples narrate the story in which animals especially leopards are killed either in retaliation or lynched by public. The priory conservation areas as identified should be considered for effective conservation and management.

The key recommendations are:

1. All priority areas identified in this report should be considered for long-term conservation and management. Site level conservation and management plans should be prepared in consultation with local stakeholders to make conservation effective in these remaining forest patches of Aravallis in the state of Haryana.

2. Opportunistic camera trapping has really given some interesting insights about the presence of the species in the landscape. There is need to conduct intensive camera trapping study across the landscape for evaluating the status and number of the wildlife species and their numbers in the area.

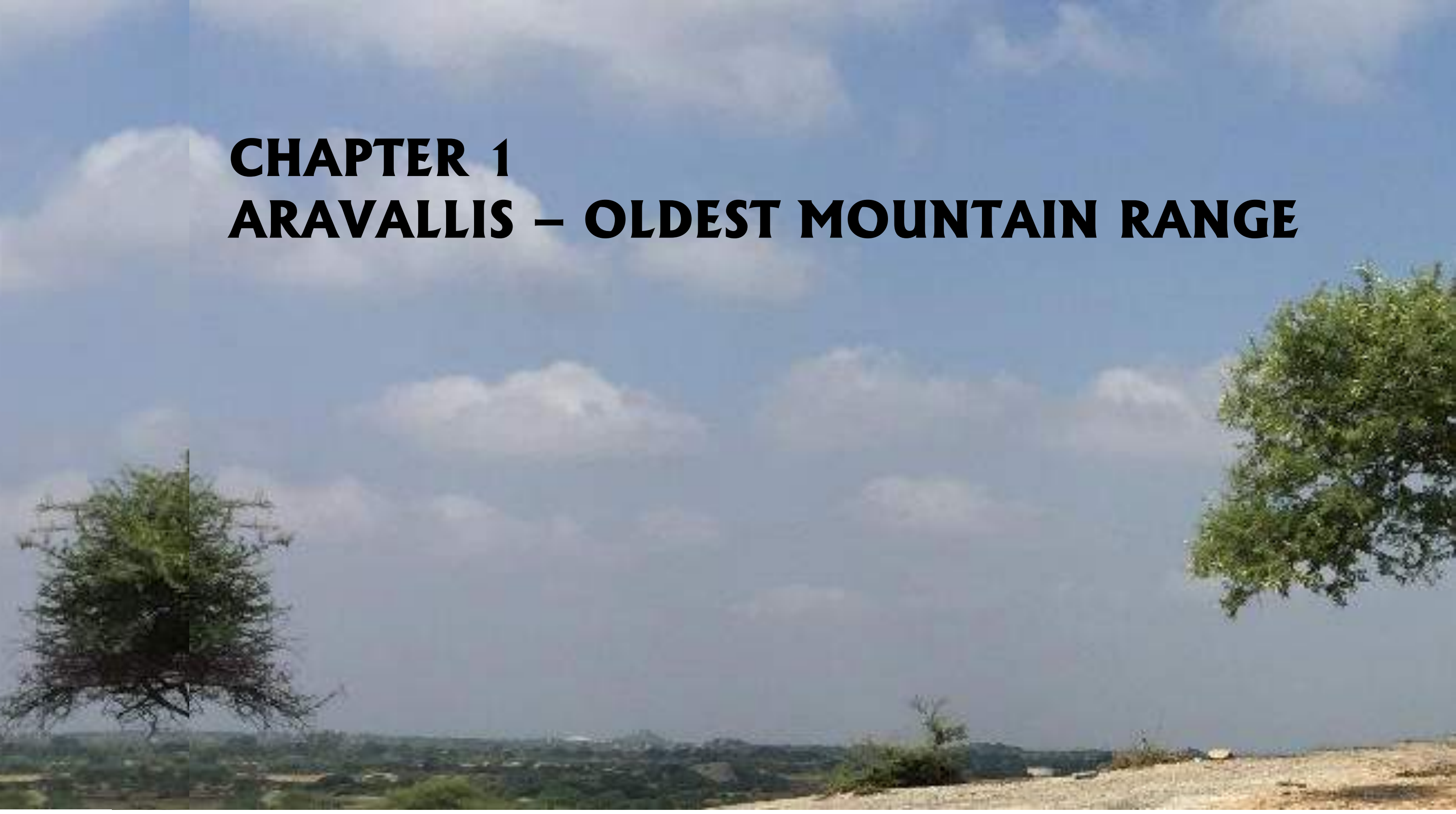
3. There is a need to identify road crossing zones for key wildlife species especially leopards to suggest mitigation measures. Radio-telemetry study will help in identifying critical leopard crossing zones.

4. Leopard as Predator and Hyena as scavenger should be considered for telemetry study in the landscape. The radio-telemetry study will help in understanding the fine scale movement pattern and landscape use by the species. It will provide data on how these species have adapted to this type of landscape, for their long-term conservation, which will provide insights in dealing with human – leopard conflict in much better way.

5. Habitat improvements in terms of removal of weeds, reducing pressures on forests should be taken on priority basis for the landscape.

6. Long term ecological monitoring should be initiated on the prioritized sites.

CHAPTER 1
ARAVALLIS – OLDEST MOUNTAIN RANGE



Aravallis Range

Aravallis form the skyline of northwest India extending from south west in Gujarat, Rajasthan to North east in Delhi and Haryana (Figure 1.1). It runs diagonally across Rajasthan extending from Champaner in Gujarat in the south west to near Delhi in the north east for a distance of about 690 km (Shetty and Singh, 1987). The elevation of the Aravalli range gradually rises in the south west direction and so the vegetation pattern and floral composition changes due to the changes in the climatic and edaphic factors.

Aravallis and their formation

The Aravalli Mountains are the prominent landform shaping western India and make up one of the oldest ranges in the world. They are highly significant from both zoogeography and evolutionary point of view. Due to its geographical location, the range has a mix of Saharan, Ethiopian, peninsular, oriental and even Malayan elements of flora and fauna. However, very few studies have been carried out on the ecology of this mountain system (Singh, 2015).

The formation of Aravalli basin was initiated about 2000 MYA. The range rose in the Precambrian event as part of the Aravallis –Delhi Oregon. These Fold Mountains are said to be formed when tectonic plates of the earth crust were pushed together. Because of this collision, huge tall structures were formed. These stupendous structures gave rise to the Aravallis, the oldest fold mountain range of the world. The present Aravalli ranges comprise only a part of the gigantic system that existed in pre-historic times. They have decreased in size and

📷 Hennie

eroded with hundreds of millions of years of weathering and erosion by the natural forces.

Geology

The Aravalli Range, oldest folded range in the world, is a series of the argillaceous rocks, which came into existence at the close of Achaean era when the sediments, which were deposited at the seas of that age, underwent an upheaval by orogenic activities. These vast mountains were peneplained in the Paleozoic times and were subsequently re-uplifted in the Mesozoic era. It is composed of metamorphosed rocks of Aravalli, the Raialos and the Delhis. Banded Gneissic complex and Bundelkhand Gneiss, both pre- Aravalli formations, are concealed at great depth indicating that Aravalli and subsequent latter formations and structures have been built up over them (Shetty and Singh, 1987).

Bundelkhand Gneiss is the oldest in India and extends from Eastern Rajasthan across Bundelkand (Shetty and Singh, 1987). This formation is mostly a normal granite in composition and varies from pink to reddish in color, medium grained, non foliated and non porphyritic, with quartz, orthoclase and subordinate microline and some ferro- magnesian minerals, mostly biotite.

Banded Gneissic complex also belongs to pre- Aravalli rocks and in age to the Bundelkhand gneissis. It underlies the alluvial plains of Rajasthan and is best exposed in south Mewar where it has attained its great complexity with a clear erosion unconformity, accompanied by thick conglomerates and great size of basic lava deposits. In the plains along the foothills of the Aravalli, range is found another type of ancient genesis, which is composed of grey, rather fine grey rock of granite composition and texture (Shetty and Singh, 1987).

Ecological Significance of Aravallis

1. **Combating desertification:** Aravallis with its lush green forests used to act as a green barrier and an effective shield against desertification. It checked the spread of the Indian Desert (Thar) towards eastern Rajasthan, Indo Gangetic plains, Haryana and Western UP. Today, the forests in the Aravalli hills no longer effectively act as a green barrier. The forests of Aravallis range are now the most degraded forests in India, most of the indigenous plant species have disappeared. The mighty Aravallis acted as the terrain, moisture and vegetation constraint when it was healthy and surviving in its original form in the form of lush green forests and gave rise to several rivers. It used to moderate the wind velocity and help in checking transpiration and evaporation. The vegetation affects the velocity of wind through a forest. Higher wind velocities increase the transpiration, which eventually speeds up desiccation.

2. Important drainage system: It acts as a water divide between the Indus basin in the North West and Ganga basin in the east covering extensive areas of North India (Rathore 2009). Any obstruction and disturbance in the natural set up will lead to large-scale changes in the areas adjoining North Indian plains and will be devastating for the environment. It will affect eastern Rajasthan, Haryana, Malwa region, western Uttar Pradesh and Delhi.

3. Enhances precipitation and checks drought: The occurrence of normal rainfall in north-west India much depends on the preservation of lush green forest cover and resultant normal evapotranspiration process over the Aravalli hills. Trees and canopy cover preserve humidity in the atmosphere and helps regulate the rainfall patterns. However, an increase amount in deforestation and soil erosion has escalated the occurrence of drought in the area. The drought subsequently affects not only the people but also the already threatened wildlife of the area.

4. **Rich habitat for biodiversity**: The Aravalli hills are rich habitat to a wide spectrum of wildlife and plant species including avifauna comprising Tiger, Leopard, Wolf, Blackbuck, Chinkara, Desert Fox, migratory common Cranes, Ducks, Coots, Pelicans etc. in its lush green forests. The wildlife is now limited to certain patches and protected areas owing to the biotic interference and deforestation.

5. **Important source for resources and minerals**: Aravallis with forest cover is integral for the ecosystem and provides numerous resources to its inhabitants including fuel wood, fodder, fruits, vegetables and important commercial products like rubber, raisins and a range of economically viable products. Furthermore, Aravallis is also rich in Non-ferrous minerals like Zinc, Gold, silver (Rathore, 2009) and ferrous minerals like Copper ore and lead, non-metallic minerals and building stones like marble, limestone etc.

Changing environmental status of Aravallis

1. Aravallis conversion into desert: The deforestation and developmental activities have destroyed the once dense forests covering most of the Aravallis. Due to excessive run off and soil erosion, Aravallis are progressing towards barren mountains devoid of vegetation. These recently generated ecological hazards will eventually increase desertification in Aravallis.

2. Drifting of Sand through Aravalli Gaps: The Aravallis hill ranges are not continuous, there are gaps in between them. The mountains checked the expansion of the desert until it was densely forested. The denudation of forests along the northern and central Aravalli tracts is causing the advancement of the desert particularly in the gap areas with increasing intensity of dust storms.

Furthermore, the excessive deforestation has intensified the process of soil erosion, causing siltation in the river channels and water reservoirs. The interpretation of remotely sensed data products of 1972-75, 1982-84, 1994-96 and 2005-07 has revealed that the desert sand is drifting towards northeastern plains through twelve identified gaps on the Aravalli hills extending from Magra hills in Ajmer district to Khetri-Madhogarh hills in Jhunjhunu district and northern most hillocks in Mahendragarh district of Haryana (Rathore, 2009)

3. Ecologically Vulnerable Area: Due to degradation of the ecosystem in the Hills, the fragile and vulnerable areas have emerged and expanded at a faster rate which require proper identification, assessment, mapping and monitoring for the restoration of ecological balance. Dungarpur-Banswar, Gap area on the Aravalli Range, Upper Banganga Vally, Magra Area, Girwa-Gogunda Tract, Jaisamand Lake Area, Daragarh-Banara-Maja-Dariba Area, Abu-Sirohi and Chappan Hills of South Aravalli areas are extremely most vulnerable area in the Aravalli (Rathore, 2009). Aravalli ranges in the Gurgaon district in Haryana along with Alwar district of Rajasthan have been notified (May 1992) as ecologically sensitive areas, therefore in-depth study of the area is essential.

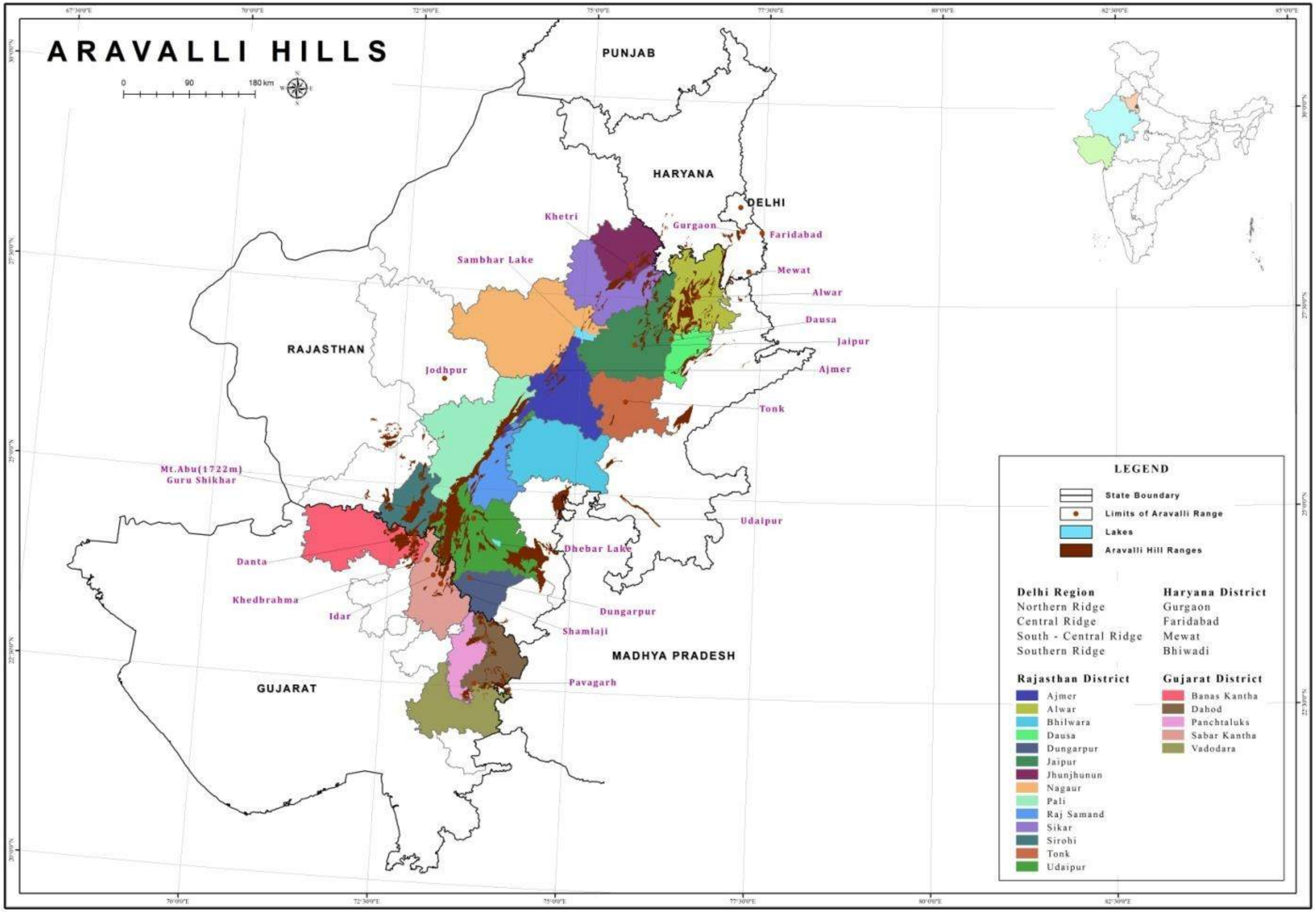


Figure 1.1: Extent of Aravallis range in North Western India

John Pheasant

CHAPTER 2
HARYANA

General, Location and Topography

The geographical area of the state is 44212 sq km which is 1.3% of India's geographical area. It is between 27°39' to 30°35' N latitude and between 74°28' and 77°36' E longitude. Haryana is located at a height of 220 to 1200 meters above the sea level. a. Haryana is a small State and is bounded in the north by Himachal Pradesh, north-west by Punjab and west and south-west by Rajasthan and in the east by Uttar Pradesh. Delhi is situated on its eastern boundary (Sinha, 1992). It is primarily an agricultural state with almost 81% of its land under agriculture. The forest and tree cover extends to 6.49 % of the total geographical area of the state. Since Haryana is situated in the foothills of Himalayas so the climate in winters is extremely cold and even touches 0 degrees but the summers here are extremely hot and the temperature goes above 40 degrees sometimes touching even 47 degrees. The State has semi-arid conditions in most parts. Haryana has eight rivers with Ghaggar and Yamuna being the main rivers of state.

History

The state, which became an independent political state of the nation on November 1, 1966 is also home to rich cultural heritage. In terms of economic development too, Haryana has come a long way. However, in rural areas agriculture is the main occupation.

Geography of Haryana

The state represents a variety of landscapes varying from hills in the northern region to almost flat alluvial plains in the central parts, and sand dunes in the southern regions. Haryana has four main geographical features.

Paridhi Jain

- Alluvial plains of Yamuna-Ghaggar forming the largest part of the state(eastern Haryana)
- The Shivalik Hills (narrow foothill zone in the north)
- Semi-desert sandy plain/sandunes (southwest close to Rajasthan)
- The Aravalli Range (southern Haryana)

The general slope of the state is from north to south but the slopes become reserve further south and southwest due to the presence of subdued ranges of Aravalli Hills. The entire state is drained by the tributaries of Ghaggar –Hakra river mainly the Markanda, the Saraswati, The Chautoung, and the Tangri apart from other seasonal streams. The Sahibi, the Dohan and the Krishnavati originating from Aravalli ridges are flowing from south to north (NWIA, 2010)

Geology of Haryana

Haryana comprises a variety of rocks belonging to following three different geological domains (GSI, 2012).

1) Pre-Cambrian rocks of Aravali Mountains,
2) Tertiary rocks of Himalayas (Shivaliks)
3) Quaternary deposits of Indo-Gangetic Plains.

The Geological formations range from Precambrian to the recent and can be divided into geological systems namely Aravallis, Shivalik and the Indo Gangetic plains. Soils in the state are mainly derived from these geological units (GSI, 2012)

The geology of Haryana is predominated by the Quaternary alluvium and Aeolian sediments covering nearly 95% of area. The rest of the area comprises Proterozoic and Tertiary rocks exposed in the southern and northeastern extremities of the state, respectively. The Proterozoic rocks of Haryana, represented by the Delhi Supergroup, are the northeastern continuation of rocks of the Alwar and Khetri basins of northeastern Rajasthan.

The rocks of Delhi Super-group constitute a part of the main Aravalli Range originating from Gujarat in the southwest to Haryana in the northeast. This supergroup comprises thick pile of meta-sediments having a cumulative thickness of 6000 m, which is divided into an older Alwar Group and younger Ajabgarh Group. The Delhi Super-group of rocks continues uninterruptedly from the northern parts of Rajasthan to Haryana and maintains the similar structural trends.

The Firozpur Jhirka Bhondsi ridge is an anticlinal ridge with its southerly closure located at Nowganwa (Podipur) and having a 20^{o} plunge towards $S20^{o}W$. The western limb of the fold dips at about 45^{0} towards west, whereas, the easterly dipping eastern limb is truncated by a fault. The Delhi Harchandpur ridge is a part of this regional anticline, which is separated from the former due to a block faulting (GSI, 2012).

Climate of Haryana

The climate of the state is sub-tropical, semi-arid to sub-humid, continental and monsoonal. The state has three main climatic regions- Hot Arid region, hot semi arid region and hot sub humid region. Summers are very hot (up to 47^{o} Celsius) and winters are very cold (1^{o} Celsius). The months of May and June are the hottest and the coldest months are December and January. The soil temperature regime is hyperthermic and the soil moisture regimes are Ustic Aridic (NWIA,2010).

Rainfall

Rainfall recorded in the region is low and erratic in most parts except for some areas of the Karnal and Ambala districts. Shivalik Hills region receive highest rainfall and the Aravalli Hills region records the least rainfall. Monsoon season normally spans from July to September and it sometimes causes local flooding. Winter rains are usually received between December and February. The average annual rainfall recorded from the state is about 650 mm and varies from less than 300 mm in southwestern parts to over 1000 mm in the Shivalik Hills region (GSI, 2012).

Forest Cover in Haryana

Haryana is primarily an agricultural state with almost 80% of its land under cultivation. As per India State of Forest Report, FSI, 2013, the Forest Cover in the state is 1586 sq.km, which is 3.59% of the state's geographical area, and the Tree Cover in the state is 1282 sq. km, which is 2.90% of the geographical area. Overall, the Forest and Tree Cover of the Haryana state is 6.49% of its geographical area.

Protected Areas

The Haryana state of north India has 2 National Parks (Sultanpur and Kalesar), 8 Wildlife Sanctuaries, 2 Wildlife Conservation Areas, 5 Animal & Bird Breeding Centers, 1 Deer park and 49 herbal parks which are managed by Forest Department, Government of Haryana. Some of the well-known breeding centers include the Chinkara and Peacock breeding centre at Jabua and Vulture Conservation and breeding Centre at Pinjore.

Wetlands

Haryana has 1827 wetlands spread over an area of 22500 sq. m. (HSRSAC & SAC, 1998). The wetlands constitute 0.62% of the total geographic area of the state (SACON 2004). Panchkula has the highest, (around 3.53%) geographic area under wetland. The other two districts viz. Yamuna Nagar and Karnal have 2.79% and 1.65% areas under wetland respectively. Some wetlands of the state, which attract migratory birds, are – the Sultanpur National Park, Bhindawas Bird sanctuary, Basai and wetlands of Yamuna.

Demography

The state of Haryana has been witnessing the high rate of urbanization owing to migration and rural push factors. The state has about 29% Urban population in 2001 that is now increased to about 35% in 2011 (Census of India, 2011). The total population of Faridabad district is 18, 09,733. In Gurgaon district, population is 15,14,432. Total population of Mahendragarh, Mewat and Rewari is 9,22,088, 10,89,263 and 9,00,332 respectively (Census, 2011).

Table 2.1: Population across five districts of Intensive Study Area

District	Population 2011	Population 2001	Change in population 2001-2011	Percentage Increase 2001-2011
Faridabad	18,09,733	13,65,465	4,44,268	32.54
Gurgaon	15,14,432	8,70,539	6,43,893	73.14
Mahendragarh	9,22,088	8,12,521	1,09,567	13.48
Mewat	10,89,263	7,89,750	2,99,513	38.65
Rewari	9,00,332	7,65,351	1,34,981	17.64

Source: Director of Census Operations, Haryana

Types of Forests in Aravallis Haryana

The forests of Aravallis hills in Haryana are primarily classified as Northern Tropical Dry Deciduous forest according to Champion and Seth classification (1964). The type of vegetation is classified into following two subclasses:

1. Northern Dry Mixed deciduous Forest: Its distribution is throughout India expect in eastern part, which is too moist and in the western part because it is too dry. Usually the upper canopy of this kind is light but even and continuous, height rarely exceeding 15m with thin shrubby underground. A prominent feature of the forest is the contrast between hot weather, when it is entirely leafless, soil almost exposed, and at the time of monsoon period, it takes almost luxuriant appearance. Floristic: *Acatia leucophloea, Bosewellia serrata, Balanites roxburghii, Holoptelea integrifolia, Acacia catechu, Butea monosperma, Maytenus senegalensis, Bauhinia racemosa, Flacourtia indica,* whereas common scrubs in this type is *Capparis deciduas, Zizyphus nummularia, Capparis sepiari, Flueggia leucopyrus, and Carissa spinarm.*

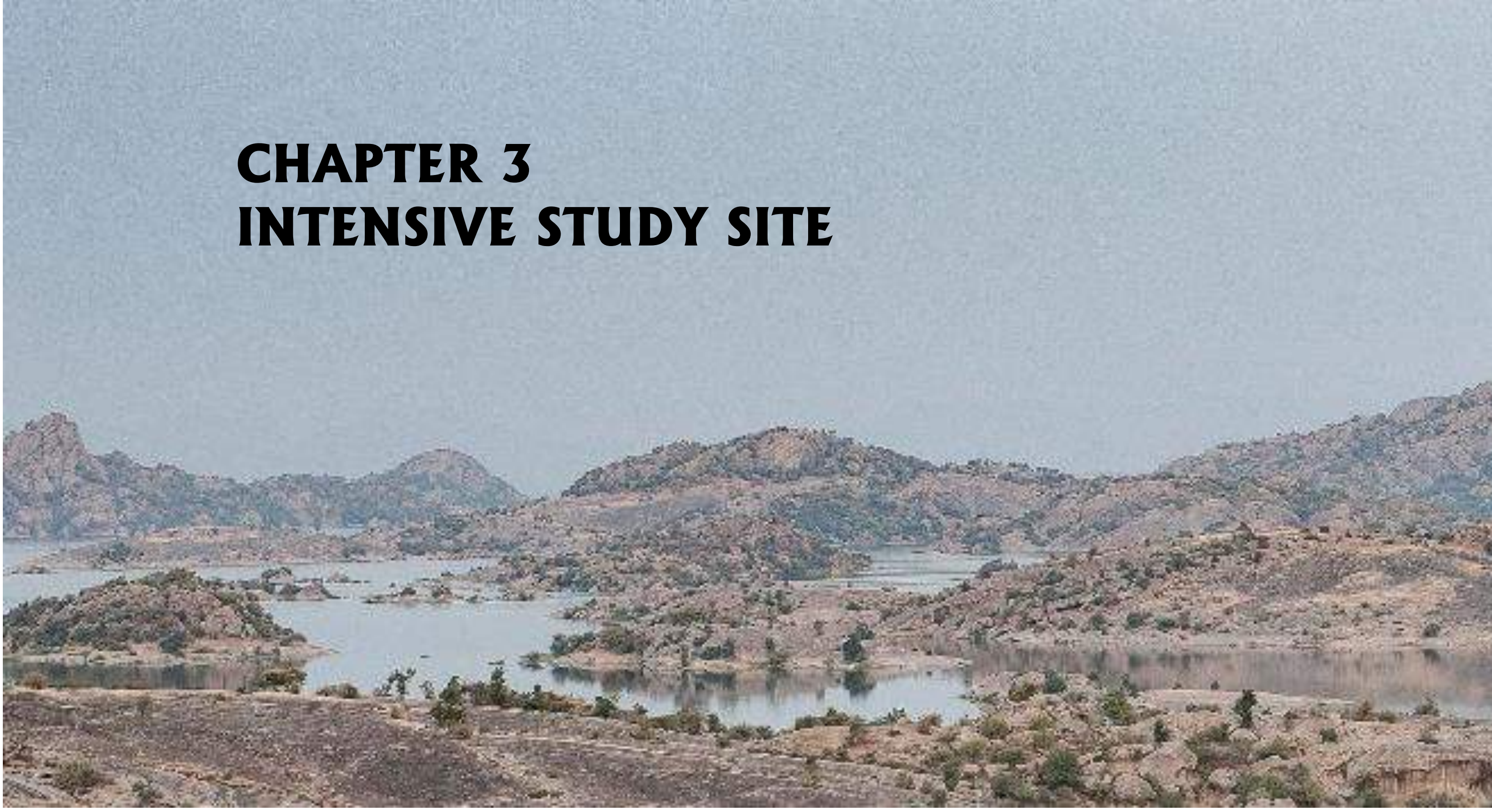
2. Dry Deciduous Scrub: It is the degraded form of dry deciduous forest, found near the habitation. Shrubby growth from 3 to 6 m with low broken soil cover is the main characteristic of this type of forest. Floristic: *Acacia leucophloea, Acacia senegal, Diospyros Montana, Acacia catechu, Butea monosperma, Flcourtia indica* are the common species.

Fauna

Haryana is bestowed with very rich diversity of wildlife. The mammalian species include the leopard, jackal, hyena, jungle cat, fox, goral, wild boar, langur, rhesus macaque, ungulate species like the Sambar, Nilgai, Barking deer, Chinkara, Chital and smaller mammals include the Civet, Mongoose, Indian hare, Indian crested porcupine, Gerbils, Squirrels (Habib et al., 2013). They are mainly limited to hilly regions of northeastern and southern parts of the state. Presence of large number of wetlands hosts a good diversity of avifauna like the Pochards, Darter, Harriers, Ducks, Coots, Storks, and Ibis etc. Several species of snakes, lizards, amphibians and tortoises constitute the Herpetofauna of the state.


Paridhi Jain

CHAPTER 3
INTENSIVE STUDY SITE



The intensive study area selected was the Aravalli region of the Haryana Landscape. Aravallis bound Haryana in the southwest region. The northern point of the range continues as isolated hills and rocky ridges into Haryana State, ending in Delhi. The famous Delhi Ridge is the last leg of the Aravalli Range, which traverses through southern Delhi and terminates into Central Delhi where Raisina hill is its last extension. Sites in five divisions namely, Mahendragarh, Rewari, Faridabad, Gurgaon and Mewat with an area of 1899 km^2, 1594 km^2, 741 km^2, 1258 km^2, 1507 km^2 respectively, were extensively surveyed for mapping the land use area/Land cover pattern and the status of key wildlife species.

Physiography of Various Divisions

1. Gurgaon: Gurgaon district comprises of both hills on one hand and depressions on the other, forming irregular and diverse nature of topography. Two ridges (i) the Firozpur-Jhirka Delhi ridge forms the western boundary and (ii) the Delhi ridge forms the eastern boundary of the district. The district comprises of sand dunes (Figure 3.1), sandy plains, alluvial plains, open forests (Figure 3.2), scrublands, salt affected areas, low lands, lakes, hills and pediments. These hills are northern continuation of Aravalli hills. The northwestern part of the district is covered with sand dunes lying in the westerly direction due to southwestern winds. The extension of the Aravalli hills and the presence of sand dunes collectively form the diverse physiography of the district.

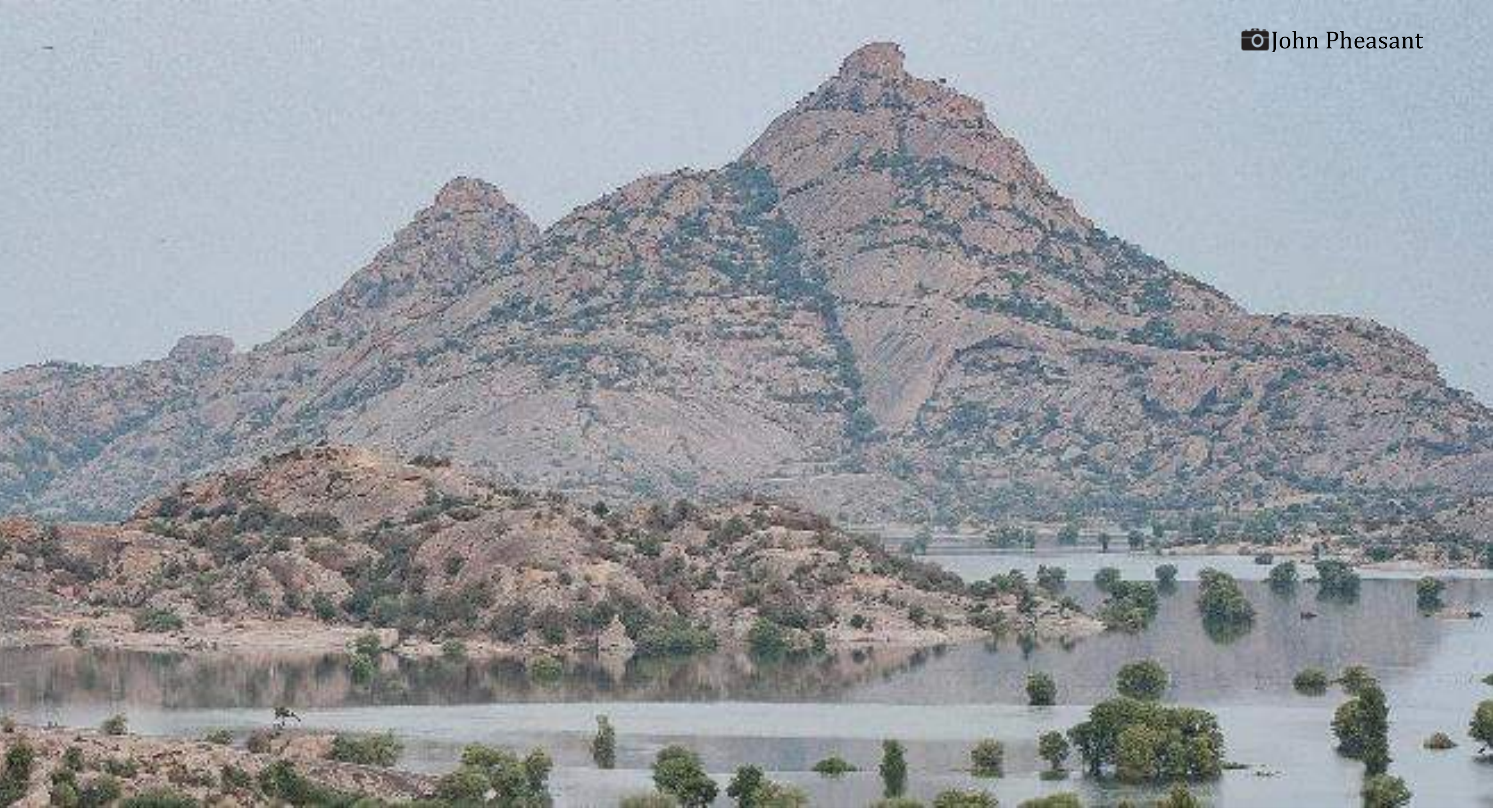


Figure 3.1: Sand dunes in Harchandpur, Gurgaon, Haryana, India.

Figure 3.2: Forests of Raisina, Gurgaon, Haryana, India.

2. Mewat district: The district has undulating topography and is more or less bowl shaped. The sporadic ridges and hillocks make a semi- circle in the west, south and east of Punhana (27^0 51’45”/77^0 12’30”). Mewat district has distinct topographic features with flat alluvial plains over most of the region, long and narrow pediments and local undulations caused by windblown sands at the foothill zones and the plains. The soil of Mewat is light in texture, particularly sandy, sandy loam and clay loam. Most of the forest area in Mewat is surrounded by upper hills which are mostly barren (Figure 3.3) however semi-arid areas are also present in some areas (Figure 3.4) The ground water in the district area is saline, and salinity increases with depth.

Figure 3.3: Barren hills in Dhallaka Mallaka Panchgaon, Mewat, Haryana, India.

Figure 3.4: Aravallis in Nangal, Mewat, Haryana, India.

3. Faridabad: Faridabad has mountainous physiography and has alluvium deposits. The alluvial plains have been divided into two units. Khadar that is the low-lying flood plain of newer alluvium and Banger, an upland plain made of older alluvial and is spread towards west. There are also few artificial lakes namely Surajkund, Badhkal, Peacock and Dhauj Lake and abandoned mining pits who have become aquifers over the years. Dense forests of manger bani are of high conservation priority (Figure 3.5).

Figure 3.5: Aravallis in Faridaba (Mangar Bani), Haryana, India.

4. Mahendragarh district: The Mahendragarh district is the domain of dry-land topography throughout. Presence of inland streams, semi-arid hills (Figure 3.6) sandy plain, shifting sand dunes devoid of vegetation, fixed or fossil sand dunes, dissected upland tract, and often barren, denuded rocky hill ranges and their outcrops provide an ensemble of terrain features truly associated with semi-arid to arid environment.

5. Rewari district: The district can be divided into four terrains i.e. Barren rocky/stony waste/sheet rocky, Sandy plain with sand dunes, Old flood plains and occasional hillocks (Figure 3.7) and Undulating uplands with or without scrub.

Figure 3.6: Aravallis in Mahendragarh (Madhogarh), Haryana, India.

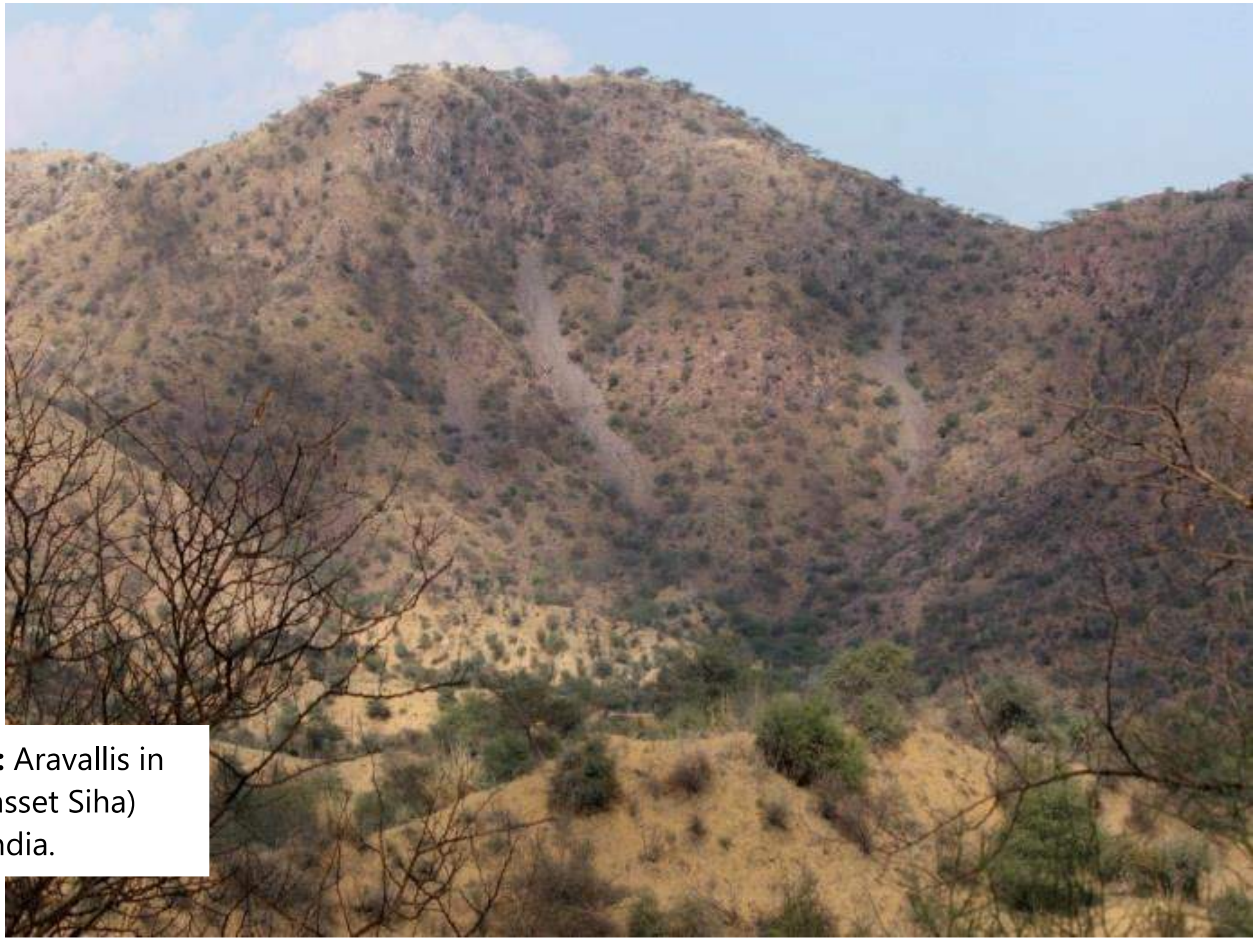
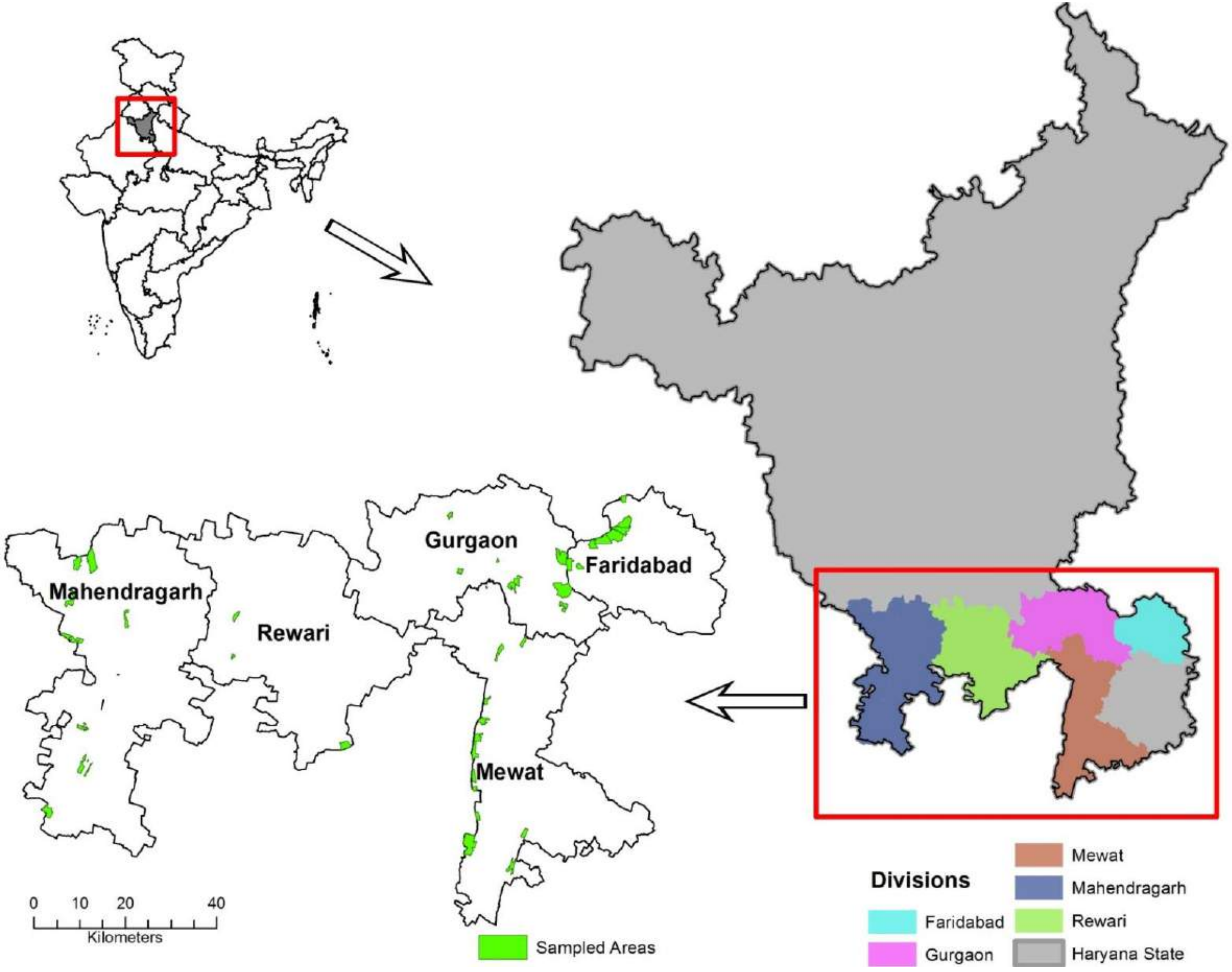


Figure 3.7: Aravallis in Rewari (Masset Siha) Haryana, India.



Map showing location of study area of Aravallis Landscape Haryana, India

Threats to the biodiversity in the study area:

1. Soil Erosion: Increase in deforestation is leading to an increase in the amount of soil erosion especially in the hilly areas and slopes. Large amount of areas are being converted to barren lands in absence of vegetation and urbanization.

2. Soil Salinity: Salinity of soil is a major environmental hazard in Haryana, which adversely affects the agricultural production by reducing the plant growth and rendering areas unsuitable for normal cultivation. Areas with such soils are left barren because of their non-productive nature. The ground water in Mewat district is highly saline due to high TDS. Salinity also affects the biodiversity when there is absence of fresh water sources.

3. Invasion of Invasive Alien Species: Alien species that become invasive are main drivers of biodiversity crisis throughout the world. Species like *Lantana camara* and *Prosopis juliflora* have had serious depleting effects on the flora of the state. *Prosopis juliflora* and *P. pallida* are tropical species that have become seriously invasive in many parts of Africa, Middle East and Indian subcontinent. (Kaur et al, 2012).

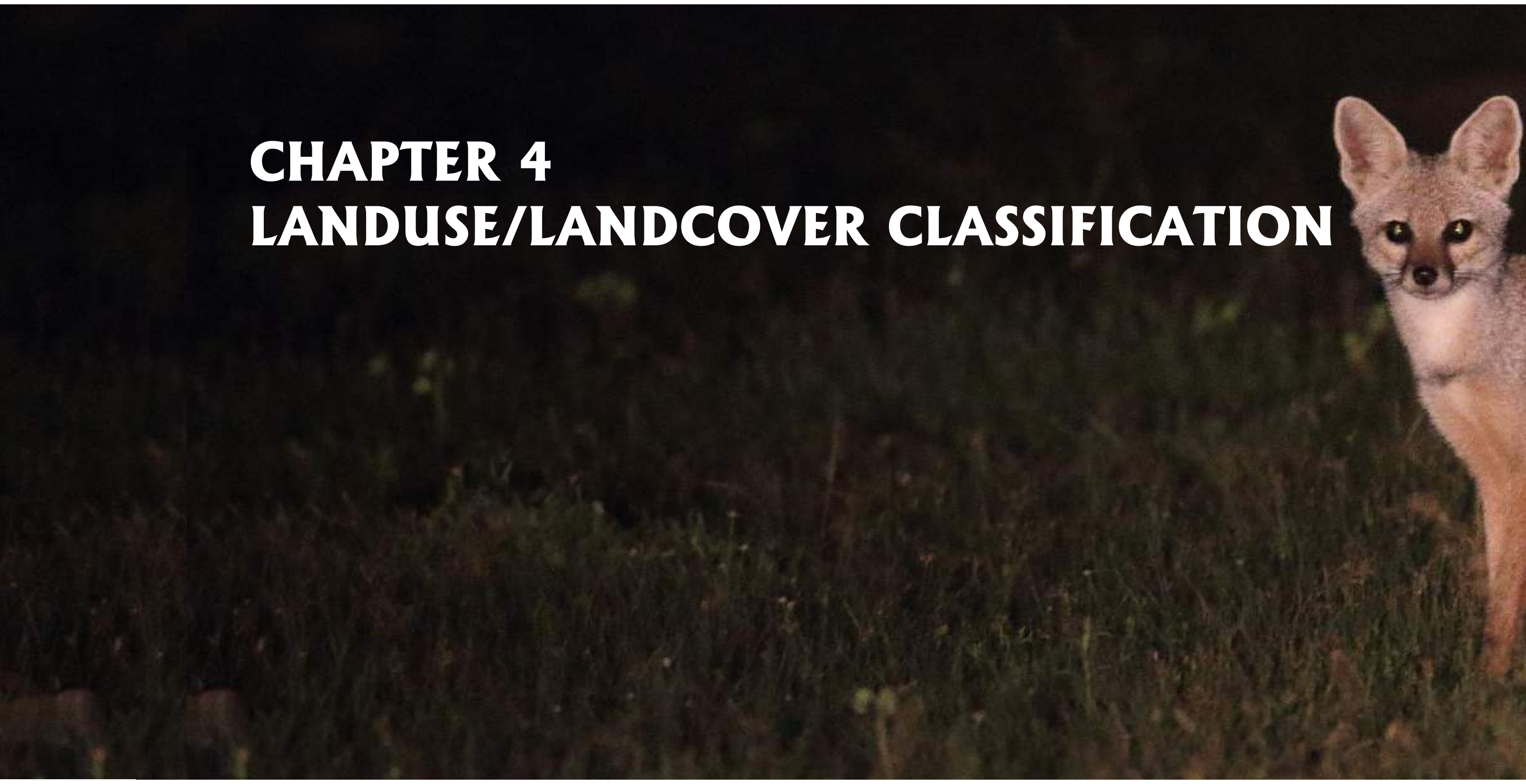
4. Floods and Drought: In the absence of perennial surface drainage, the slopes of natural water migration are limited. When high rainfall occurs within a short span of time, the water gets accumulated on the surface and causes flooding (GSI 2012).

5. Sand migration and formation of sand dunes: Haryana lies on the northeastern fringe of the Thar Desert and experiences arid semi-arid climate. As a result, sand migration is common along the desert boundaries. Due to the depletion of the forest cover over the Aravallis the desert is migrating towards Haryana through the gaps. Haryana along with Alwar has been included in the ecologically vulnerable area. Some of the parts of Haryana like the Khudana, khol khaletha and Madhogarh area have large areas as sandunes.

6. Anthropogenic pressure: Increase in human population (Plate 3.11), (Plate 3.12) adjacent to the forest and feral dogs have become threat for the biodiversity. Livestock grazing causes loss to the native vegetation and leads to conflict between man and wildlife. Mining in some parts of Haryana is destroying habitats at a faster rate. Noise from mining blasts are forcing wild animals to shift base from forests to residential areas.

Highways passing though wildlife habitats are threat to the movement of animals. Emergence of new highways and roads are a potential danger especially at the nighttime. One such example is the Gurgaon Faridabad expressway, which has seen numerous such incidents. Informative awareness signs for the speeding vehicles can be installed as a potential safety measure for the animals.

Bilal Habib



CHAPTER 4
LANDUSE/LANDCOVER CLASSIFICATION

The terms land use and land cover is often used interchangeably, but each term has its own unique meaning. Land cover refers to the characteristics and surface cover of Earth's Surface, as represented by natural elements like vegetation, water, bare earth, impervious surface and other physical features of the land. Identification of land cover establishes the baseline information for activities like thematic mapping and change detection analysis. Land use refers to the activity, economic purpose, intended use, and/or management strategy placed on the land cover type(s) by humans or land managers. Changes in intent or management practice likewise constitute land use change. When used together the phrase Land Use / Land Cover generally refers to the categorization or classification of human activities and natural elements on the landscape within a specific period based on established scientific and statistical methods of analysis of appropriate source materials. Land cover is the physical material at the surface of the earth. Land use is the description of how people utilize the land for the socio economic activity urban and agricultural land uses are two of the most commonly recognized high-level classes of use. At any one point or place, there may be a multiple and alternative land uses, the specification of which may have a great dimension. Hence, Land use is the activity for which the man uses land. Remote Sensing and Geographical Information System (GIS) provide efficient methods for analysis of land use and land cover aspects and tools for Land Use Land Cover planning and modelling. Satellite Remote Sensing data is usually the most accurate and up to date tool to study the Land Use and land cover which leads to detection of change.

Vinit Arora

Knowledge of land use and land cover is important for many planning and management activities and considered as essential element for modeling and understanding the earth as a system. Land cover maps are presently being developed from local to national to global scales. The use of panchromatic, medium-scale aerial photographs to map land use has been as accepted practice since the 1940s. More recently, small-scale aerial photographs and satellite images have been utilized for land use/land cover mapping (Thomas et AL., 2004). Land use and land cover (LULC) classes characterize important information of natural landscape and human activities on the Earth's surface (Gong et al. 2011). In recent decades, remotely sensed data have been widely used to provide the land use and land cover information such as degradation level of forests and wetlands, rate of urbanization, intensity of agricultural activities and other human-induced changes.

Thematic layers

Thematic data layers like roads and settlements were digitized from Survey of India (SOI) topo-sheets of 1: 50000 scale. Digitization error like node errors were corrected for each of the GIS layers. Edge matching was done before mosaicking of sheets. The digitized roads were overlaid on geometrically corrected satellite data of IRS P6 LISS III for the year 2011 to update the roads previously digitized with SOI topo sheets. The road and settlement map is for the intensive study area is shown in Figure 4.1. We used beat as basic unit for the survey. The beat boundaries were provided by Haryana Forest Department and were checked for topological consistencies for analysis in GIS domain. The landuse/landcover with respect to surveyed beats is provided in Table 4.1

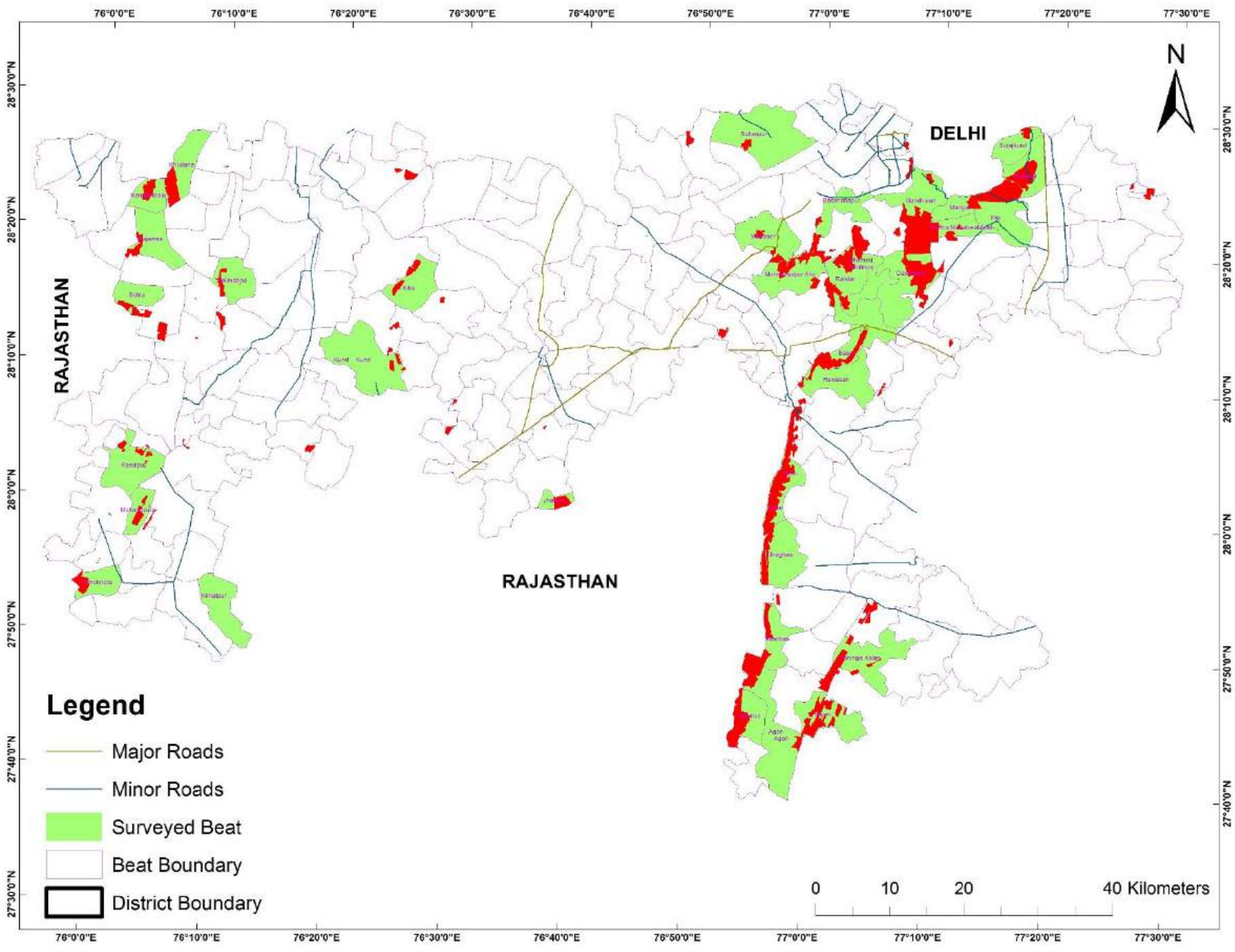


Figure 4.1: Map of intensive study area depicting sampling beats, ranges, district administration boundaries, major/minor roads and forest cover. Major and minor roads are also shown in the map.

Table: 4.1: Landuse/Landcover Classification (Surveyed Beats) 2016, Aravallis Haryana

S .No.	Landuse/Landcover Type	Area (sq. km.)	Area %
1.	Open Forest	80.61	7.3
2.	Scrub	218.02	19.74
3.	Grassland	1.74	0.16
4.	Plantation	15.13	1.37
5.	Agriculture	617.2	55.87
6.	Barren	49.98	4.52
7.	Waterlogged	17.51	1.59
8.	Waterbody	1.46	0.13
9.	Canal	0.54	0.05
10.	Settlement	89.17	8.07
11.	Industrial Area	14.28	1.29
	Total	**1105.64**	**100**

Landuse / Landcover Classification

It is necessary to convert a satellite image to a thematic map of a different landuse and landcover type; this will make it possible to work quantitatively with the characteristic of the area and to understand the distribution of different landcover types. The satellite based remote sensing data of LANDSAT 7, LANDSAT 8 was used for LU/LC mapping, change detection, vegetation and forest cover mapping. Delineation of polygons was based on shape, size, tone, texture, shadow, aspect and association as interpretation keys. Mapping was carried out on the scale of 1:50000. Satellite image of October month 2016 was used for visual interpretation.

During the reconnaissance survey, transects were walked in different landuse/landcover type within the intensive study area. An understanding was gained on specific vegetation types of the area. On field GPS locations were marked according to the land cover type. By using compass directions were determined and photographs were captured in four directions (North, East, West and South), which were geo-tagged later.

Agriculture dominates the landscape covering 77.37 % of the area, followed by settlement, scrub and open forest covering 9.44 %, 6.11 % and 1.76% respectively (Figure 4.2, Table 4.2).

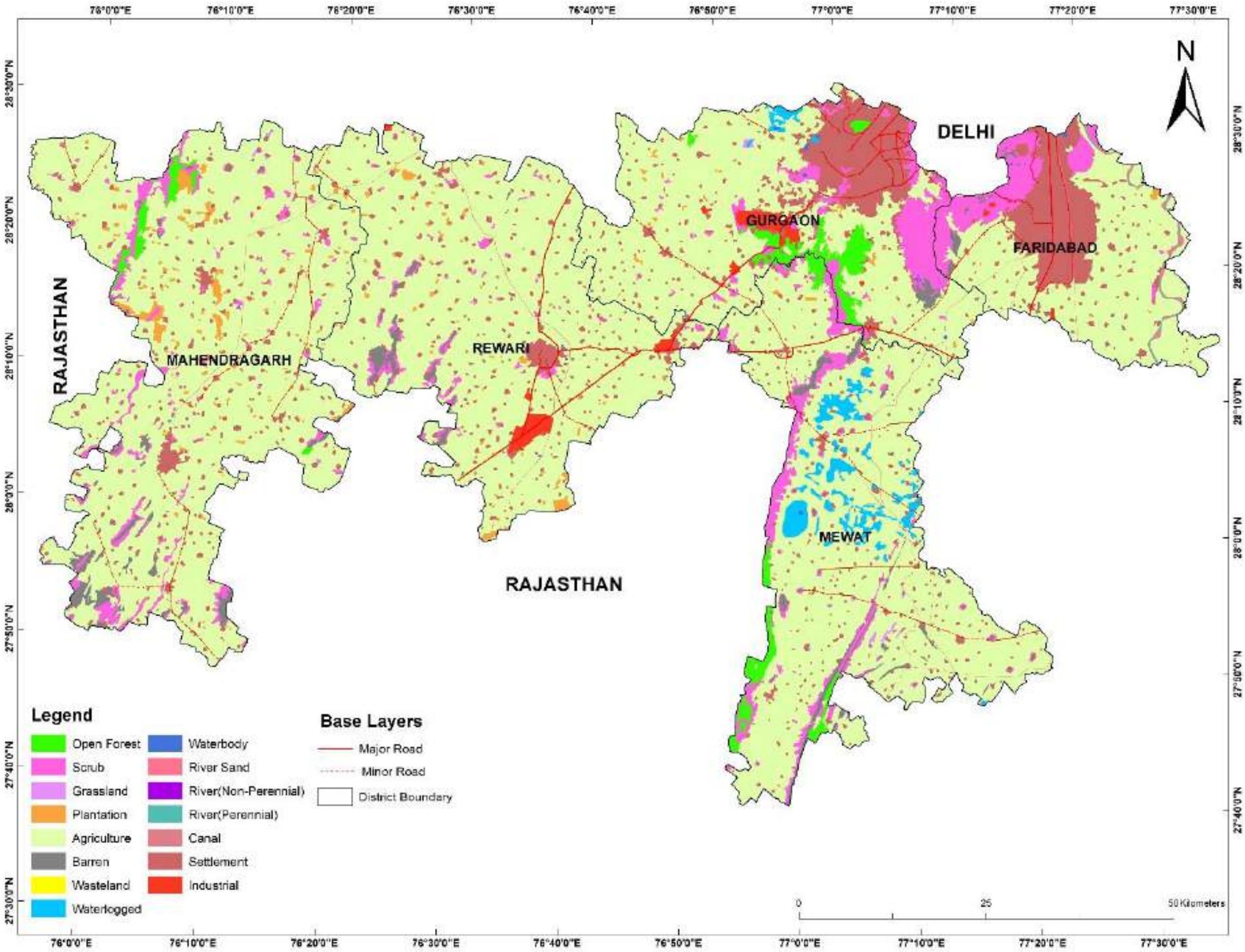


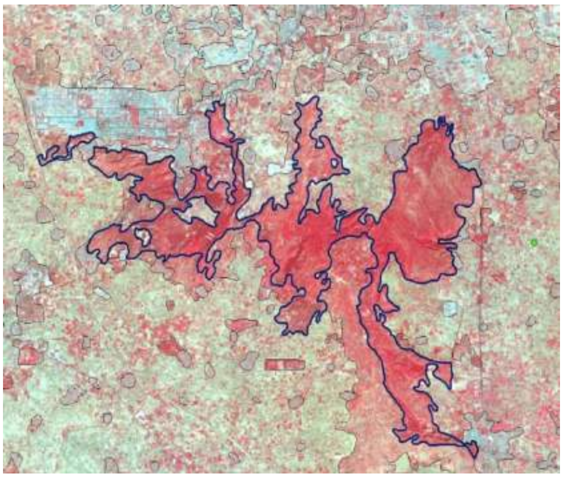
Figure 4.2: Landuse and Landcover of Aravallis Haryana (2016)

Table: 4.2: Landuse/Landcover Area Statistics (2016), Aravallis Haryana

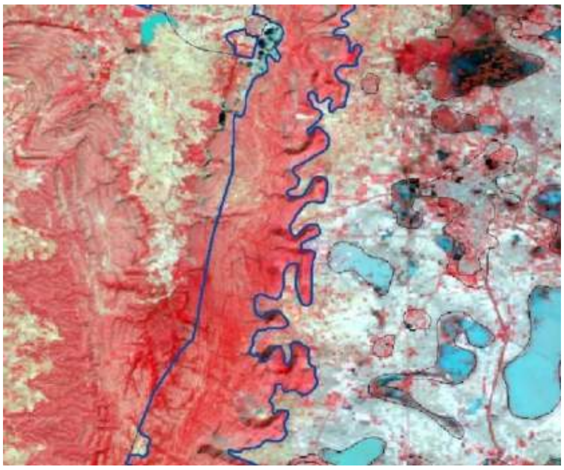
S .No.	Landuse/Landcover Type	Area (sq. km.)	Area %
1	Open Forest	119.36	1.76
2	Scrub	413.49	6.11
3	Grassland	12.37	0.18
4	Plantation	78.37	1.15
5	Agriculture	5235.35	77.37
6	Barren	101.45	1.49
7	Wasteland	0.49	0.007
8	Waterlogged	83.33	1.23
9	Waterbody	6.16	0.09
10	River Sand	8.18	0.12
11	River (Non Perennial)	0.14	0.002
12	River (Perennial)	5.5	0.08
13	Canal	16.58	0.24
14	Settlement	638.95	9.44
15	Industrial Area	46.14	0.68
	Total	**6765.94**	**100**

Visual Interpretation

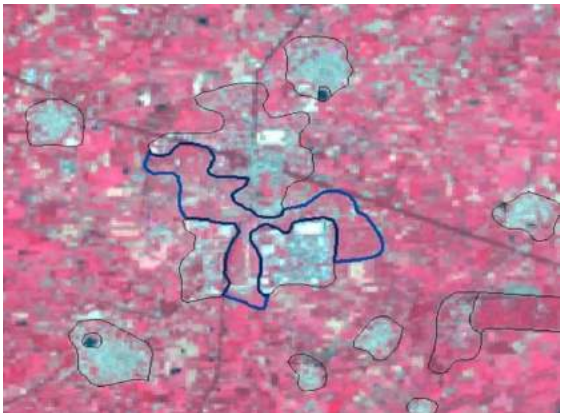
The visual interpretation of satellite images is a complex process. It includes the meaning of the image content but also goes beyond what can be seen on the image in order to recognize spatial and landscape patterns. This process can be roughly divided into 2 levels: The recognition of objects such as streets, fields, rivers, etc. The quality of recognition depends on the expertise in image interpretation and visual perception. A true interpretation can be ascertained through conclusions (from previously recognized objects) of situations, recovery, etc. Subject specific knowledge and expertise are crucial.



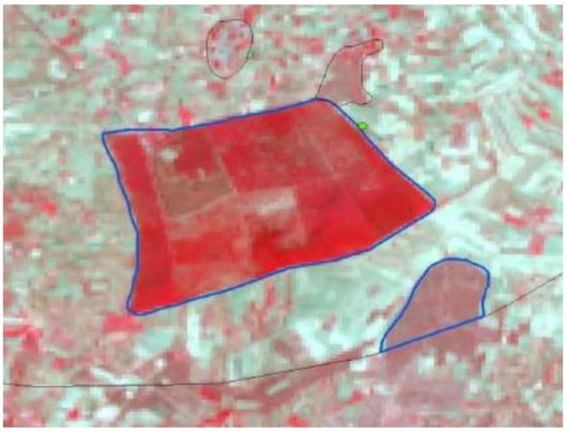
Open Forests are the mixtures of trees, shrubs and grasses in which, unlike closed forests, the canopies do not form a continuous closed cover. It appears light red in FCC of a satellite image with coarse to mottled texture.



Scrub is found on the fringes of dense forest and settlements. They are also formed due to abandonment of agricultural field. They appear in light red to dark brown in colour depending on the canopy cover and soil background. Their size will vary from small to big, irregular to discontinuous in shape, contiguous to non-contiguous in appearance. The course to mottled texture is due to thin tree/vegetation cover and exposure of terrain underneath.

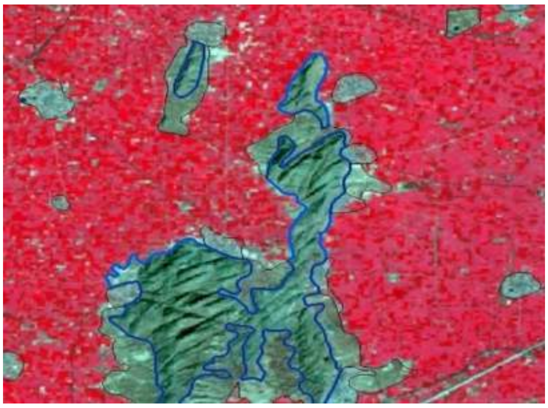
Grasslands occur where rainfall is not enough to support the growth of forest but not so little to form a desert either. It appears light red with irregular shapes and non-contiguous in pattern in the study area.

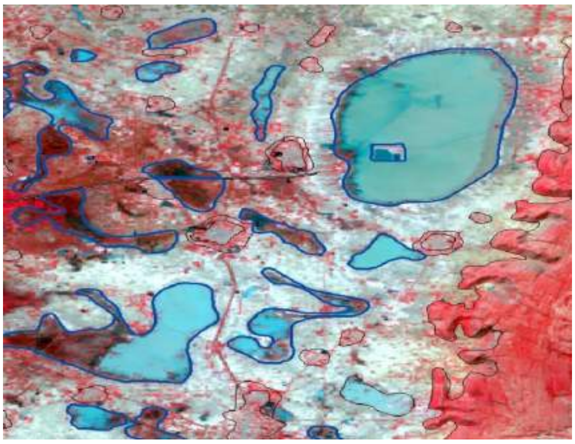
Plantations are large artificially established forest, farm or estate where crops are grown for sale, mostly in distant market. In study area, poplar and eucalyptus's plantation is common. In satellite imagery, it appears in dark red to brown tones with regular pattern and smooth edges.

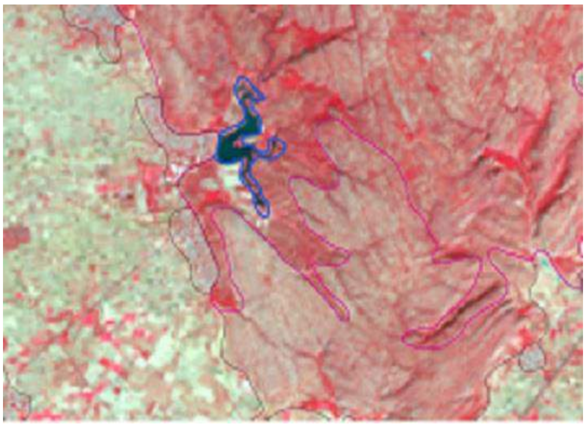
Agricultural Land used for farming and for production of food, fiber and other commercial and horticulture crops. It appears in bright red to pink in color with varying shape and size in a contiguous to non-contiguous pattern. Its spatial extent varies in size and shape with smooth texture (when the crop is in full matured state) to coarse or mottled (at the early stages of planting and growth). It is contiguous under irrigated (canal, tank or well etc.) areas and noncontiguous in unirrigated or rain fed dry lands

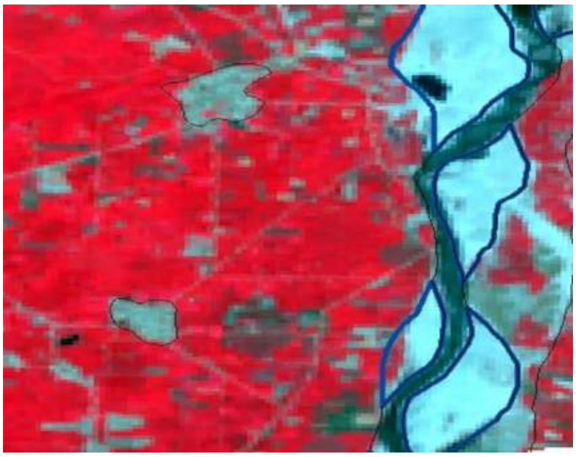
Barren Rocky appear in greenish blue to yellow to brownish tone (subject to varying rock type) vary in size with irregular and discontinuous shapes very coarse to coarse to medium texture, linear to contiguous and dispersed in pattern. Barren describes an area of land where plant growth may be sparse, stunted, and/or contain limited biodiversity.

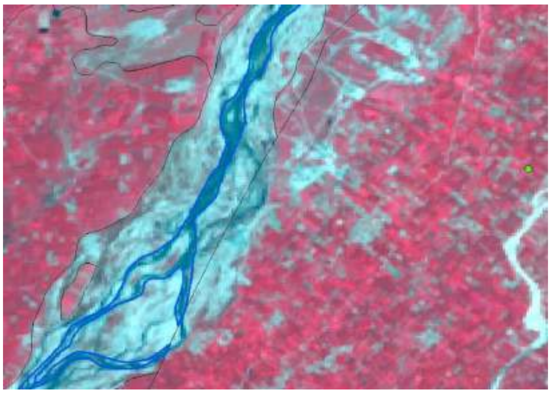
Waterlogged Area or lands are seen in light to dark blue tone, (depending upon the water spread and organic matter). It varies in size with irregular and discontinuous shapes, smooth to mottled texture, which is due to presence of aquatic vegetation.

Water bodies (lakes, reservoir, and tanks) appear light blue and dark blue tone depending up on the turbidity, volume of water etc. They can be small, medium and large with smooth to mottled texture. It is noncontiguous and dispersed in pattern.

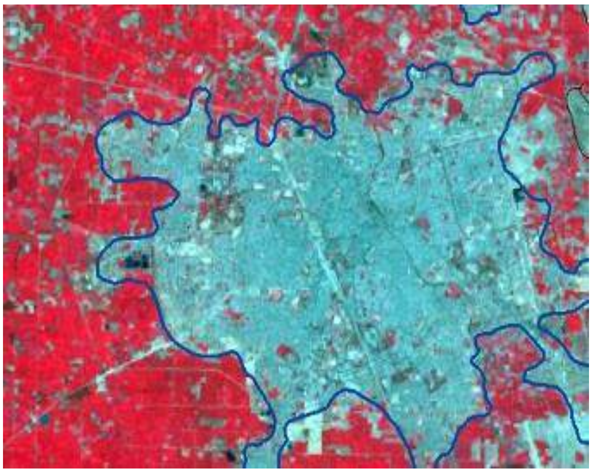
 

River Sand appears bright white to bluish in a FCC of a satellite image with irregular shapes, smooth to mottled texture and linear pattern.

River/Streams appear in light blue to dark blue to black (subject to shallow surface water spread, deep and more volume of water, turbidity etc.,) long and narrow to wide in size with irregular and sinuous shape, smooth to medium in texture (in case of high turbidity). It occurs as natural rivers/streams (perennial and non-perennial), non-perennial or dry river occurs in lighter tones of blue while perennial occurs in darker tones of blue.

Canals appear light blue to dark blue with a linear pattern. Canals occur in inland plains, desert plains along the contour and gently sloping grounds in association with settlement.



Built-up comprises of developed areas like buildings, industrial structures, transportation network etc. The physical size or built –up sprawl with transport network can be used to classify a settlement as urban or rural. It is identifiable on the imagery by its dark bluish green (Cyan) to bluish tone, definite size, shape and texture. Often, built-up land with high density of buildings etc., appear in dark tone at the center and lighter on peripheries because of being less dense and less developed. The pattern is contiguous to non-contiguous (punctuated by vacant lands and vegetation), clustered or scattered.

Change Detection

To analyze the pattern of landuse and landcover in the study area, a temporal analysis was carried out from 1980 to 2016. Satellite image of Landsat 7 was used. A change statistic was evaluated following the methodology depicted in Figure 4.3. The LULC map for the year 2016 was considered as the base map. The map was overlaid on 1980, 1990 and 2000 satellite data and all these were registered with uniform projection parameters. Wherever the variation between the spectral reflectance in the satellite data and LULC map was observed the polygons were edited.

Change statistics and confusion matrix for change analysis has been calculated to depict the rate of change and pattern respectively. The details of the change are provided in Tables 4.3, 4.4, 4.5. Agriculture is one the dominant landuse type covering more than 50% each year. There is significant increase in the area of settlement and industrial area from 1980 to 2016.

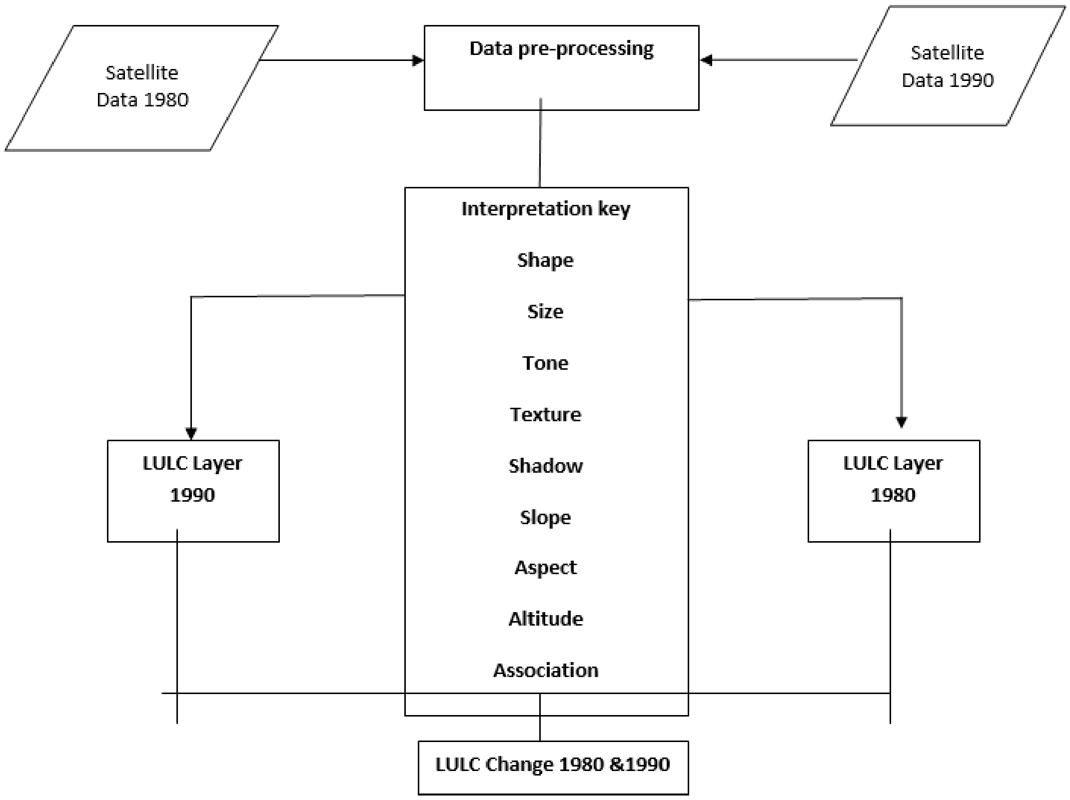


Figure 4.3: Flowchart depicting generation LULC and Change Detection Analysis for Aravallis Haryana

Table 4.3: Landuse and Landcover change from 1980 to 1990 in Aravallis Haryana, India

Class	1980		1990		Change	
	Area (km²)	Area (%)	Area (km²)	Area (%)	Area (km²)	Area (%)
Open Forest	119.68	1.7	119.66	1.7	0.02	0↓
Scrub	390.96	5.77	394.46	5.83	3.5	0.89↑
Grassland	19.89	0.29	20.38	0.301	0.49	2.4↑
Plantation	31.59	0.46	70.38	1.04	38.97	122.79↑
Agriculture	5773.88	85.33	5696.6	84.19	77.28	1.33↓
Barren	102.46	1.51	102.47	1.51	0.01	0.009↑
Wasteland	18.2	0.2	4.6	0.067	13.6	74.72↓
Waterlogged	19.59	0.28	25.85	0.38	6.26	31.95↑
Waterbody	2.68	0.033	2.2	0.032	0.48	17.91↑
River Sand	9.77	0.14	10.99	0.16	1.22	12.48↑
River (Non Perennial)	5.03	0.07	2.1	0.03	2.93	58.25↓
River (Perennial)	8.29	0.12	6.75	0.108	1.54	18.57↓
River Scrub	0.063	0.0009	0.12	0.001	0.057	90.47↑
Canal	16.58	0.24	16.58	0.24	0	0
Settlement	247.53	3.6	289.71	4.2	42.18	17.04↑
Industrial	0	0	3.34	0.049	3.34	100↑
Total	**6765.94**	**100**	**6765.94**	**100**		

Table 4.4: Landuse and Landcover change from 1990 to 200 in Aravallis Haryana, India

Class	1990		2000		Change	
	Area (km²)	Area (%)	Area (km²)	Area (%)	Area (km²)	Area (%)
Open Forest	119.66	1.7	119.66	1.54	0	0
Scrub	394.46	5.83	401.92	5.94	7.46	1.8↑
Grassland	20.38	0.301	12.77	0.18	7.61	37.34↓
Plantation	70.38	1.04	72.47	1.07	2.09	2.96↑
Agriculture	5696.6	84.19	5495	81.21	201.6	3.5↓
Barren	102.47	1.51	107.17	1.58	4.7	4.58↑
Wasteland	4.6	0.067	0.176	0.002	4.424	-96.17↓
Waterlogged	25.85	0.38	33.39	0.49	7.54	29.16↑
Waterbody	2.2	0.032	3.55	0.05	1.35	61.36↑
River Sand	10.99	0.16	6.6	0.09	4.39	39.94↓
River (Non Perennial)	2.1	0.03	0.49	0.007	1.16	76.66↓
River (Perennial)	6.75	0.108	7.39	0.109	0.64	9.4↓
River Scrub	0.12	0.001	0.18	0.002	0.06	50↑
Canal	16.58	0.24	16.58	0.24	0	0
Settlement	289.71	4.2	465.67	6.88	175.96	60.73↑
Industrial	3.34	0.049	22.44	0.33	19.1	572↑
Total	**6765.94**	**100**	**6765.94**	**100**		

Table 4.5: Landuse and Landcover change from 2000to 2016 in Aravallis Haryana, India

Class	2000		2016		Change	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Open Forest	119.66	1.54	119.36	1.76	0.3	-0.25↓
Scrub	401.92	5.94	413.49	9.44	11.77	2.8↑
Grassland	12.77	0.18	12.37	0.18	0.4	-3.13↓
Plantation	72.47	1.07	78.37	1.15	5.9	8.1↑
Agriculture	5495	81.21	5235.35	77.37	259.65	-4.72↓
Barren	107.17	1.58	101.45	1.49	5.72	-5.33↓
Wasteland	0.176	0.002	0.49	0.09	0.314	178↑
Waterlogged	33.39	0.49	83.33	100	59.94	149.56↑
Waterbody	3.55	0.05	6.16	1.23	2.61	73.52↑
River Sand	6.6	0.09	8.18	0.12	1.58	23.93↑
River (Non Perennial)	0.49	0.007	0.14	0.002	0.35	-71.42↓
River (Perennial)	7.39	0.109	5.5	0.08	1.89	-25.57↓
River Scrub	0.18	0.002	0	6.11	0.18	100↓
Canal	16.58	0.24	16.58	0.24	0	0
Settlement	465.67	6.88	638.95	0.007	173.28	37.21↑
Industrial	22.44	0.33	46.14	0.68	23.7	105↑
Total	**6765.94**	**100**	**6765.94**	**100**		

Analysis of Landuse/Landcover Change

Agriculture constituted about 85.33 % in 1980. The landuse change analysis reveals that area under agriculture has reduced by 7.96 % by 2016. Agriculture has been one of the prime contributors in the state economy.

Built-up includes residential, non-residential built-up, open, vacant, recreational airport, railway station, yard, landfill sites, etc. There has been a tremendous increase in the built-up area from 1980 to 2016. Area under settlement was 251.07 km^2 and it increased by 5.8 % by 2016.

Wastelands includes waterlogged, barren rocky and river sand. The wastelands accounted for 2.1 % of total area in 1980, which increased substantially by 2.8 %.

Green Areas - non-agriculture vegetated areas, which include open forest area, plantation and scrub. The change analysis indicates a decrease in the Green area during 1980- 2016. There is a need to substantially increase the Green cover in order to improve the environmental conditions, particularly the ridge/undulating areas of the sub-region and as well as in the large cities and around their periphery.

Water bodies include rivers (Perennial and Non-perennial), canals, lake/ tank/ pond, etc. There is decrease in the area of rivers and streams while there is increase in the area of artificial water bodies.

The LULC change maps from the year 1980 to 2016 are show in Figure 4.4, 4.5 and 4.6 along with details of change in change matrix Table 4.5, 4.6 an d 4.7.

Paridhi Jain

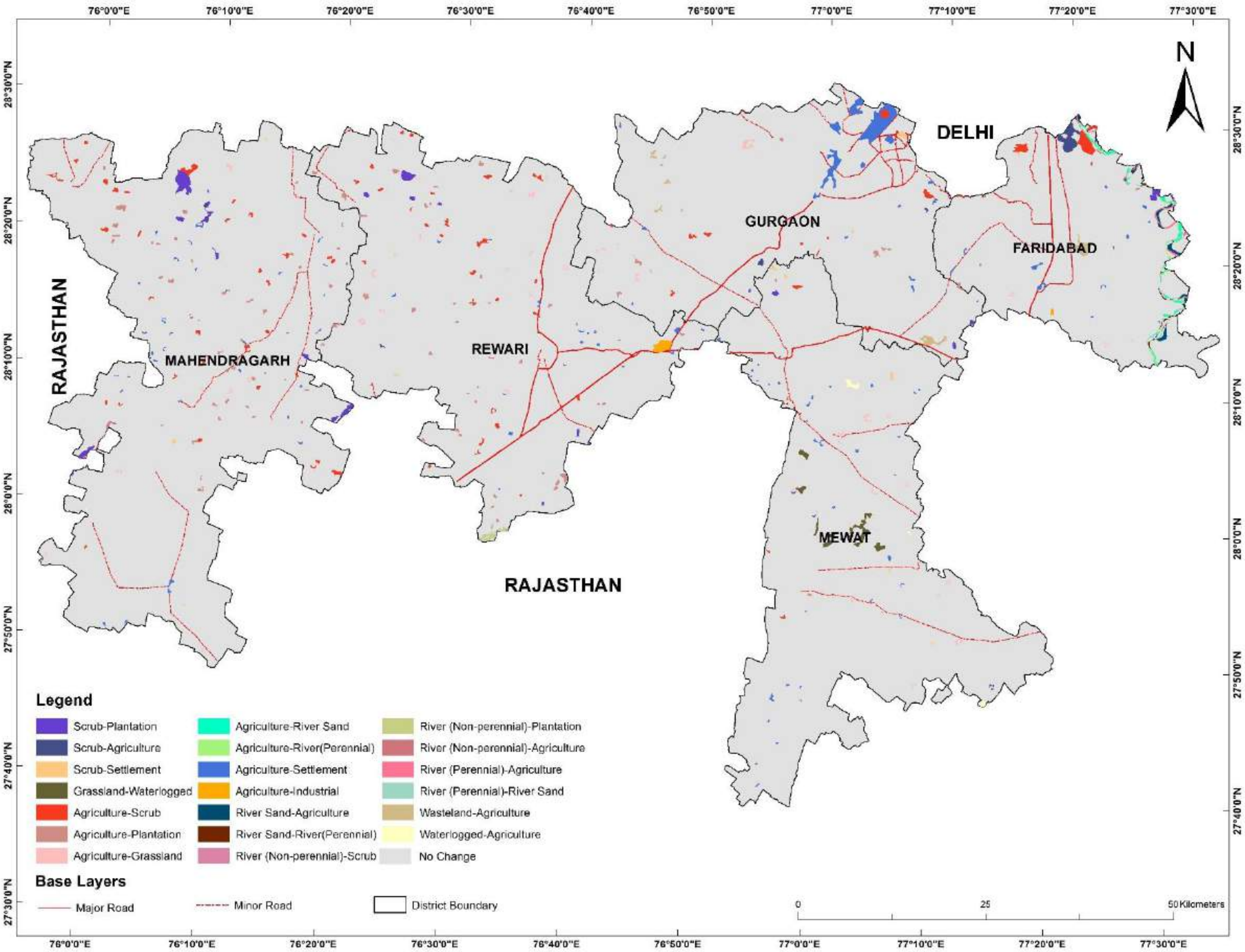


Figure 4.4: LULC Change map between 1980 and 1990 - Aravallis Haryana, India

Table 4.6: Change matrix of LU/LC from 1980 to 1990 in Aravallis Haryana, India

Class	A	B	C	G	I	O.F	P	R.S	R.NP	R.P	R.Sc	Sc	S	WL	WB	W	Total (1980)
A	**5671**	0	0	8.9	3.3	0	18.4	4.7	0	3.4	0	29.46	35.75	0	0.45	0	**5773**
B	0	**102**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**102.4**
C	0	0	**16.6**	0	0	0	0	0	0	0	0	0	0	0	0	0	**16.6**
G	0	0	0	**11.4**	0	0	0	0	0	0	0	0	0.18	0	0	8.21	**19.89**
I	0	0	0	0	**0**	0	0	0	0	0	0	0	0	0	0	0	**0**
O.F	0	0	0	0	0	**133**	0	0	0	0	0	0	0	0	0	0	**119.6**
P	0	0	0	0	0	0	**31.5**	0	0	0	0	0	0	0	0	0	**31.59**
R.S	4.6	0	0	0	0	0	0	**3.4**	0	1.3	0.12	0.19	0	0	0	0	**9.7**
R.NP	0.56	0	0	0	0	0	1.79	0	**2.1**	0	0	0.5	0	0	0	0	**5.03**
R.P	3.16	0	0	0	0	0	0	2.7	0	**1.96**	0	0.27	0.14	0	0	0	**8.29**
R.Sc	0	0	0	0	0	0	0.06	0	0	0	**0**	0	0	0	0	0	**0.063**
Sc	7.2	0	0	0	0	0	15.8	0	0	0	0	**365.1**	2.84	0	0	0	**390.96**
S	0	0	0	0	0	0	0	0	0	0	0	0	**247.4**	0	0	0	**247.53**
WL	6.71	0	0	0	0	0	2.72	0	0	0	0	0.931	3.13	**4.709**	0	0	**18.2**
WB	0.9	0	0	0	0	0	0	0	0	0	0	0	0	0	**1.75**	0	**2.68**
W	1.8	0	0	0	0	0	0	0	0	0	0	0	0.127	0	0	**17.62**	**19.59**
Total (1990)	**5696**	**102**	**16.6**	**20.4**	**3.34**	**119**	**70.38**	**10.99**	**2.1**	**6.75**	**0.12**	**394.4**	**289.71**	**4.6**	**2.2**	**25.85**	**Diagonal values are Unchanged area**

Note: A: Agriculture, B: Barren, C: Canal, G: Grassland, I: Industrial, O.F: Open Forest, P: Plantation, R.S: River Sand, R.NP: River (Non-Perennial), R.P: River (Perennial), R.Sc: (River Scrub), Sc: Scrub, S: Settlement, WL: Wasteland, W.B: Waterbody, W: Waterlogged

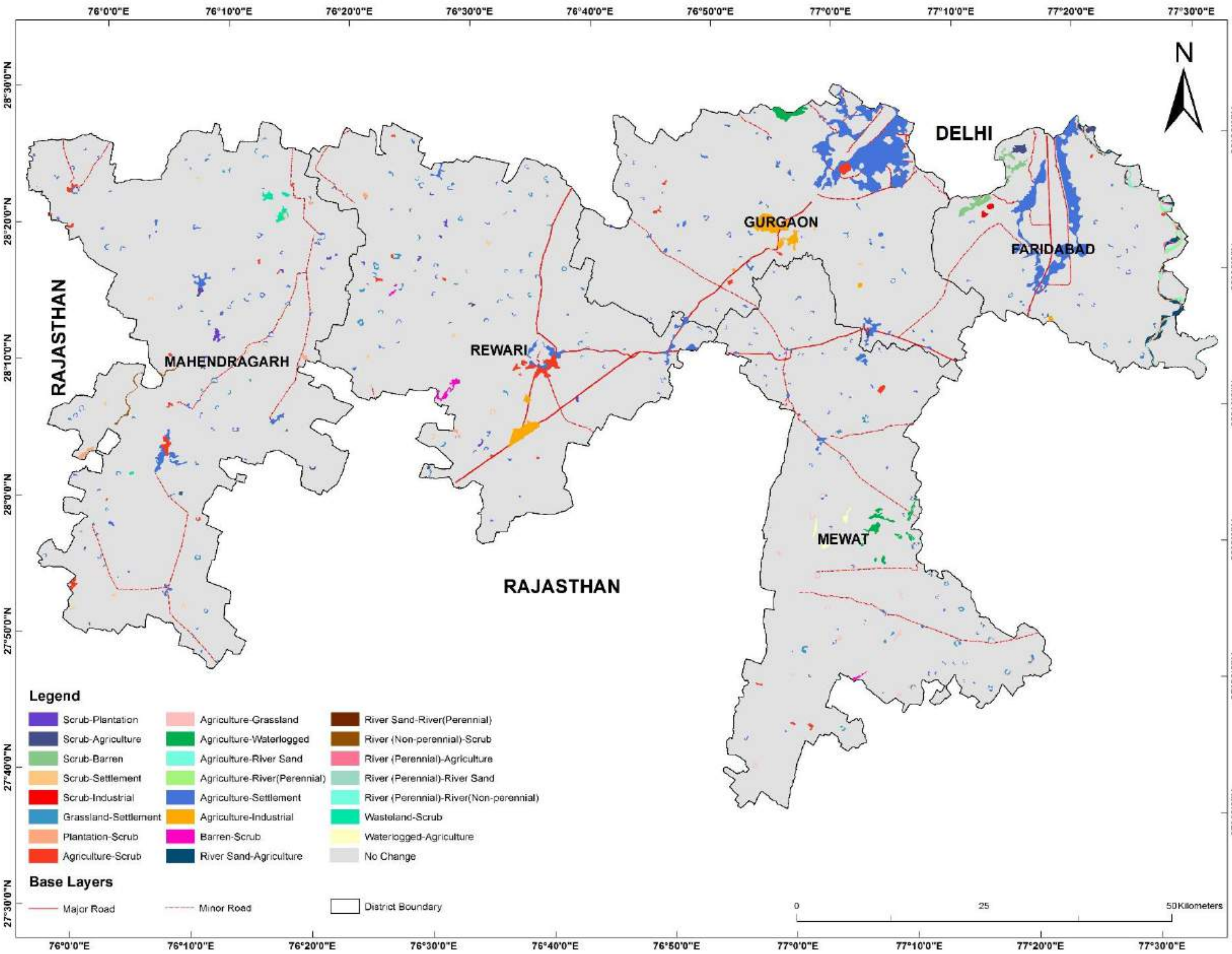


Figure 4.5: LULC Change map between 1990 and 2000 - Aravallis Haryana, India

Table 4.7: Change matrix of LU/LC from 1990 to 2000 in Aravallis Haryana, India

Class	A	B	C	G	I	O.F	P	R.S	R.NP	R.P	R.Sc	Sc	S	WL	WB	W	Total 1990
A	**5477**	0.3	0	3.89	18	0	4.05	2.04	0	2.3	0	16	160.2	0	1.1	9.9	5696
B	0	**99.4**	0	0	0	0	0	0	0	0	0	2.9	0	0	0	0	102.4
C	0	0	**25.5**	0	0	0	0	0	0	0	0	0	0	0	0	0	25.54
G	1.37	0	0	**8.64**	0	0	0	0	0	0	0	0.153	10.17	0	0	0	20.36
I	0	0	0	0	**3.33**	0	0	0	0	0	0	0	0	0	0	0	3.34
O.F	0	0	0	0	0	**119**	0	0	0	0	0	0	0	0	0	0	119.7
P	1.56	0	0	0	0	0	**64.34**	0	0	0	0	3.04	1.44	0	0	0	70.3
R.S	5.7	0	0	0	0	0	0	**2.5**	0	2.4	0.12	0.08	0	0	0	0	10.97
R.NP	0	0	0	0	0	0	0.26	0	**0.07**	0	0	1.7	0	0	0	0	2.1
R.P	1.8	0	0	0	0	0	0	1.9	0.4	**2.4**	0.066	0.06	0	0	0	0	6.7
R.Sc	0	0	0	0	0	0	0	0	0	0.01	**0.11**	0	0	0	0	0	0.128
Sc	4.2	7.3	0	0	1.07	0	3.8	0	0	0.056	0	**374.5**	3.18	0	0.216	0	394.5
S	0	0	0	0	0	0	0	0	0	0	0	0	**289**	0	0	0	289.6
WL	0	0	0	0.23	0	0	0	0	0	0	0	3.31	0.96	**0.1**	0	0	4.6
WB	0.06	0	0	0	0	0	0	0	0	0	0	0	0	0	**2.16**	0	2.2
W	2.45	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**23.38**	25.83
Total 2000	**5495**	**102**	**16.8**	**12.7**	**22.4**	**119**	**72.47**	**6.6**	**0.49**	**7.39**	**0.18**	**401.6**	**465.6**	**0.176**	**3.55**	**33.39**	**Diagonal values are Unchanged area**

Note: A: Agriculture, B: Barren, C: Canal, G: Grassland, I: Industrial, O.F: Open Forest, P: Plantation, R.S: River Sand, R.NP: River (Non-Perennial), R.P: River (Perennial), R.Sc: (River Scrub), Sc: Scrub, S: Settlement, WL: Wasteland, W.B: Waterbody, W: Waterlogged

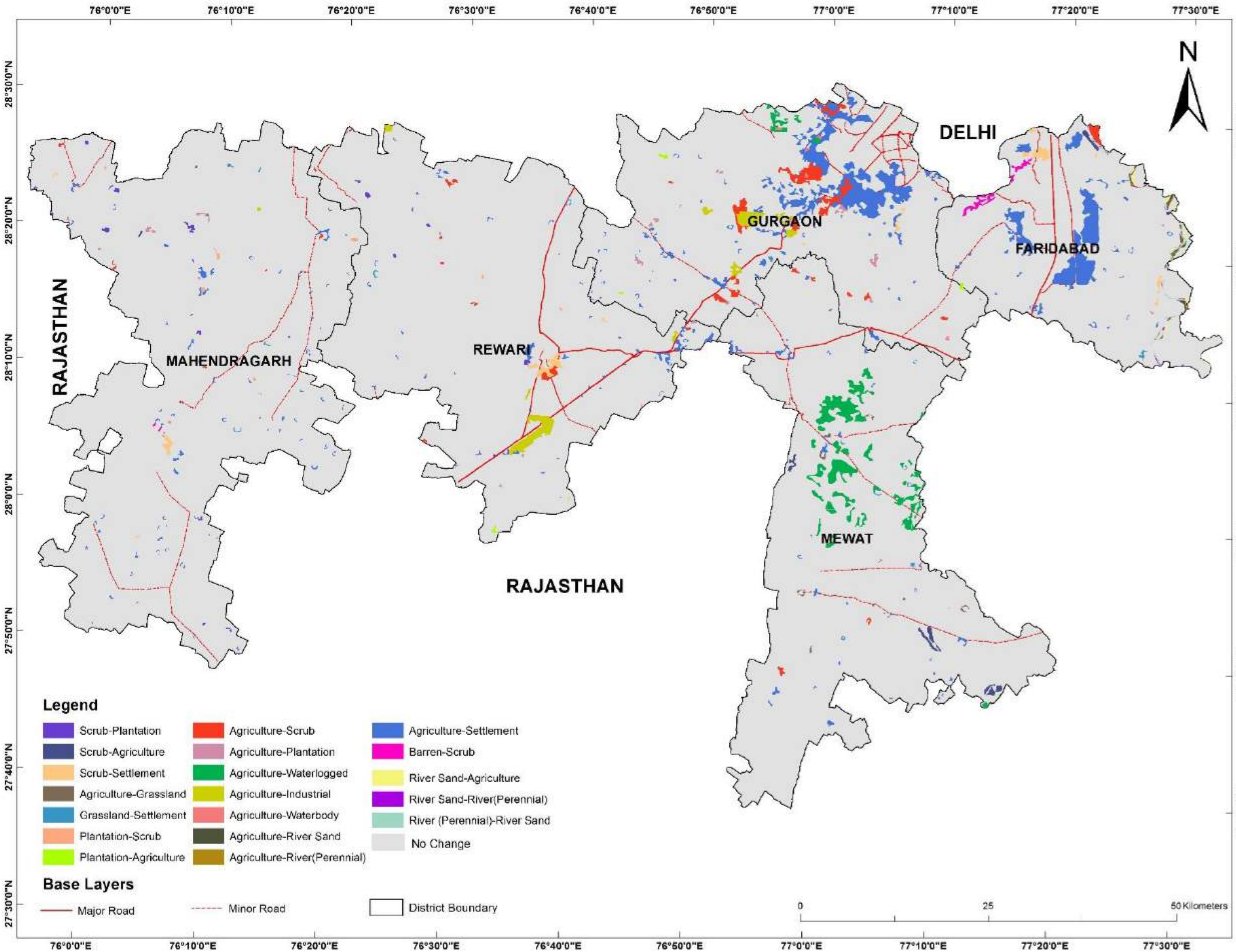


Figure 4.6: LULC Change map between 2000 and 2016 - Aravallis Haryana, India

Table 4.8: Change matrix of LU/LC from 2000 to 2016 in Aravallis Haryana, India

Class	A	B	C	G	I	O.F	P	R.S	R.NP	R.P	R.Sc	Sc	S	WL	WB	W	Total 2000
A	**5220**	0	0	2.14	23.9	0	5.54	2.19	0	1.3	0	32.47	154	0.32	1.6	51	5495
B	0	**101**	0	0	0	0	0	0	0	0	0	4.9	0.4	0	0.2	0	107.1
C	0	0	**16.6**	0	0	0	0	0	0	0	0	0	0	0	0	0	16.6
G	0	0	0	**10.2**	0	0	0	0	0	0	0	0	2.4	0	0.1	0	12.79
I	0	0	0	0	**22.4**	0	0	0	0	0	0	0	0	0	0	0	22.45
O.F	0	0	0	0	0	**119**	0	0	0	0	0	0	0.3	0	0	0	119.7
P	1.61	0	0	0	0	0	**68.38**	0	0	0	0	1.7	0.75	0	0	0	72.48
R.S	2.3	0	0	0	0	0	0	**3**	0	1.1	0	0.11	0	0	0	0	6.6
R.NP	0.4	0	0	0	0	0	0	0	**0.07**	0	0	0	0	0	0	0	0.47
R.P	1.7	0	0	0	0	0	0	2.8	0	**2.6**	0	0.12	0	0	0	0	7.3
R.Sc	0.1	0	0	0	0	0	0	0.08	0	0	**0**	0	0	0	0	0	0.18
Sc	7.5	0	0	0	0.16	0	4.47	0.04	0	0.27	0	**373.8**	14.97	0	0.613	0	402
S	0	0	0	0	0	0	0	0	0	0	0	0	**465**	0	0	0	465.64
WL	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.17**	0	0	0.17
WB	0	0	0	0	0	0	0	0	0	0	0	0.31	0.099	0	**3.1**	0	3.5
W	0.72	0	0	0	0	0	0	0	0	0	0	0		0	0.33	**32.32**	33.3
Total 2016	**5235**	**101**	**16.6**	**12.3**	**46.1**	**119**	**78.38**	**8.1**	**0.1**	**5.5**	**0**	**413.6**	**638.8**	**0.4**	**6.1**	**83.3**	**Diagonal values are Unchanged area**

Note: A: Agriculture, B: Barren, C: Canal, G: Grassland, I: Industrial, O.F: Open Forest, P: Plantation, R.S: River Sand, R.NP: River (Non-Perennial), R.P: River (Perennial), R.Sc: (River Scrub), Sc: Scrub, S: Settlement, WL: Wasteland, W.B: Waterbody, W: Waterlogged

Vegetation Type

A vegetation type map of the study area was prepared. Champion and Seth's (1968) classification scheme was considered as it follows a hierarchical approach wherein climatically driven forest ecosystems with distinct physiognomy and phenology are primarily classified as type groups. The prepared vegetation list was discussed with component specialist, and data so finalized was validated on ground. The satellite based remote sensing data of Landsat 8 was used for delineation of polygons by using various visual interpretation keys and depicted in Figure 4.7 and area details in Table 4.9.

As per forest type of Champion and Seth (1968), only two types of vegetation classes are present, namely Northern Dry Mixed Deciduous Forest (5B/C_2) and Dry Deciduous Scrub (5/DS_1).

Table 4.9: Area under different vegetation types, Aravallis Haryana, India

Vegetation Type	Area (km^2)
Northern dry mixed deciduous	119.4
Deciduous scrub	413.5
Grassland	12.4
Plantation	78.4
Waterbody	11.8
Non-Forest	6130.6

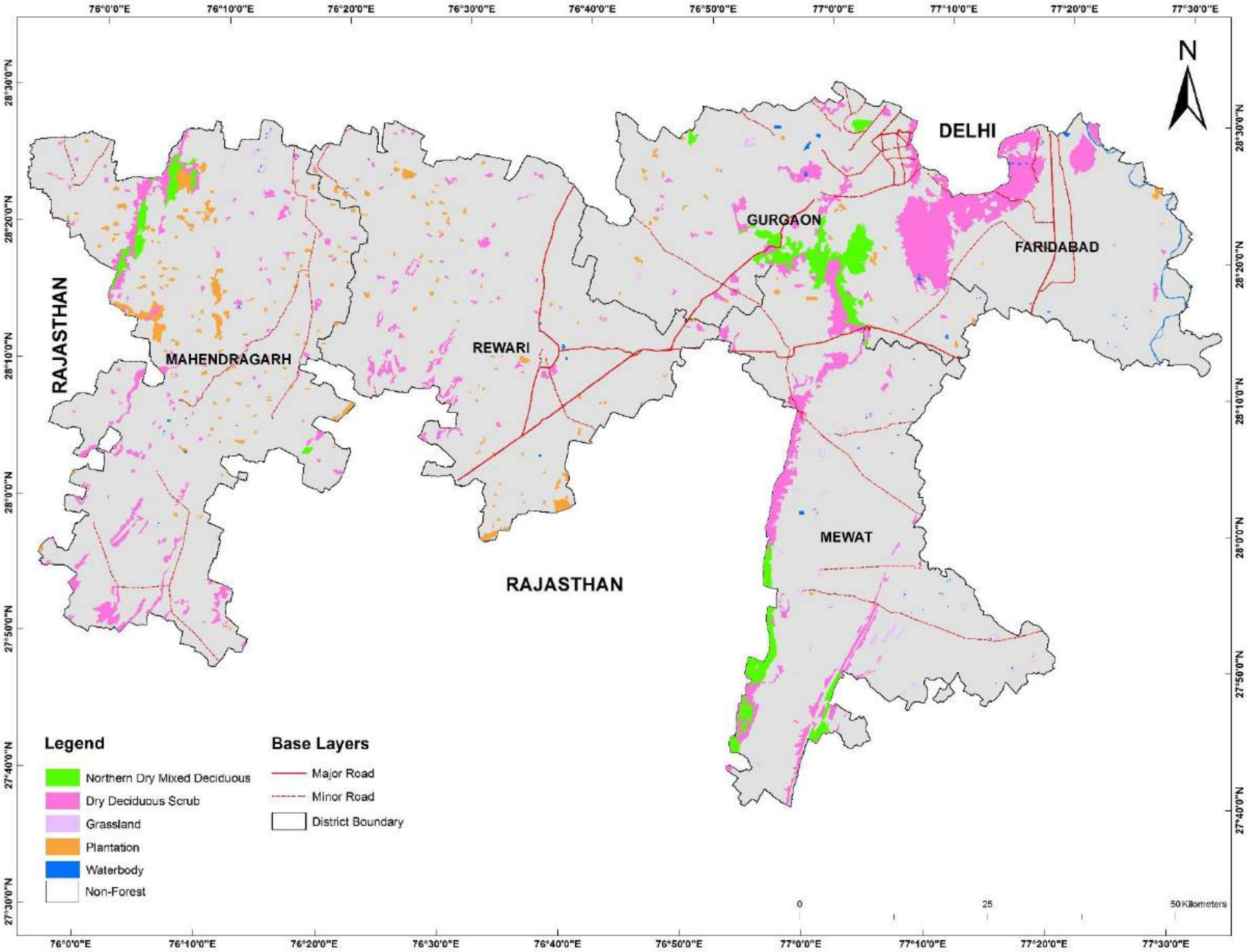


Figure 4.7: Vegetation Type Map of Aravallis Haryana (2016)

Digital Elevation Model and Aspect

ASTER 30 m DEM was used for the generation of a DEM for Aravallis, Haryana. The original data is processed to fill sinks in the DEMs using Arc Map. Further, using spatial analysis tool of ArcMap aspect and relief maps were developed (Figure 4.8, and 4.9). Higher slope values represent steeper terrain while lower slope values represent flatter terrain. Further, in low to moderate slopes the runoff is slow allowing more water to percolate while in steep slopes the runoff is high and less infiltration occurs and has poor groundwater potential (Waiker & Nilawar, 2014). The aspect has significance in understanding the slope stability (Chandel, et al., 2011). The range of elevation of the Haryana is 170 m to 1500 m.

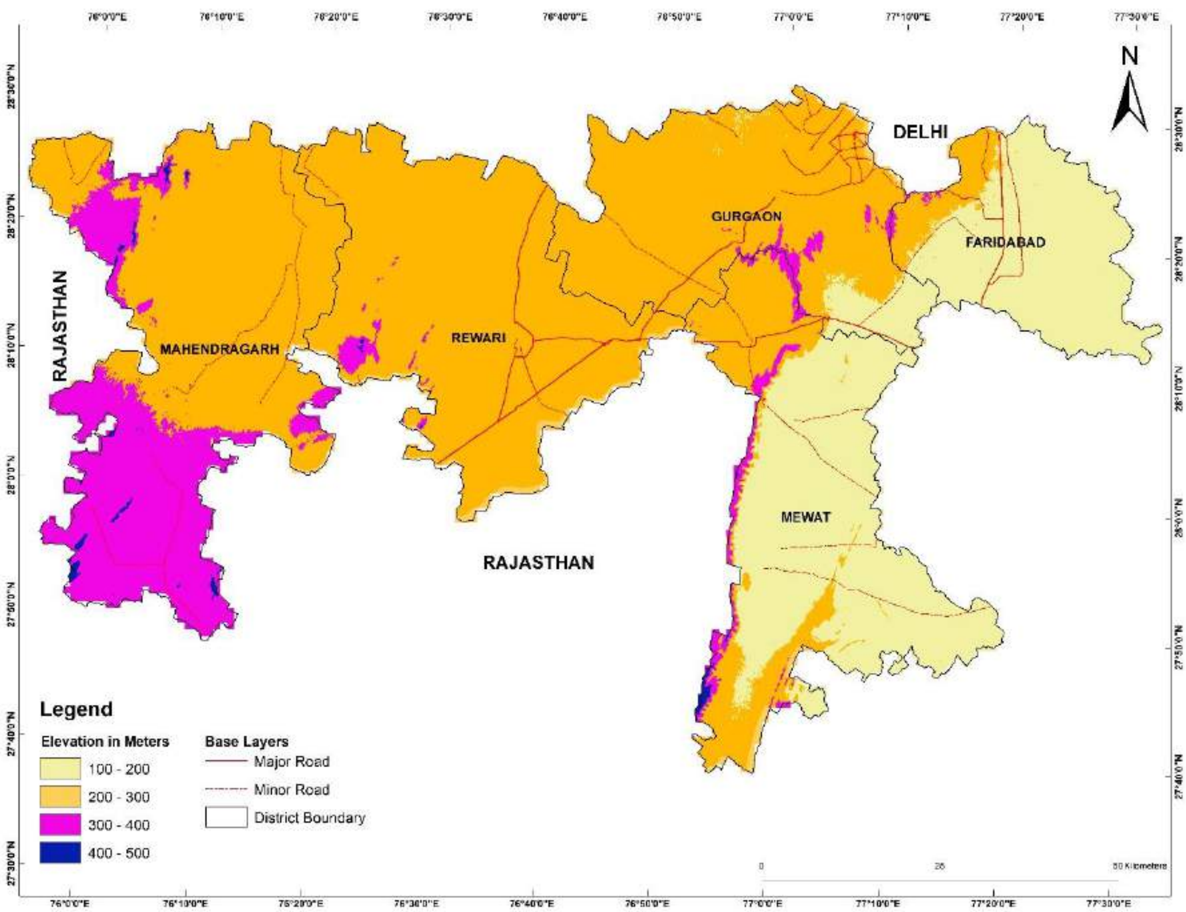


Figure 4.8: Relief Map (Intensive Study Site) Aravallis Haryana, India

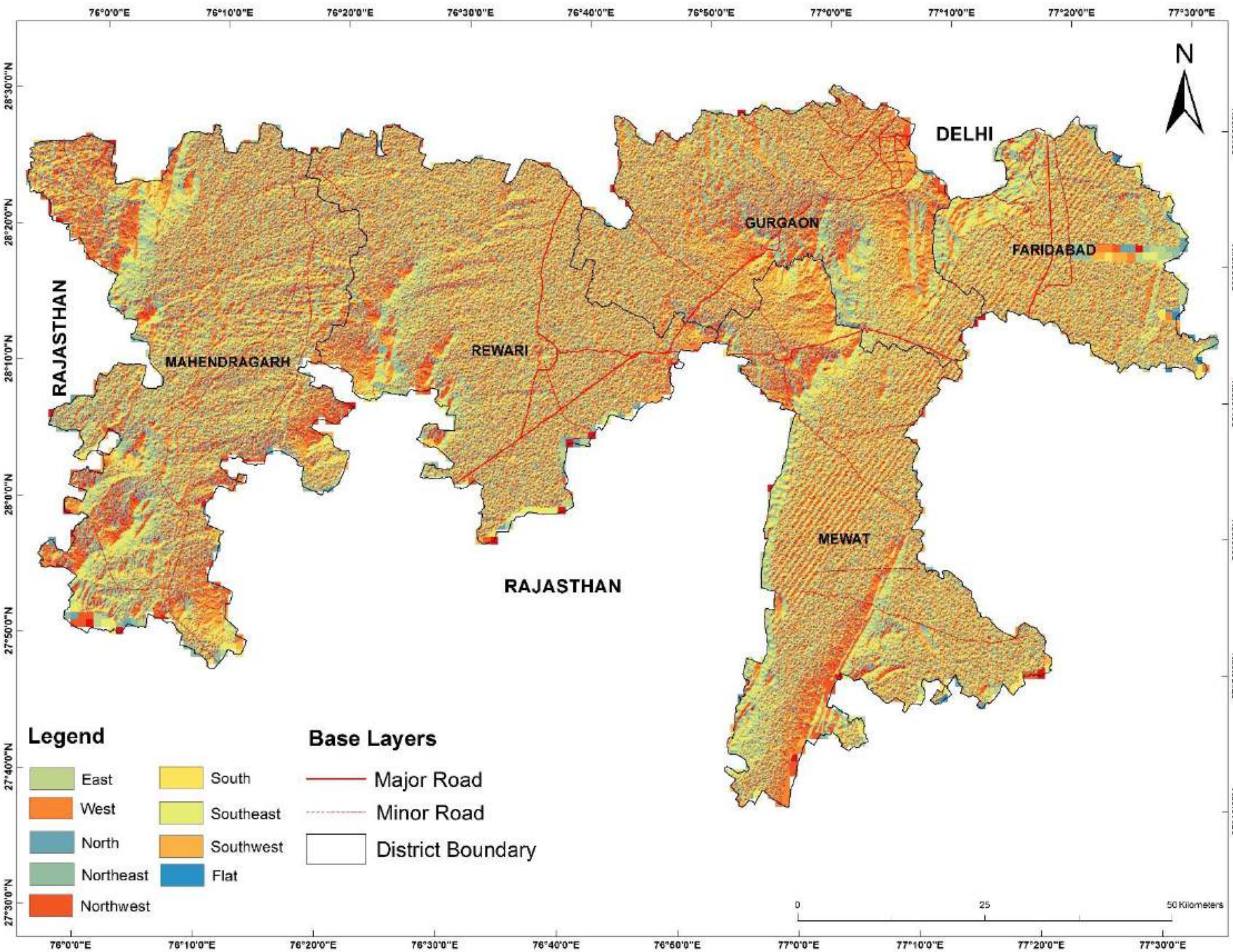
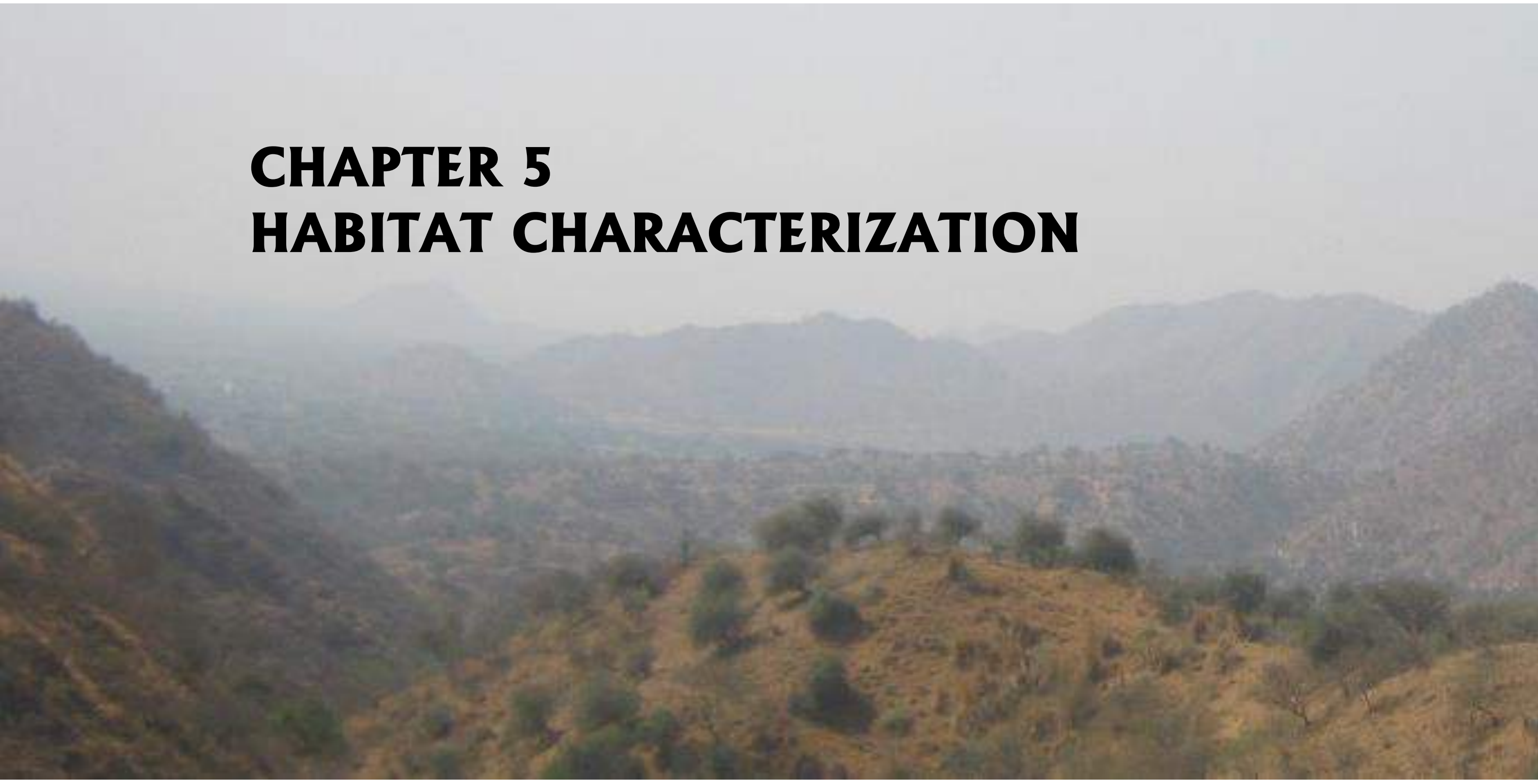


Figure 4.9: Aspect Map (Intensive Study Site) Aravallis Haryana, India



CHAPTER 5
HABITAT CHARACTERIZATION

Habitat and its quality are a primary indicating factor of the distribution and abundance of animals and basis for most conservation and management decisions. Habitat is an area with the combination of necessary resources (e.g., food, cover, water) and environmental conditions (temperature, precipitation, presence or absence of predators and competitors) that promotes occupancy by individuals of a given species (or population) and allows those individuals to survive and reproduce. It comprises the interaction among soils, hydrology, vegetation, and climate. A habitat provides the necessary ecological functions and processes to preserve the biological communities that live within it for all or a portion of their life cycle.

Vegetation parameters were characterized across each beat. 10 m radius circular plots where sampled at a distance of 400 m on each line transect of 2 km length. At each sampling point tree cover, grass cover and shrub cover was recorded. Associated data such as distance from road, village, and number of lopped tress and no. of lopped tress were also recorded for each sampling plot. These parameters were used as covariates for occupancy estimation. Occupancy estimates are higher in the areas where the habitat covariates such as Shrub cover and tree cover are highest.

Gurgaon – Raisna (Site) had highest tree cover followed by Damdama. Tree cover within the Gurgaon district was lowest at Manesar site. The variation of Grass, Shrub and Tree cover across sampled sites is shown in Figure 5.1.

📷Paridhi Jain

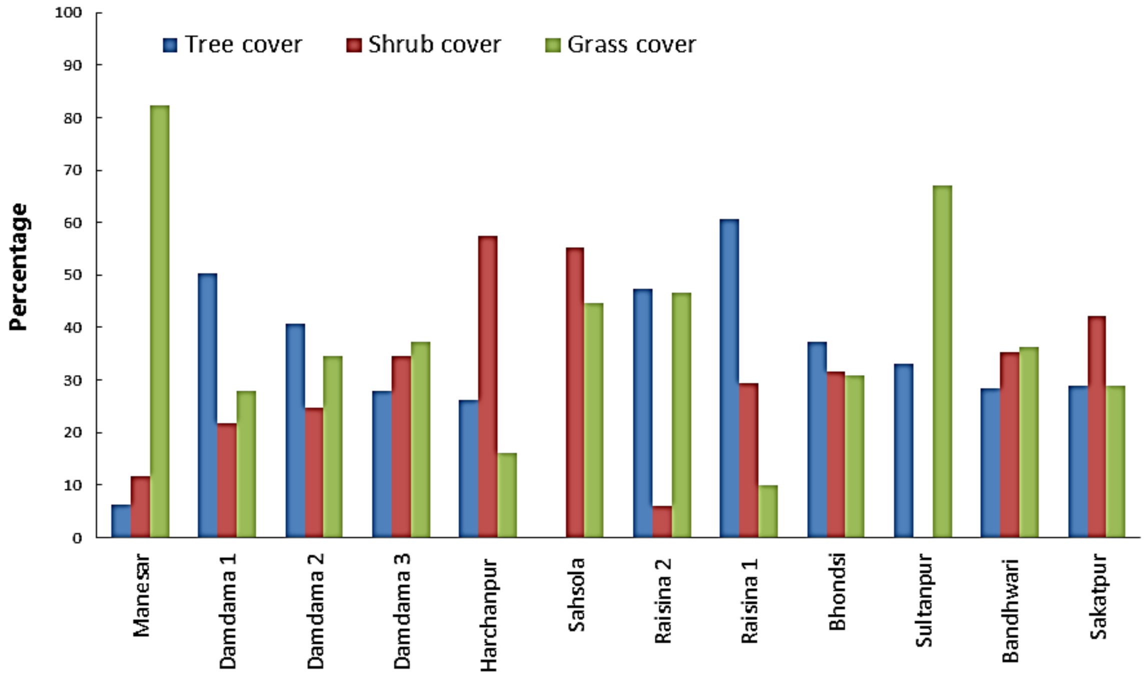


Figure 5.1: Percent Tree, Shrub and Grass Cover across various Sampling Sites in Gurgaon, Haryana, India

Faridabad - Mangar 1 and Mangar 2 had almost uniform pattern of presence of Tree, Shrub and Grass Cover. Grass cover and shrub cover was relatively high in Pali Bhakhiri and Kot. The variation of Grass, Shrub and Tree cover across sampled sites is shown in Figure 5.2.

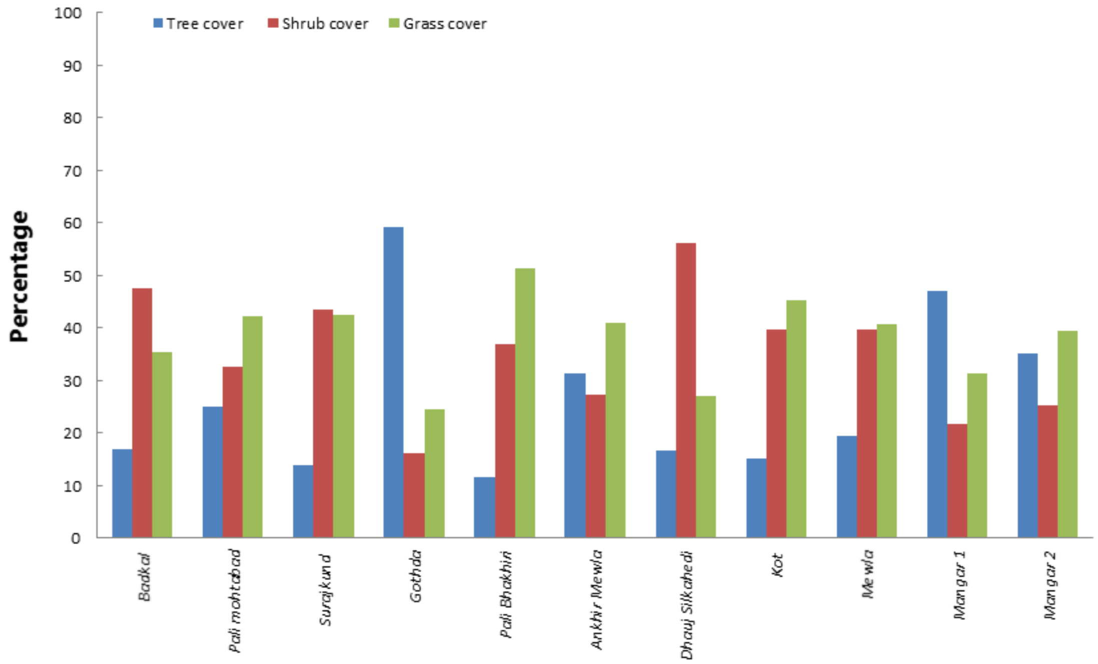


Figure 5.2: Percent Tree, Shrub and Grass Cover across various Sampling Sites in Faridabad, Haryana, India

Rewari - Tree cover and shrub cover was highest in Jabua. Khol Khaletha had highest percentage of grass cover**.** The variation of Grass, Shrub and Tree cover across sampled sites is shown in Figure 5.3.

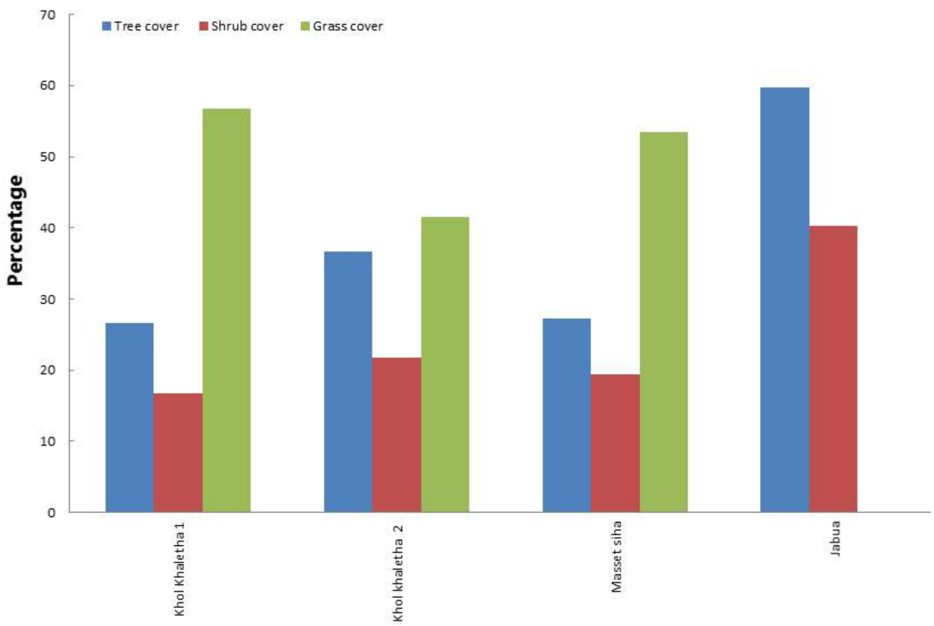


Figure 5.3: Percent Tree, Shrub and Grass Cover across various Sampling Sites in Rewari, Haryana, India

Mewat - Tree cover was in highest in Kota Khandewla with almost no grass cover and very less shrub cover. Grass cover was high Panchgaon site. The variation of Grass, Shrub and Tree cover across sampled sites is shown in Figure 5.4.

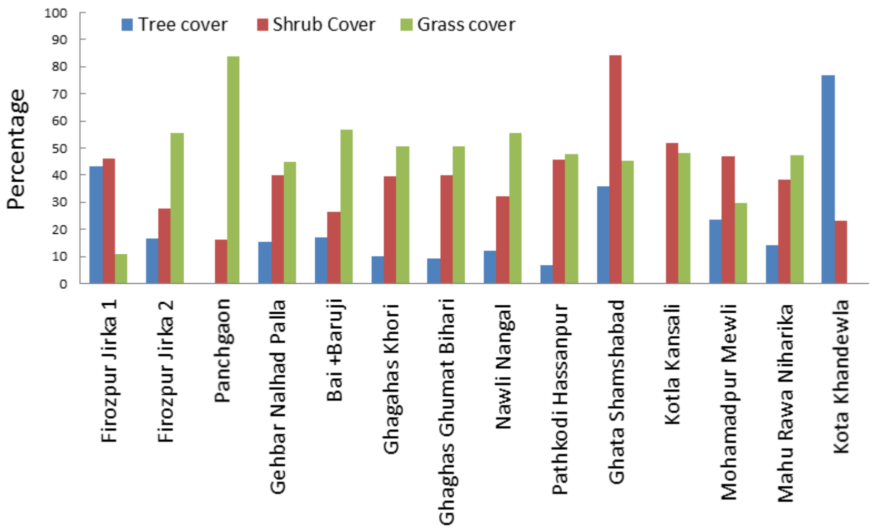


Figure 5.4: Percent Tree, Shrub and Grass Cover across various Sampling Sites in Mewat, Haryana, India

Mahendargarh - Tree cover was highest in Sohla Budin Reserve Forest followed by Salimabad. Shrub cover was highest in Panchota while Salimabad and Khudana had almost no shrub cover. Grass cover was highest at Khudana. The variation of Grass, Shrub and Tree cover across sampled sites is shown in Figure 5.5.

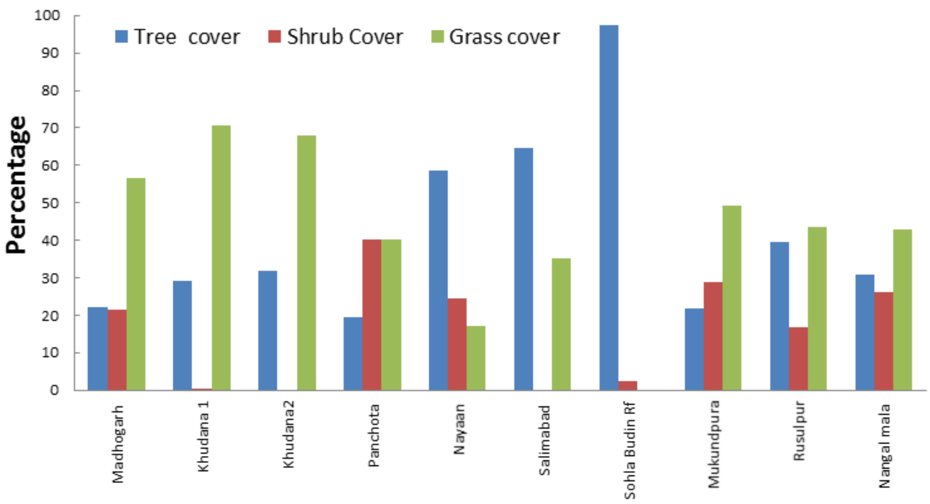


Figure 5.5: Percent Tree, Shrub and Grass Cover across various Sampling Sites in Mahendargarh, Haryana, India

CHAPTER 6
POPULATION STATUS UNGULATES AND BIRDS

Introduction

The study was conducted in southern Haryana with emphasis on the Aravalli Landscape from January to April 2016 to identify priority areas for conservation. 51 sites were sampled in five forest divisions of Aravallis Haryana namely Gurgaon, Faridabad, Mewat, Mahendargarh and Rewari. Line transect surveys were conducted to estimate the density of ungulates and birds. Ungulates recorded on the surveys were Nilgai and Chinkara. Birds species recorded on the line transect were Grey francolin, Peafowl and Black francolin. Density of species has been calculated using distance sampling. Density has been calculated only for Nilgai and Grey francolin, as for the other species sightings were low to calculate the density.

Distance Sampling

Distance sampling has been widely used for estimating the abundance and density of animal species mainly using the line transect and point transect. In both the techniques the observer walks on a straight line (line transect) or series of points searching for objects of interest (animals or cluster of animals). For each object, detected distance from the line or point is recorded.

Three assumptions for estimation of density are critical (Buckland et al, 2001):

- Objects directly on the line or point are always detected (i.e. they are detected with probability 1)
- Objects are detected at their initial location, prior to any movement in response to the observer.
- Distances and angles are measured correctly.

📷Vinit Arora

Methodology

Line transect sampling was done by two observers. Observers surveyed one transect per day typically starting at 0600 -0700 hrs and finishing at 0800 - 0900 hrs. Transect of 2 km length was monitored twice at each site across the intensive study site. While walking the transect cluster size, animal bearing, sighting distance and species were recorded. Analysis was done on the software Distance version 6.0. Best-fit model was selected based on Akaike information criteria (AIC). AIC provides an objective and quantitative method for model selection. Table 6.1 shows details of transect monitoring efforts and species recorded.

Table 6.1: Transect Monitoring Effort and Species Reported for Aravallis Haryana, India

No. of Sites Surveyed			51
No. of Transects Walked			51
Length of Each Transect			2 Km
No. of Monitoring's of Each Transect			2
Total Distance Covered			204 Km
No. of man power hours			153
No. of Species Recorded			04
Species Recorded	No. of Sightings	Individuals Counted	Mean Group Size ± SE
Nilgai	37	167	4.51 ± 0.68
Chinkara	07	14	2 ± 0.48
Grey Francolin	34	75	2.17 ± 0.32
Peafowl	11	23	2.92 ± 0.70

Results

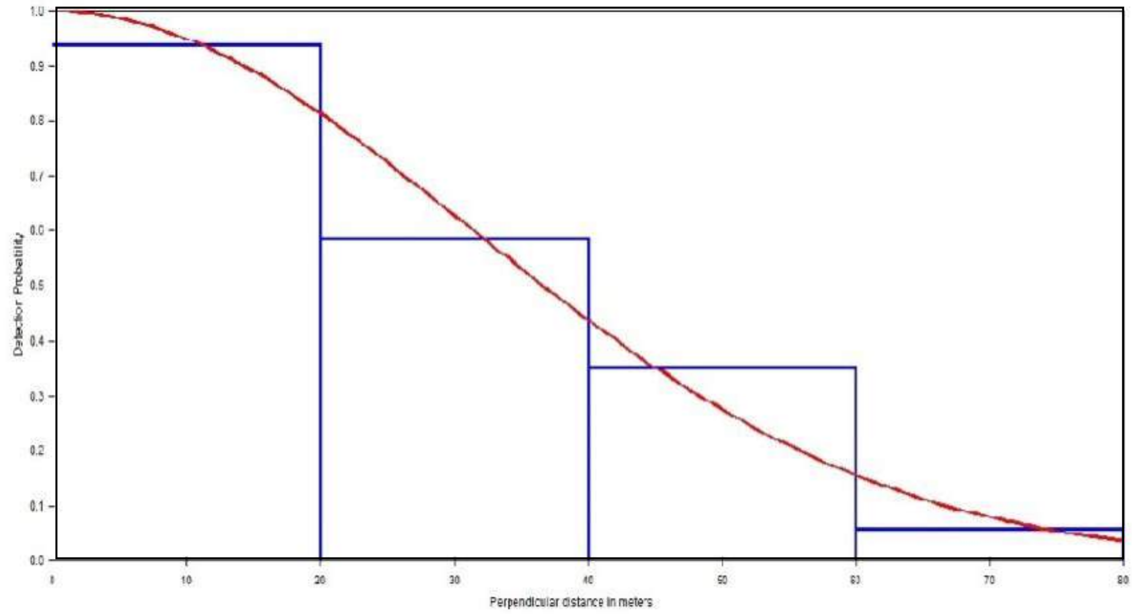
Population estimation:

Density of Nilgai and Grey Francolin was estimated using software Distance. For other species the number of sightings were two less to run distance software for density estimates. The density of the individuals (D), groups (DS), effective strip width (ESW), encounter rate (n/L), detection probability (p) and expected value of cluster size (Es) are given in Table 6.2. The detection probability against the perpendicular distance is shown in Figure 6.1.

Individual Densities of Nilgai was 8.31 animals per sq. km in the Aravallis, Haryana while Grey francolin density was 0.15 animals per sq km. **Group density** of Nilgai was 2.083 group per sq km and of Grey francolin was 0.07 group per sq km. **Expected cluster size** for Nilgai was 3.99 ± 0.70 while of Grey francolin was 2.19 ± 0.27. **Encounter rate** is the number of individuals encountered per kilometer. The encounter rate of Nilgai and grey francolin was 0.16 and 0.17 respectively. **Detection Probability** of Nilgai was 0.48 while of Grey francolin was 0.19.

Table 6.2: Individual Density, Group Density, Effective Strip Width, Average Group Size and Encounter Rate of Nilgai and Grey Francolin Aravallis, Haryana

Parameters	Nilgai	Grey Francolin
Individual Density (No. of Animal/Km^2)	8.31	0.15
Standard Error	2.69	0.004
Percent CV	32.4	30.12
95% Confidence Interval	4.44 – 15.54	0.08 – 0.27
Group Density (No. of Groups/Km^2)	2.083	0.07
Standard Error	0.56	0.001
Percent CV	27.18	27.41
95% Confidence Interval	1.22 – 3.54	0.04 – 0.12
Effective Strip Width (in meters)	38.63	11.75
Standard Error	5.46	1.55
Percent CV	14.14	13.26
95% Confidence Interval	29.0 – 51.4	8.94 – 15.31
Average Group Size	3.99	2.19
Standard Error	0.70	0.27
Percent CV	17.63	12.5
95% Confidence Interval	2.79 – 5.70	1.7 – 2.83
Encounter Rate (No. seen/Km Walk)	0.16	0.17
Percent CV	23.2	24.2
Probability of a greater chi-square value, P	0.72	0.96



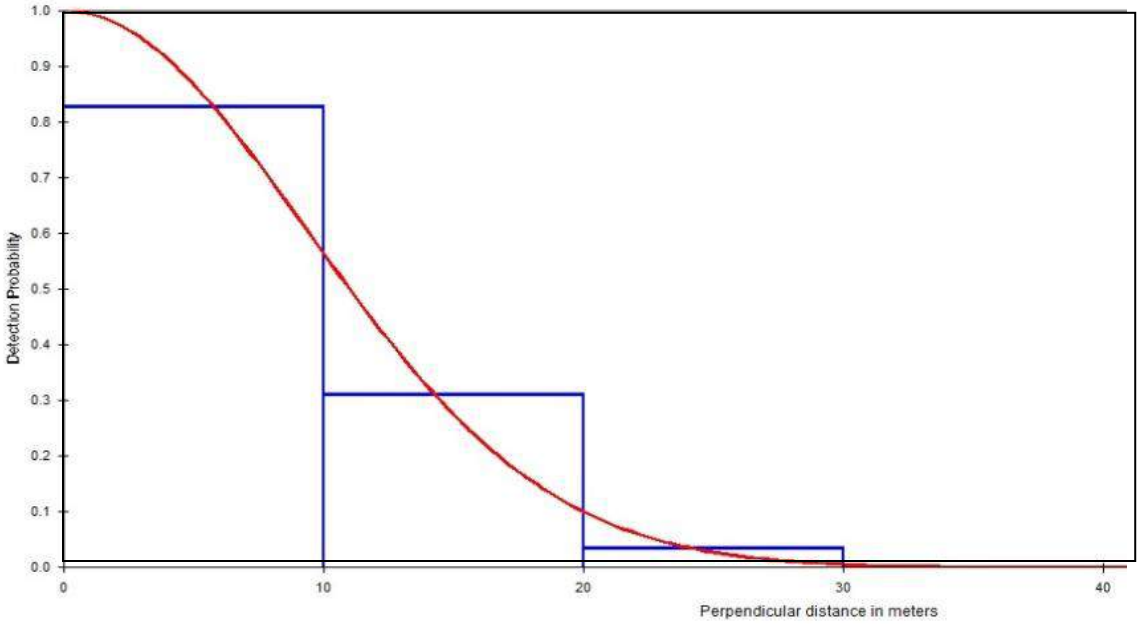
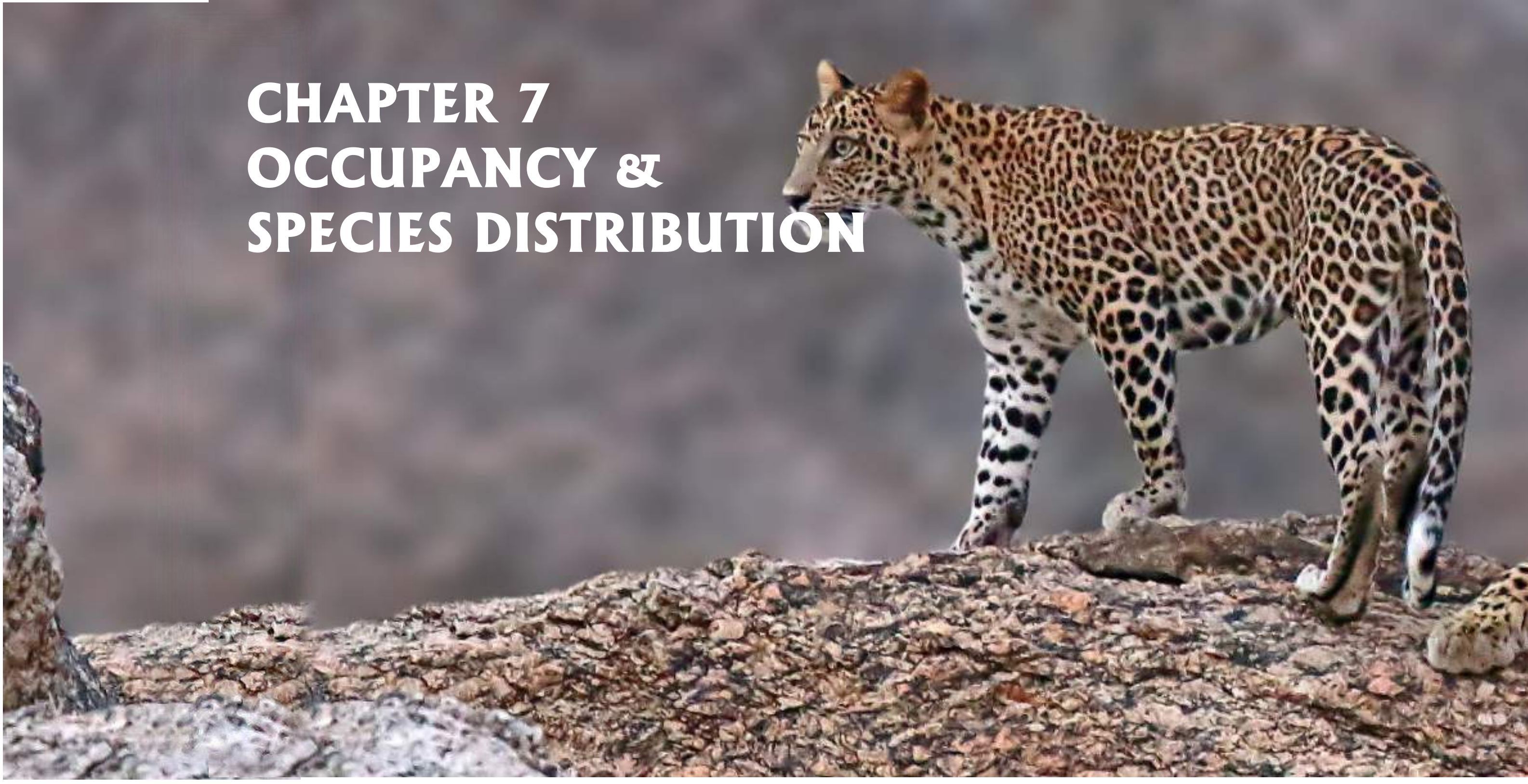


Figure 6.1: Detection Probability vs Perpendicular Distance of Nilgai and Grey Francolin, Aravallis, Haryana, India (Above – Nilgai; Below – Grey Francolin)



CHAPTER 7 OCCUPANCY & SPECIES DISTRIBUTION

Introduction

Wildlife species are rarely detected with accuracy, regardless of the technique employed. Non-detection does not mean that a species was absent unless the probability of not detecting a species is 100%. A species may be truly absent or not detected and considered absent. Occupancy models (Mackenzie et al 2002, 2003, and 2004) use Information from repeated observations at each site to estimate detectability. Detectability may vary with site characteristics (e.g., habitat variables) or survey characteristics (e.g., weather conditions), whereas occupancy relates only to site characteristics. Occupancy model is based on two key parameters: psi (ψ), which is the probability that a site is occupied and pi (the probability of detecting the species on survey i, given the species is present on the site (Donovan, 2007).

All models have assumptions, and occupancy models are no exception. Critical assumptions for data collected during a single sampling season include: (1) Occupancy state is "closed." Species are present at occupied sites for the duration of the sampling season. Occupancy does not change at a site within the sampling season, but it can change between sampling seasons. (2) Sites are independent. Detection of the target species at one site is independent of detecting the species at other sites. This might be a problem if your sites are closely spaced, allowing animals to move.

Field Sampling and Analysis

Sign surveys were conducted across 51 sites in the intensive study area. Signs such as pugmarks, scats and territory markings were recorded across the sampling sites as measure for presence of a particular species in a given beat. Pugmarks separated by

Surendra Chauhan

minimum 30 m distance were considered as separate signs. For estimating the occupancy of ungulates direct sightings and pellet groups (ungulates) were taken into account. Signs/Sightings of 10 species were recorded during the survey. The species included Leopard, Jackal, Hyena, Wolf, Fox, Jungle cat, Mongoose, Civet, Porcupine and Rhesus Macaque. Jackal was the most widespread carnivore with 166 signs in total followed by Hyena. The capture matrix was generated from the data collected during the survey. Data on site and survey co-variates was also collected during the survey. Analysis was carried in software Presence to estimate occupancy values Individual Occupancy (Psi) estimates were calculated based on Simple Single Season model along with other parameters. Site-specific covariates like vegetation, type of habitat, terrain and disturbance in the study area were used to estimate occupancy.

Occupancy was estimated for Leopard, Hyena, Nilgai and porcupine based on their relationship with covariates. Jackal was present in almost every grid with 92% naive occupancy hence its occupancy. Wolf, jungle cat, fox, honey badger, fox and rhesus macaque presence were also recorded but with extremely low number of signs across the sampling sites, hence their occupancy could not be calculated. The details of these species along with number of signs recorded for each species are given in Table 7.1. Figure 7.1 shows the location of survey sites and Table 7.2 provides details of sites surveyed along with beat name.

Table 7.1: Sign Survey Effort and Species Reported for Aravalli's, Haryana, India

No. of Sites Surveyed		51
No. of Trails Walked		51
Total Distance Covered		126.68 Km
Minimum Trail Length		2 Km
Maximum Trail Length		6.06
Average Trail length		2.43 Km
No. of Man Power Hours		255
No. of Carnivore Species Recorded		10
Species Recorded and their evidences	Leopard	31
	Jackal	166
	Porcupine	91
	Mongoose	50
	Wolf	03
	Jungle cat	26
	Fox	04
	Hyena	126
	Rhesus Macaque	02
	Civet	61

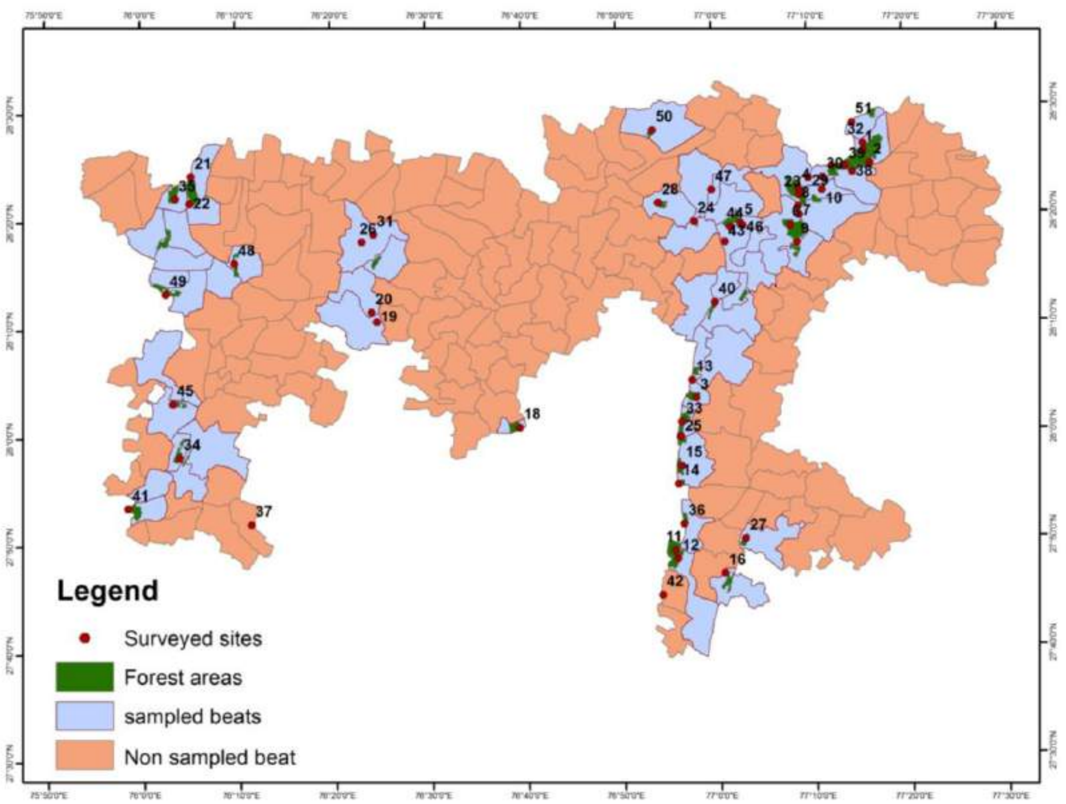


Figure 7.1: Map shows locations of survey sites in the forest areas of Aravallis Haryana with respect to beat boundaries.

Table 7.2: Surveyed sites with their respective beats, Aravallis, Haryana, India

Id	Surveyed Site	Beat
1	Ankhir Mewla	Surajkund
2	Badkal	Badkhal
3	Bai Baruji	Meoli
4	Bandhwari	Bandhwari
5	Bhondsi	Ghamroj
6	Damdama 1	Damdama
7	Damdama 2	Damdama
8	Damdama 3	Damdama
9	Damdama 4 harchanpur	Harchandpur
10	Dhauj Silakhedi	Dhoj
11	Firozpur Jirka 1	Jhir
12	Firozpur Jirka 2	Jhir
13	Gehbar Nalhad	Nallhar
14	Ghaghas Ghumat Bihari	Ghagas
15	Ghaghas Khori	Ghagas
16	Ghata Shamshabad	Biwan
17	Gothda	Gothda
18	Jabua	Jhabua
19	Khol Khaletha 1	Khol
20	Khol Khaletha 2	Khol
21	Khudana 1	Khudana
22	Khudana 2	Khudana
23	Kot	Mangar
24	Kota khandewla	Mohd.Pur
25	Kotla Kansali	Kotla
26	Madhogarh	Madhogarh
27	Mahu Rawa	Chittora
28	Manesar	Manesar
29	Mangar 1	Mangar
30	Mangar 2	Mangar
31	Maseet Siha	Siha
32	Mewla	Surajkund
33	Mewli Mohammadpur	Kotla
34	Mukundpura Rf	Mukundpura
35	Nangal mala	Nangal Mala
36	Nangal Nawli	Nasirbas
37	Nayaan	Nimatpur
38	Pali Bhakhiri	Gothda
39	Pali mohtabad	Pali
40	Panchgaon	Tauru
41	Panchota	Pachnota
42	Pathkori	Pathkhori
43	Raisina 1	Raipur
44	Raisina 2	Raipur
45	Rusulpur Rf	Rasulpur
46	Sahsola	Khod Basai
47	Sakatpur	Bhondsi
48	Salimabad Rf	Salimabad
49	Sohla Budin Rf	Sohla
50	Sultanpur	Sultanpur
51	Surajkund Lakadpur	Surajkund

Species Occupancy – Aravallis

Occupancy modeling is a hierarchical framework developed to account for the measurement error associated with the imperfect detection of a species through a series of repeated surveys at multiple locations within a defined season, where the target species is detected with either probability p, or not detected (1-*p*). The detection probability parameter (*p*), the probability of detecting a species given it is present, accounts for the false-negative measurement error, which is the compliment of detection probability (1-*p*). When a species is detected during a visit, *j*, the visit is assigned a value of "1" and when non-detection occurs, it is denoted with a "0"; a matrix of 1s and 0s is developed from multiple visits and sites to determine a species' encounter history. This encounter history matrix is ultimately used to evaluate the state parameter of interest, occupancy, Ψ, or the probability that a species is present at site *i*

Species-specific detection histories from surveys were prepared and occupancy for each species was estimated. Single-season site-occupancy models developed by Mackenzie *et al.* (2002) to estimate the detection process and the probability of site occupancy. We used the link function during model building to express the effects of covariates that varied spatially. Covariates included tree cover, shrub cover and disturbance index. Step-wise process were used to identify the model parameters that best explained data, which entailed initially holding Ψ constant (null model Ψ(.)) while fitting the measurement error model of detection probability. Once the top detection model was identified, we then fitted a suite of occupancy models to habitat covariates collected that could explain the distribution of the species at our intensive study site. Models were ranked according to their Akaike's Information Criterion (AIC) value. Occupancy analysis for jackal was not estimated as the species occurred at almost all the sites sampled and for many other species because of their overall low detection rates during the survey. The occupancy was estimated for Leopard, Hyena, Nilgai and Porcupine for the intensive study site. Best model was selected based n lowest AIC values. Model averaging was done, in case the difference between two AIC values was less than 2.

Leopard Occupancy – was estimated to be 60 % (Ψ = 0.6 ± 0.10, Table 7.3, Model Averaging). Site-specific habitat co-variates shrub cover (0.85± 0.57 Beta Coefficient) and tree cover (0.95± 0.64 Beta Coefficient) best-explained leopard occupancy (Table 7.4). Total area under leopard occupancy (Category 1) was estimated to be 200.9 sq. km. Sites namely Gamroj (Bhondsi), Raipur (Raisina), Mangar, Gothda, Badhkal, Kotla Kansali, Nimatpur (Nayaan), Khol and Panchota had higher psi estimates (Figure 7.2).

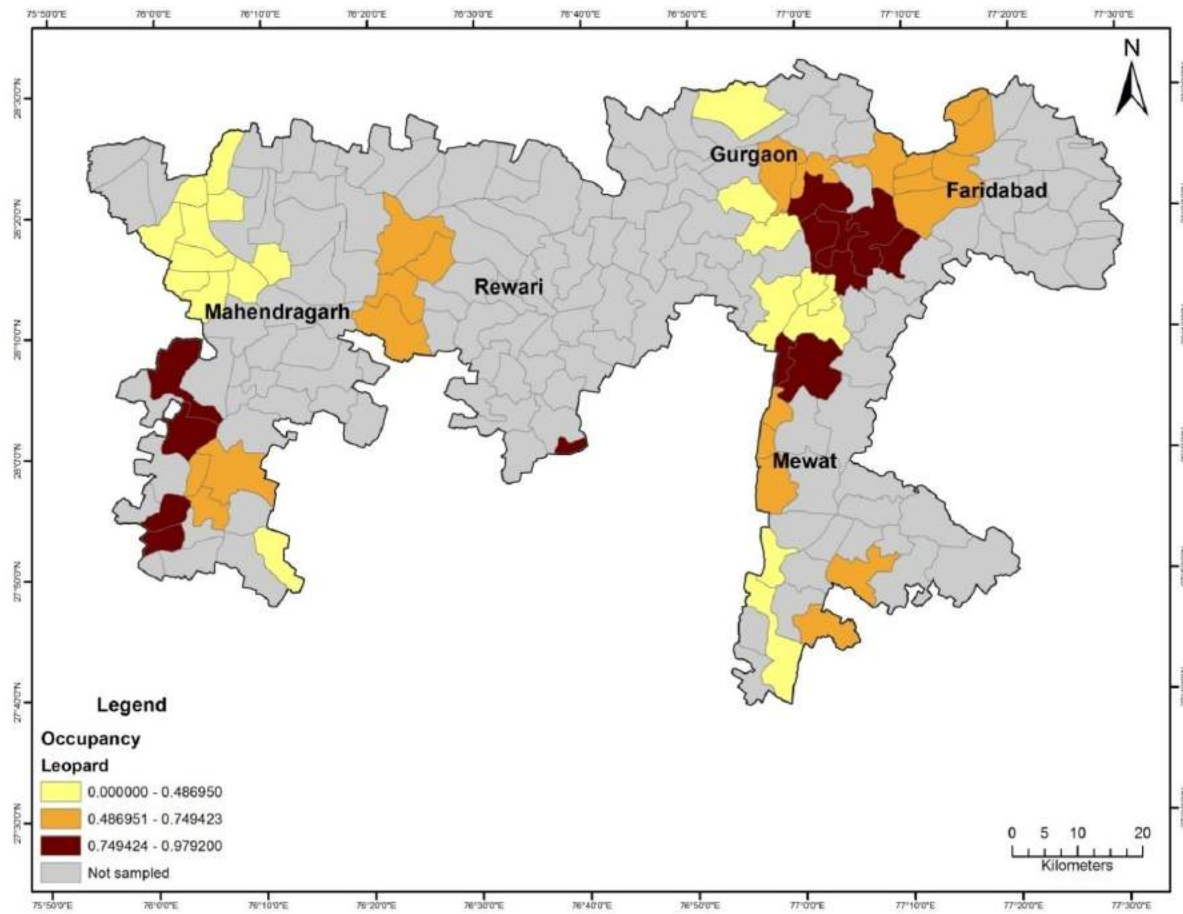


Figure 7.2: Leopard occupancy across Aravallis Haryana, India

Table 7.3: Estimates of state parameters in occupancy modelling derived from detection histories in Aravallis, Haryana, India

Species	Naïve Ψ[a]	Ψ(.)[b]	p(.)[c]	SE(p)[d]	AIC	Δ AIC	AIC wt
Leopard	0.41	0.58	0.26	0.05	178.22	1.54	0.1336
Hyena	0.68	0.69	0.77	0.03	224.45	3.74	0.1132
Nilgai	0.62	0.78	0.34	0.07	255.83	4.15	0.0672
Porcupine	0.74	0.88	0.31	0.04	255.83	4.15	0.0449

Naïve occupancy estimates were calculated following (MacKenzie et al. (2002), and represents the proportion of total sites at which a species was detected. Occupancy and detection estimates presented are the beta estimates from null model [Ψ(.) p(.)].

[a] The proportion of sites a species was actually detected.

[b] Occupancy probability – the estimation of the proportion of sites occupied, given the detection history of a species.

[c] Detection Probability – the probability of detecting a species, given it is present.

[d] Standard error of detection probability estimates.

Table 7.4: Comparison of the top fitting and null models in occupancy modelling for each species at Aravallis, Haryana, India

Species	Models	Naïve Ψ	Ψ(.)	p(.)	SE(p)	AIC	Δ AIC	AIC wt
Leopard	**psi(shrub cover tree cover .),p(.)**	**0.41**	**0.61**	**0.25**	**0.05**	**176.68**	**0**	**0.2886**
	psi(.disturbance index),p(.)	0.41	0.6	0.27	0.05	177.31	0.63	0.2106
	psi(tree cover),p(.)	0.41	0.57	0.26	0.05	177.74	1.06	0.1698
	psi(.shrub cover),p(.)	0.41	0.61	0.25	0.06	178.05	1.37	0.1455
	psi(.),p(.)	0.41	0.58	0.26	0.05	178.22	1.54	0.1336
Hyena	**psi(.weed cover),p(.)**	**0.68**	**0.68**	**0.77**	**0.03**	**220.7**	**0**	**0.7342**
	psi(.shrub cover),p(.)	0.68	0.69	0.77	0.03	225.49	4.78	0.0673
	psi(.),p(.)	0.68	0.69	0.77	0.03	224.45	3.74	0.1132
Nilgai	**psi(.tree cover weed cover),p(.)**	**0.62**	**0. 76**	**0.34**	**0.07**	**276.05**	**0**	**0.3444**
	psi(shrub cover tree grass.),p(.)	0.62	0.78	0.32	0.07	277.04	0.99	0.21
	psi(tree cover disturbance index .),p(.)	0.62	0.77	0.33	0.07	277.44	1.39	0.1719
	psi(.shrub cover tree disturbance),p(.)	0.62	0.76	0.31	0.05	278.95	2.9	0.0808
	psi(.),p(.)	0.62	0.78	0.34	0.07	255.83	4.15	0.0672
Porcupine	**psi(.shrub cover),p(.)**	**0.74**	**0.87**	**0.32**	**0.03**	**250.27**	**0**	**0.5624**
	psi(.tree cover shrub cover),p(.)	0.74	0.86	0.31	0.04	251.68	1.41	0.2779
	psi(.weed cover),p(.)	0.74	0.85	0.34	0.04	253.68	3.41	0.1022
	psi(.),p(.)	0.74	0.88	0.31	0.04	255.83	4.15	0.0449

Hyena Occupancy – was estimated to be 68 % (Ψ = 0.68 ± 0.06, Table 7.3). Site-specific habitat co-variate weed cover (- 0.77± 0.37 Beta Coefficient) best-explained hyena occupancy (Table 7.4). Most of the sampled sites had higher estimate for hyena across the landscapes. Total area under hyena occupancy (Category 1) was estimated to be 643.49 sq. km (Figure 7.3).

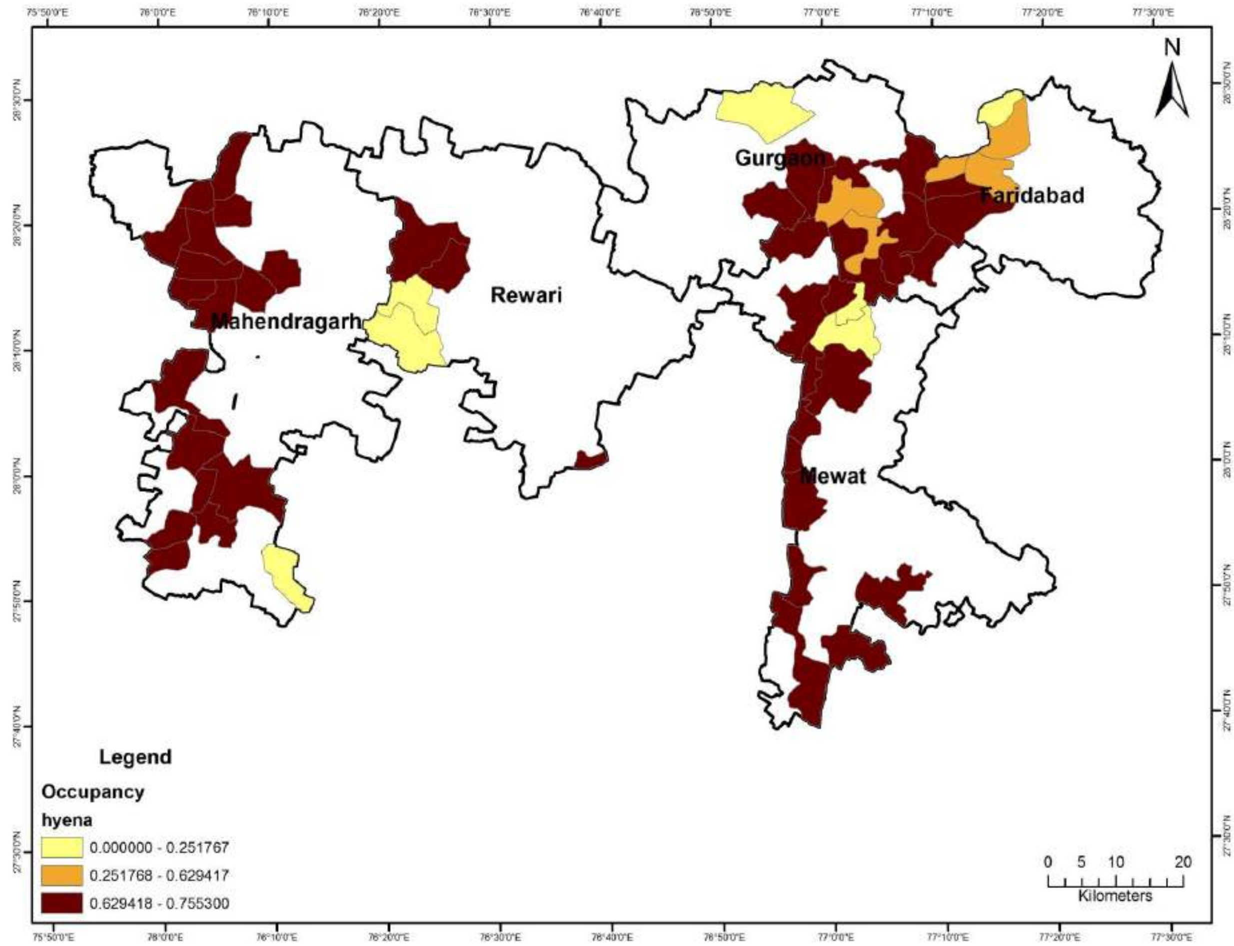


Figure 7.3: Hyena occupancy across Aravallis Haryana, India

Nilgai Occupancy – was estimated to be 77 % ($\Psi = 0.77 \pm 0.07$, Table 7.3, Model Averaging). Site-specific habitat co-variates tree cover (3.11± 1.3 Beta Coefficient) and weed cover (0.72± 0.51 Beta Coefficient) best-explained Nilgai occupancy (Table 7.4). Total area under Nilgai occupancy (Category 1) was estimated to be 131.48 sq. km. Sites namely Nimatpur, Khol, Surajkund, Sultanpur, Gamroj, Badkal and Harchandpur had higher psi estimates (Figure 7.4).

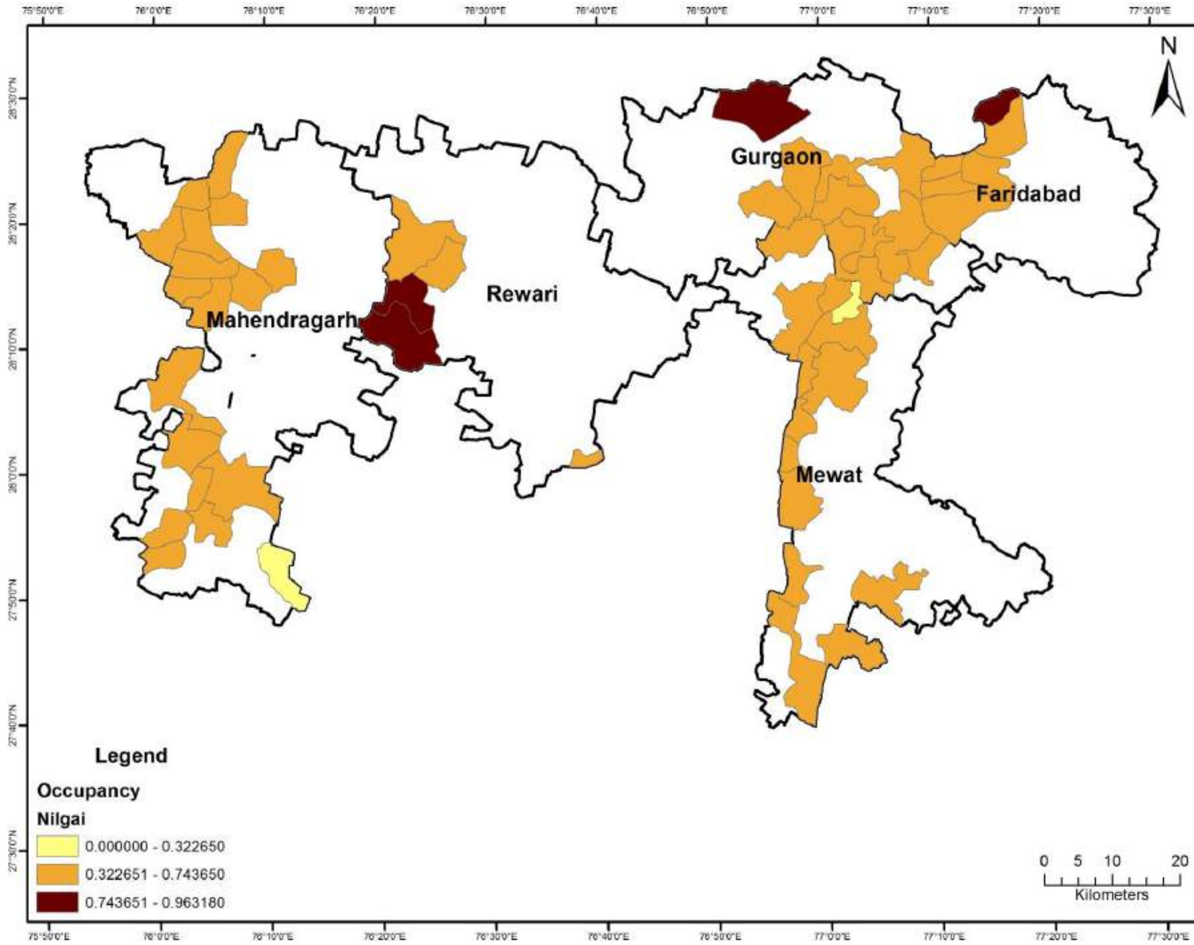


Figure 7.4: Nilgai occupancy across Aravallis Haryana, India

Porcupine Occupancy – was estimated to be 87 % (Ψ = 0.87 ± 0.05, Table 7.3). Site-specific habitat co-variates shrub cover (3.66 ± 1.25 Beta Coefficient) and tree cover (2.32± 0.83 Beta Coefficient) best-explained Porcupine occupancy (Table 7.4). Total area under Porcupine occupancy (Category 1) was estimated to be 720.28 sq. km (Figure 7.5).

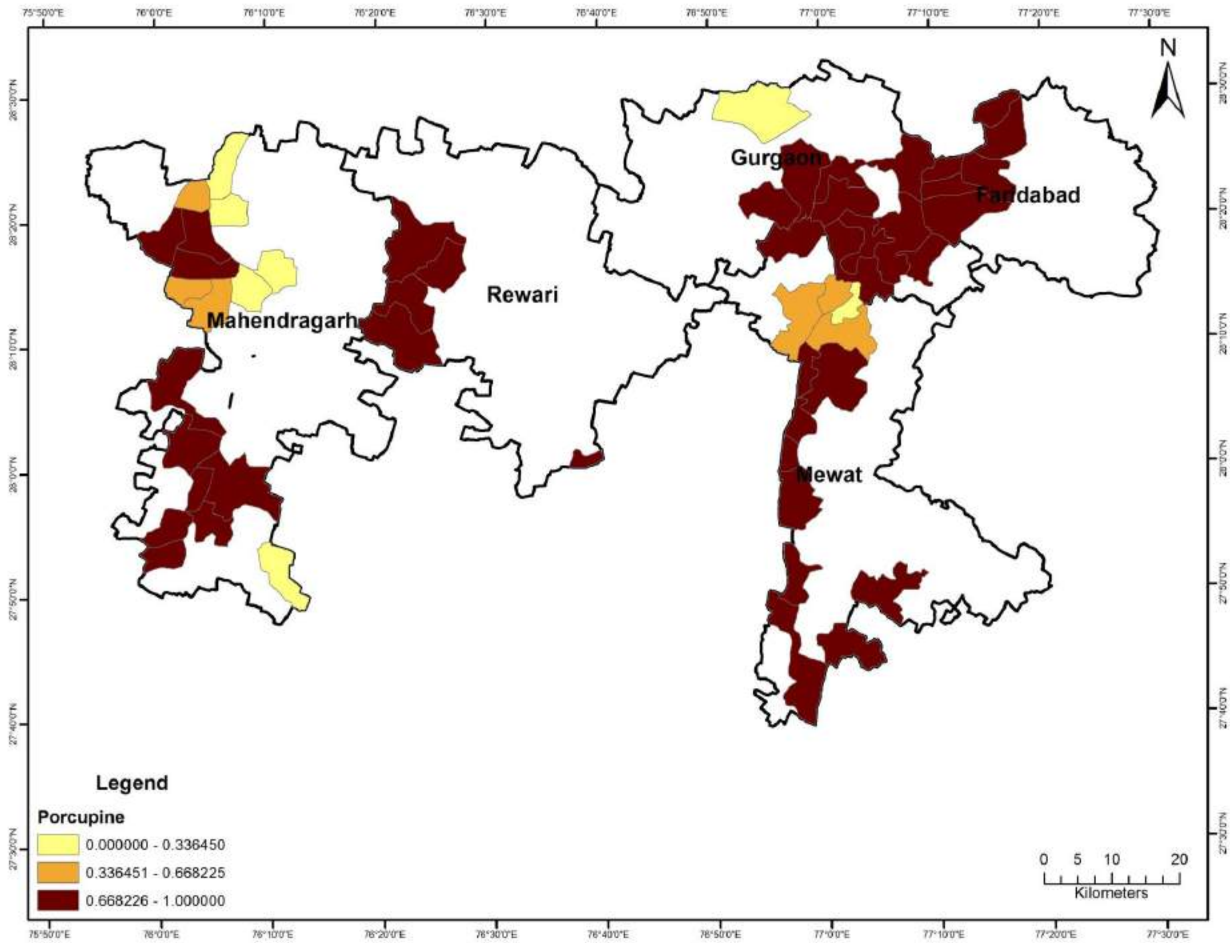


Figure 7.5: Porcupine occupancy across Aravallis Haryana, India

Synthesis

The present study reported ore signs for almost all of the carnivores as compared to the 2012 study. 2012 reported seven carnivores from the Aravalli Landscape of Haryana while the 2016 study reports 9 carnivores. Earlier report stated Leopard (8 signs), Jackal (129), Porcupine (5), Mongoose (2), Jungle cat (46), Fox (2), Hyena (17). While the 2016 study reported Leopard (31), Jackal (166), Porcupine (91), Mongoose (50), Wolf (3), Jungle cat (26), Fox (4), Hyena (126), Rhesus macaque (2) and civet (64).

Landuse/Landcover Classification for different Occupancy Classes

Occupancy values (individual psi estimates) were categorized into 3 categories (High, Medium and Low) using Jenks natural breaks classification method. Jenks natural breaks classification method is a data clustering method designed to determine the best arrangement of values into different classes. This is done by seeking to minimize each class's average deviation from the class mean, while maximizing each class's deviation from the means of the other groups. In other words, the method seeks to reduce the variance within classes and maximize the variance between classes. Landuse/landcover estimates for different occupancy category has been estimate for each species. The area under different occupancy categories and landuse classification for different species at Aravallis Haryana is given in Table 7.5.

Table 7.5: Area of different Landuse/Landcover category with respect to Occupancy of Species at Aravallis, Haryana, India

Species	Landuse/Landcover	Area (km^2) under different Occupancy Category		
		High	Medium	Low
Hyena	Agriculture	416.94	22.64	155.61
	Barren	23.65	0.96	21.51
	Grassland	0.66	0	1.082
	Open Forest	66.52	8.84	0.006
	Plantation	13.66	0.88	0.574
	Scrub	122.06	47.68	32.65
Porcupine	Agriculture	430.61	60.86	103.72
	Barren	32.51	5.18	8.445
	Grassland	0.66	0.0008	1.081
	Open Forest	66.66	8.7	0.0069
	Plantation	6.896	5.31	2.925
	Scrub	182.95	18.44	1.009
Leopard	Agriculture	148.8	264.11	182.25
	Barren	12.5	26.12	7.47
	Grassland	1	0.43	0.23
	Open Forest	18.5	21.402	35.45
	Plantation	6.1	4.88	4.14
	Scrub	14	147.34	41.01
Nilgai	Agriculture	103.4	465.09	26.64
	Barren	8.97	28.71	8.44
	Grassland	1.081	0.66	0
	Open Forest	0	75.36	0.006
	Plantation	0.387	14.55	0.187
	Scrub	17.65	173.77	10.97

Synthesis
The Landuse/Landcover utilization pattern with respect to different occupancy category clearly indicates that all species use varied habitats around scattered forest patches. Small remnant forest patches acts as refuge for the species to exploit or use the surrounding habitats. This also highlights the importance of remaining forest patches within the Aravallis landscape for long-term conservation of species and the Aravallis ecosystem.

Intensive Use Area by Species across Aravallis

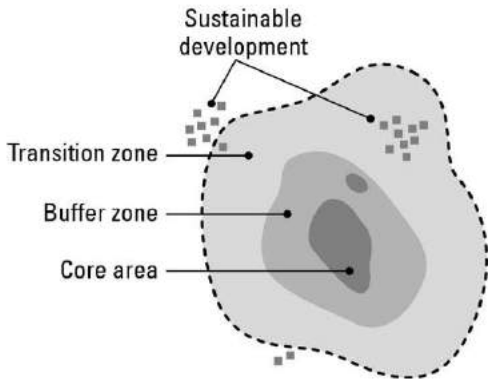
Intensive use area map or heat map is a graphical representation of data where the individual values contained in a matrix are represented as colors Heat maps are used to visualize geographic data in order to show areas where a higher density or cluster of activity occurs. To create a heat map, point data is analyzed in order to create an interpolated surface showing the density of occurrence. The Heat map plugin in Q GIS uses Kernel Density Estimation to create a density (heat map) raster of an input point vector layer. The density is calculated based on the number of points in a location, with larger numbers of clustered points resulting in larger values. Heat maps allow easy identification of "hotspots" and clustering of points. These hotspots facilitate in conservation management decisions for species.

Kernel density calculated (explained in the previous section) was divided into three categories based on Jenks natural breaks and were classified into following categories:

1. Core zone (inner region) – highest used region/ area by the species in terms of more point locations, depicted in red color in the map
2. Buffer zone (middle region) – medium used region by the species, depicted in yellow color.
3. Transition zone (outer region) - less used comparatively to other zones but the dispersal of the species is observed, depicted in green region.

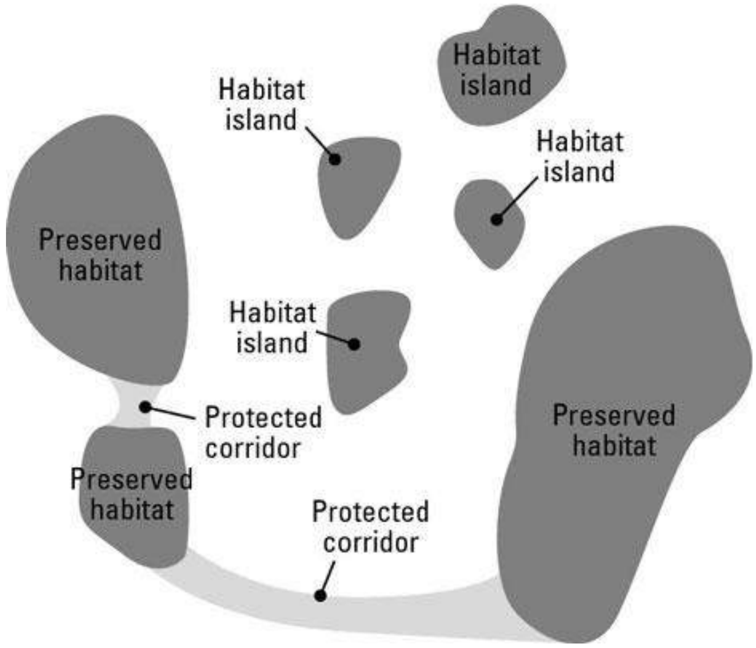
Based on intensity of use the areas have divided into these zones to base conservation priorities. All these zones represent the intensively used areas by various species. The data for kernel was recorded in the form of direct (sightings) and indirect surveys (signs rake and scrap marks). Core zone is the zone, which is repeatedly used by the animals, hence more point locations were represented in the form of higher density calculated through Heat map plugin in Q GIS. The kernel density maps for the species are shown in Figures 7.6 – 7.15.

This zonation system is often depicted in protected areas to prioritize conservation priority. Such system has been utilized here with similar objective and prioritizing areas for conservation.



The above-illustrated concept is widely used in creation of Biosphere reserves with the objective of preserving entire ecosystems with balancing human resource use.

Another concept is of Island Biogeography, where several protected and biodiversity rich areas are connected together over a vast landscape. Such habitats can be connected together through developing protected corridors, which allows species to move between the habitats and helps in improving species chance of survival.



Both the concepts of biosphere reserve and island biogeography have been illustrated over here to put forward best approaches for conserving the Aravallis Landscape. They could be included in developing effective conservation plans for the species and habitats across the landscape.

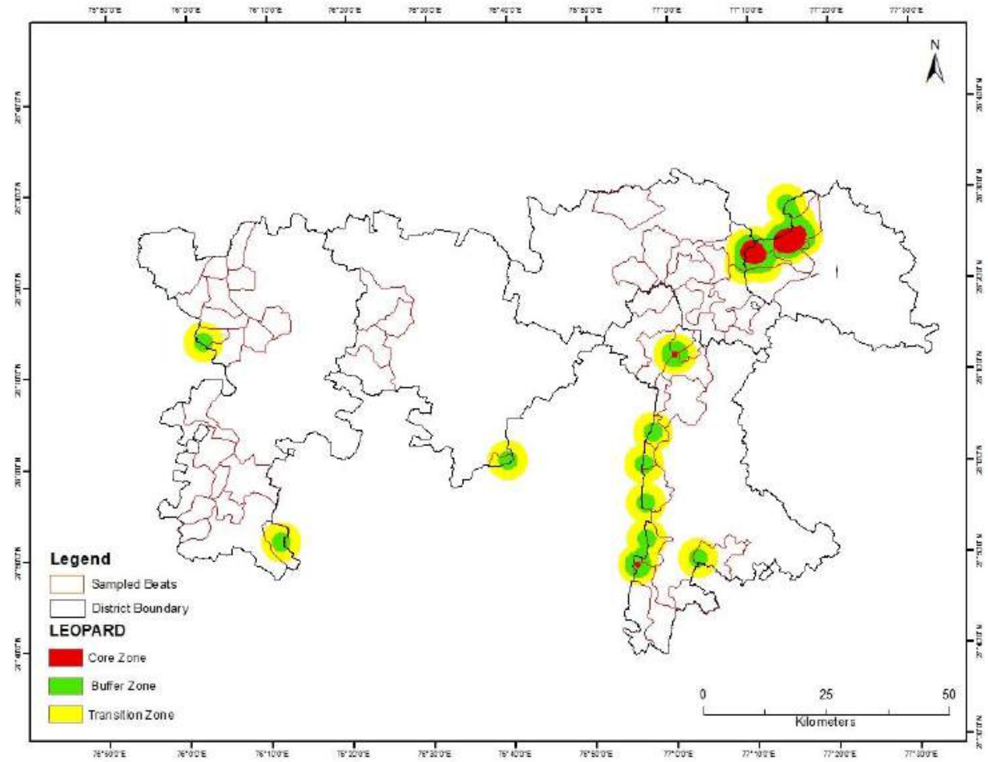


Figure 7.6: Kernel density map of Leopard in five districts of Aravallis, Haryana, India

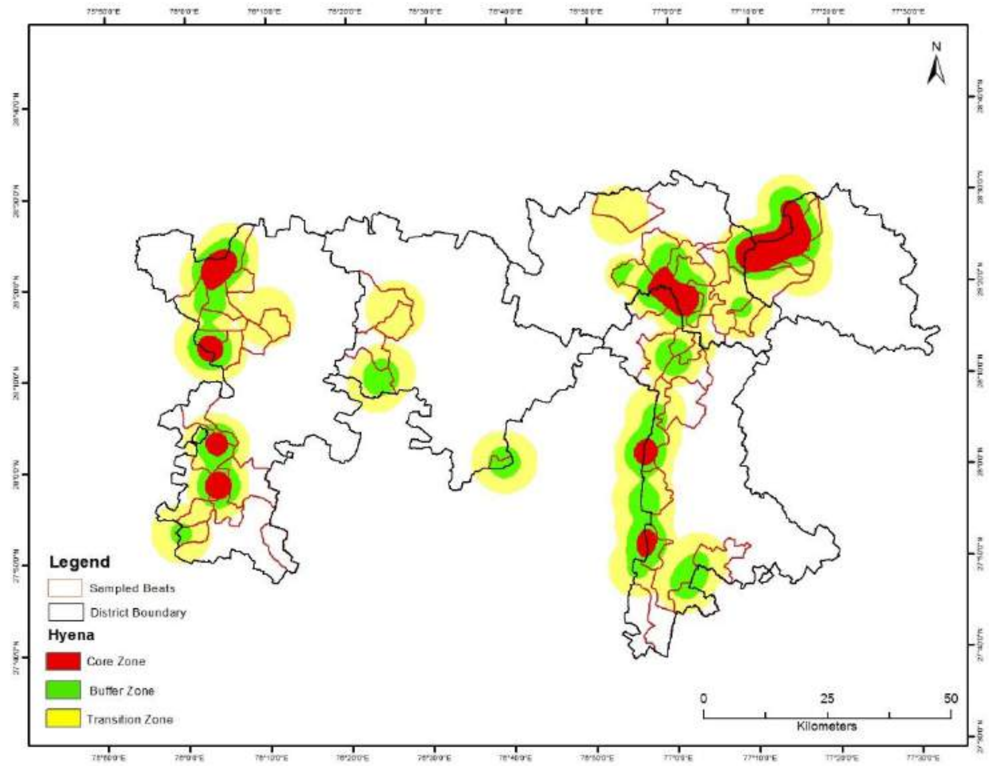


Figure 7.7: Kernel density map of Hyena in five districts of Aravallis, Haryana, India

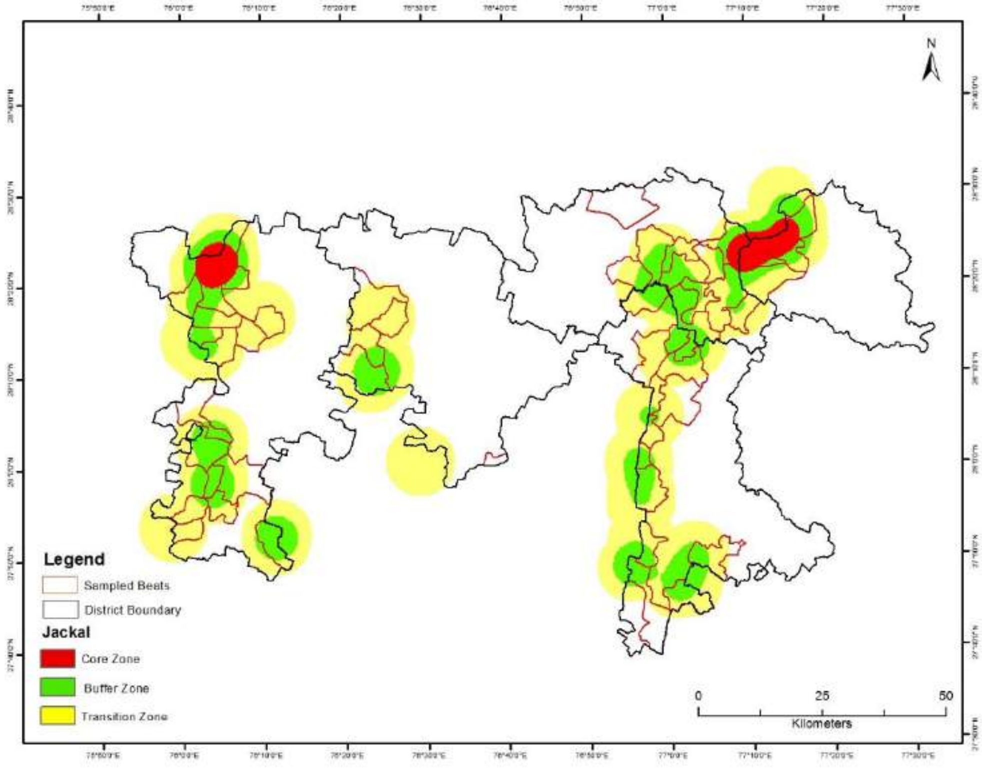


Figure 7.8: Kernel density map of Jackal in five districts of Aravallis, Haryana, India

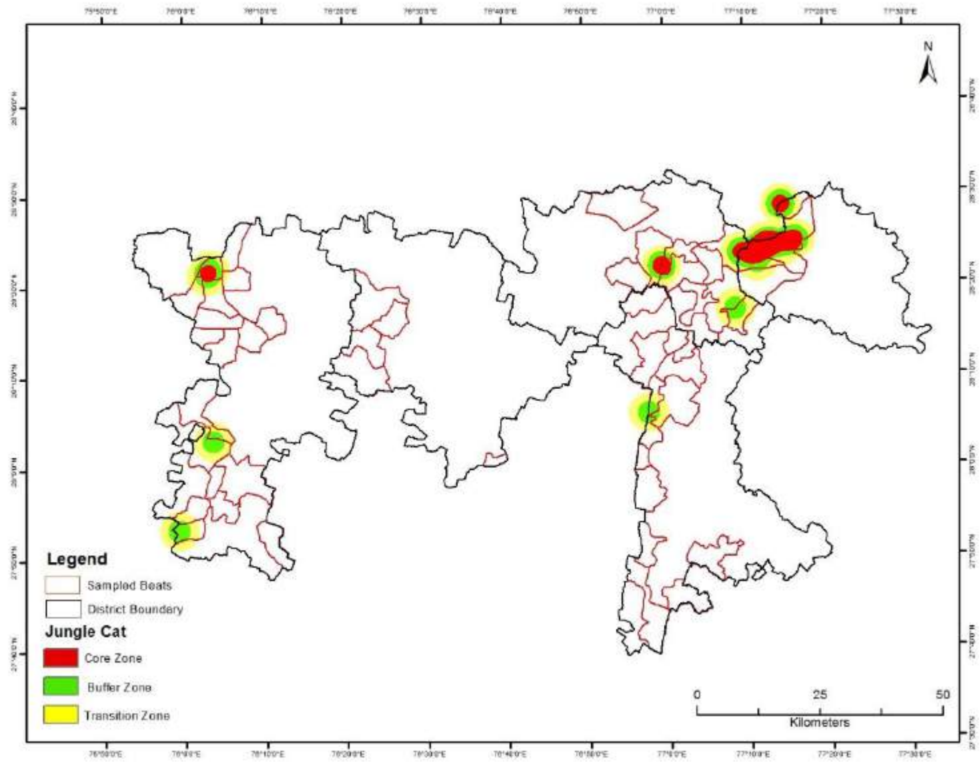


Figure 7.9: Kernel density map of Jungle Cat in five districts of Aravallis, Haryana, India

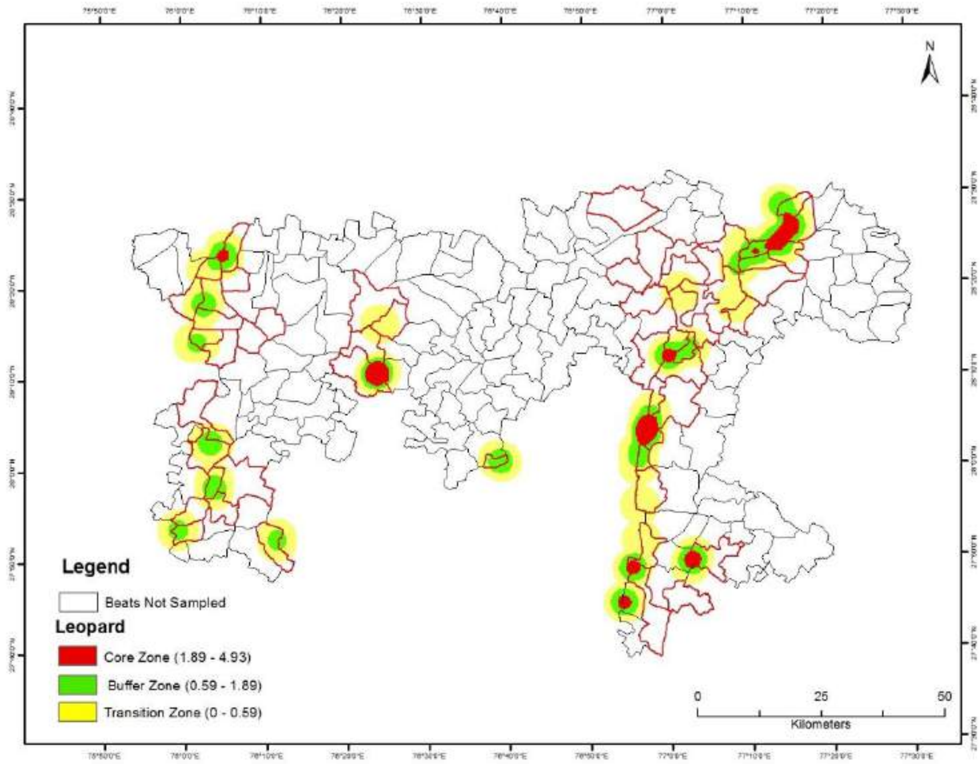


Figure 7.10: Kernel density map of Porcupine in five districts of Aravallis, Haryana, India

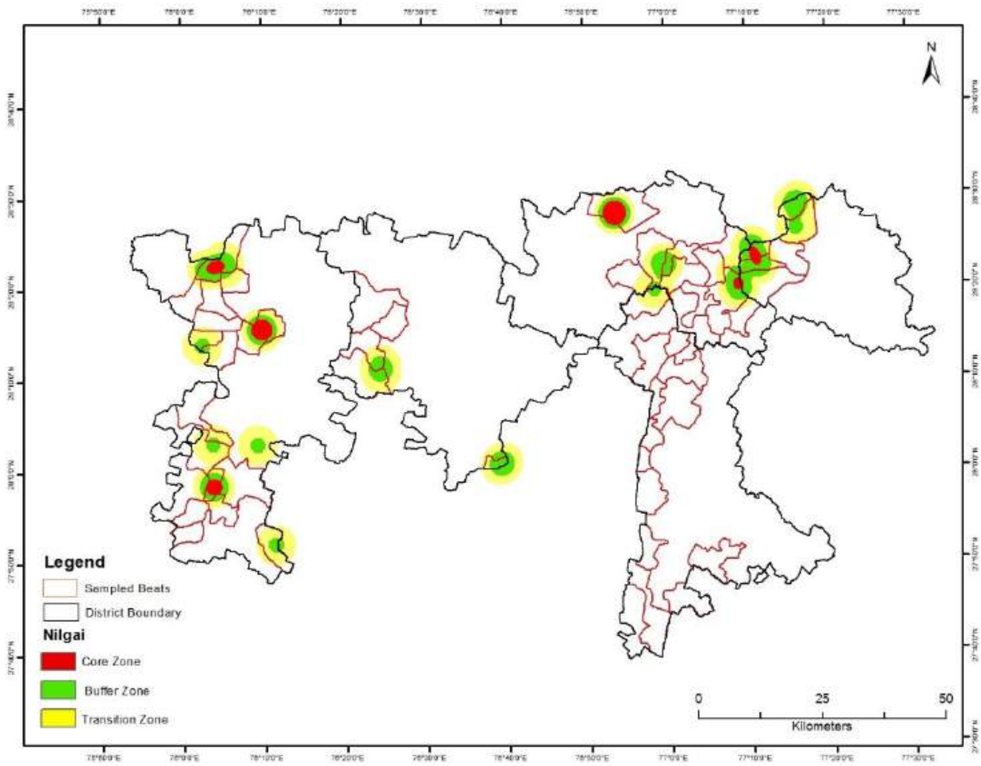


Figure 7.11: Kernel density map of Nilgai in five districts of Aravallis, Haryana, India

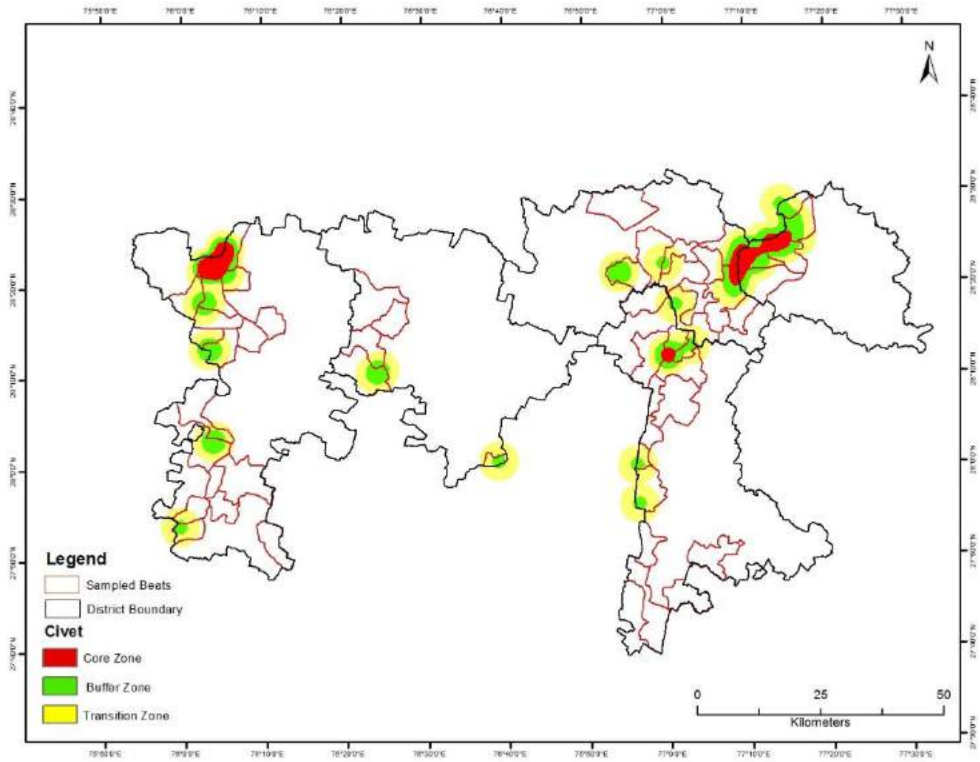


Figure 7.12: Kernel density map of Civet in five districts of Aravallis, Haryana, India

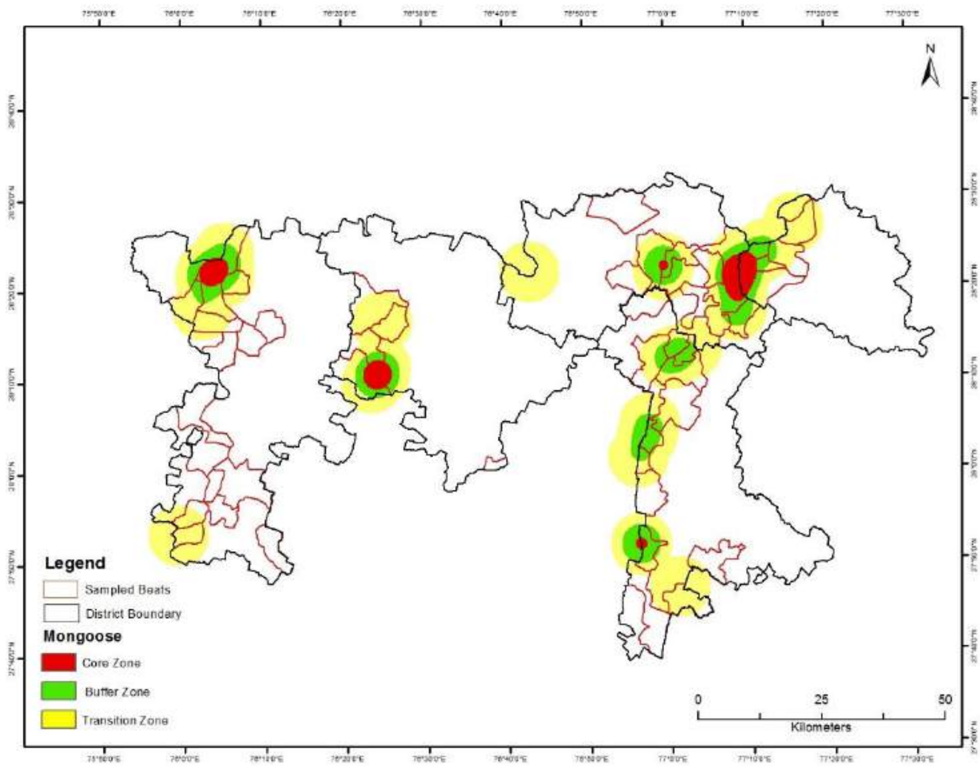


Figure 7.13: Kernel density map Mongoose in five districts of Aravallis, Haryana, India

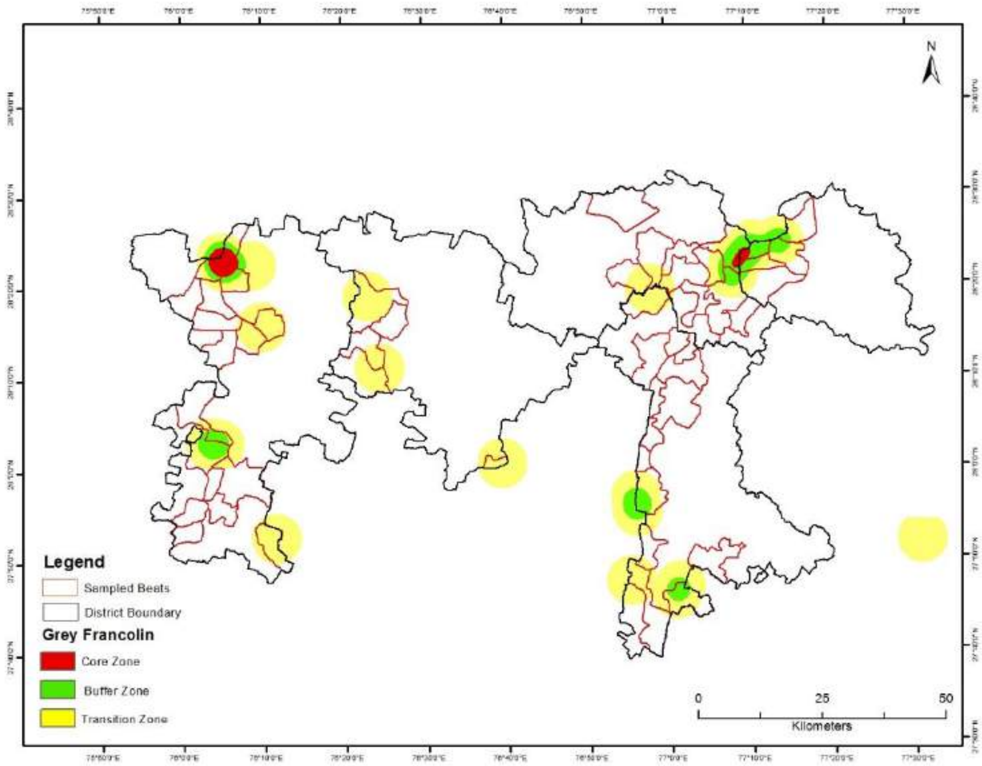


Figure 7.14: Kernel density map of Grey Francolin in five districts of Aravallis, Haryana, India

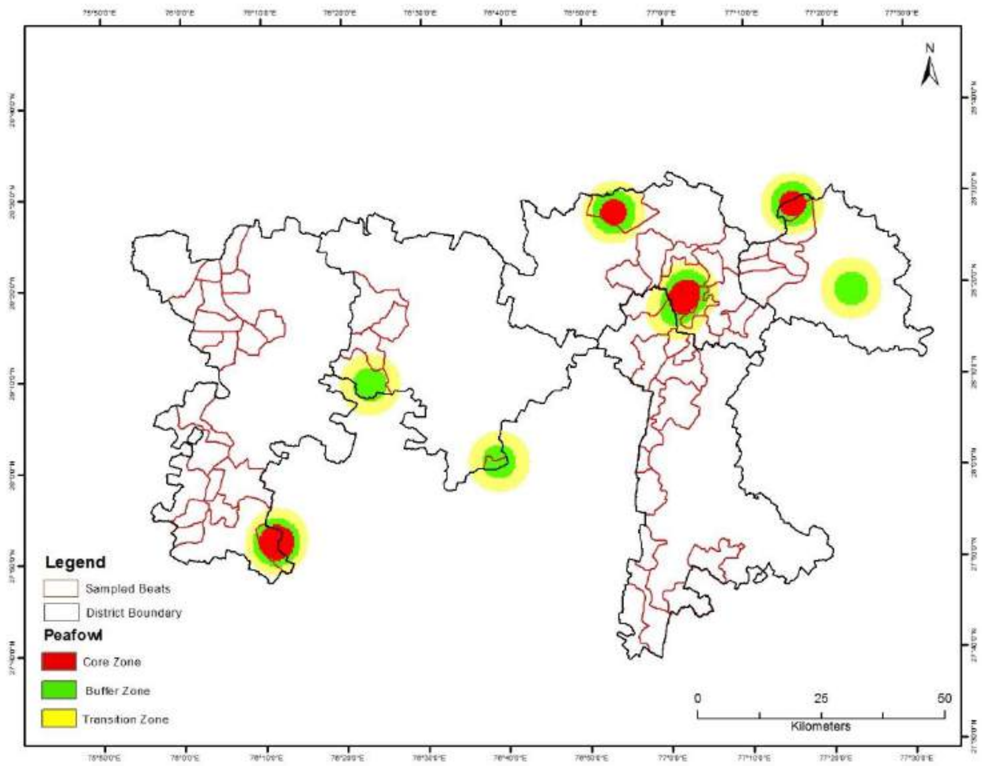


Figure 7.15: Kernel density map of Peafowl in five districts of Aravallis, Haryana, India

Synthesis

Leopard kernel density was highest in Gothda, Dhoj, Mangar, Badkal, Gamroj (Bhondsi) and Raipur (Raisina 1& 2). In case of hyena intensity of signs were high over the landscape indicating the animal is well distributed. Jackal intensity of signs was highest in Khudana, Gothda, Badkal, Dhoj & Rusulpur. Porcupine kernel density was highest in Dhoj, Badhkal, Surajkund, Tauru (Panchgaon), Khod Basai (Sahsola), Meoli (Bai Baruji), Chittora (Mahu Rawa), Jhabua, Madhogarh, Khudana and Pachnota. Nilgai intensity of signs was highest in Sultanpur, Dhoj, Gothda, Badhkal, Madhogarh, Khudana and Mukundpura. Grey francolin intensity of signs was highest in khudana, Gothda, Badhkal, Dhoj and Rusulpur. For civet intensity of signs were high in Nangal mala, Khudana, Mangar, Dhoj, badkhal, Gamroj and Raipur. For mongoose areas of high sign intensity were Dhoj, Khol, Khudana, Khod Basai, Nangal mala. In case of Peafowl, areas of high intensity were Nimatpur, Gamroj, Raipur, Surajkund and Sultanpur.

Extent of Landuse/landcover across intensive use areas

Three zones core, buffer and transition zone was individually clipped with the shape file of LULC 2016 and areas were calculated for each class and species separately. The details of areas across different landuse/landcover category and conservation priority zones for each species in the Aravallis Landscape of Haryana are given in Table 7.6.

Table 7.6: Landuse/Landcover area under different conservation priority zones for key species of Aravallis, Haryana, India

Species	Landuse/Landcover	Area (km^2) under different categories		
		Transition	Buffer	Core
Hyena	Agriculture	1104.09	357.32	104.54
	Barren	35.74	40.33	8.81
	Grassland	3.45	0.47	0
	Open Forest	24.21	53.36	41.61
	Plantation	17.31	18.08	4.46
	Scrub	117.25	123.6	123.84
Porcupine	Agriculture	523.13	131.72	18.13
	Barren	39.01	26.54	12.86
	Grassland	0.58	0.2	0
	Open Forest	58.88	23.65	10.08
	Plantation	11.76	8.16	0
	Scrub	134.93	118.42	56.72
Leopard	Agriculture	201.91	66.35	2.30
	Barren	13.05	15.30	0.70
	Grassland	0.54	0.00	0.00
	Open Forest	10.68	17.82	0.00
	Plantation	3.54	5.60	0.00
	Scrub	78.14	90.10	37.25
Nilgai	Agriculture	317.54	114.95	34.63
	Barren	18.81	18.52	1.66
	Grassland	0	0	1.12
	Open Forest	24.64	13.15	0.14
	Plantation	14.45	0	3.55
	Scrub	94.4	83.86	17.09
Jackal	Agriculture	1412.92	465.85	40.95
	Barren	48.32	52.80	2.90
	Grassland	3.7	0.23	0
	Open Forest	32.76	82.1	10.61
	Plantation	27.08	11.51	3.56
	Scrub	132.19	184.68	84.8
	Settlement	188.48	57.76	3.6
Jungle Cat	Agriculture	165.66	42.92	1.36
	Barren	18.77	11.78	1
	Grassland	0.06	0	0
	Open Forest	8.14	5.75	0
	Plantation	2.3	0.66	0
	Scrub	74.63	55.4	32.15

Species	Landuse/Landcover	Area (km^2) under different categories		
		Transition	Buffer	Core
Civet	Agriculture	344.05	105.6	21.17
	Barren	27.64	18.55	4
	Grassland	0.13	0	0
	Open Forest	37.14	19.62	7.59
	Plantation	13.96	9.94	0.88
	Scrub	92.92	96.92	63.12
Grey Francolin	Agriculture	560.02	63.68	10.24
	Barren	35.89	7.08	0
	Grassland	0.69	0	0
	Open Forest	59.5	11.47	6.55
	Plantation	17.99	1.43	3.47
	Scrub	123.78	84.64	16.88
	Settlement	58.57	2.41	0.13
Mongoose	Agriculture	835.61	193.97	30.72
	Barren	44.48	19.31	12.5
	Grassland	1.35	0.28	0
	Open Forest	59.31	21.14	7.16
	Plantation	11.77	7.65	0
	Scrub	167.78	93.87	62.81
	Settlement	116.6	16.48	1.91
Peafowl	Agriculture	284.88	148.99	50.2
	Barren	6.52	8.53	9.71
	Grassland	0	0	1.08
	Open Forest	10.75	14.42	15.31
	Plantation	2.81	5.04	1.03
	Scrub	25.67	24.8	23.94
	Settlement	50.21	22.52	6.98

Priority Areas for Conservation

Overlay analysis approach was used to identify priority areas for conservation in Aravallis, Haryana India. We used presence of species, occupancy level, species diversity, habitat quality and extent of habitat as parameters to delineate priority conservation areas. Based on overlay analysis approach, the conservation priority areas were identified for the Aravallis. The details of species-specific priority areas are given in Table 7.7 and overall priority conservation areas for the Aravallis Haryana are shown in Figure 7.16.

Table 7.7: Species – specific priority conservation areas across Aravallis Haryana, India

Beats/Species	Hyena	Leopard	Jackal	Mongoose	Nilgai	Peafowl	Porcupine	Grey Francolin	Civet
Badkhal									
Dhoj									
Gamroj									
Gothda									
Jhir									
Khudana									
Kotla									
Manger									
Mohd. Pur									
Mukundpura									
Nangal Mala									
Raipur									
Rusulpur									
Sohla									
Surajkund									
Bhondsi									
Khol									
Madhogarh									
Meoli									
Chittora									
Tauru									
Sultanpur									
Nimatpur									
Khod Basai									

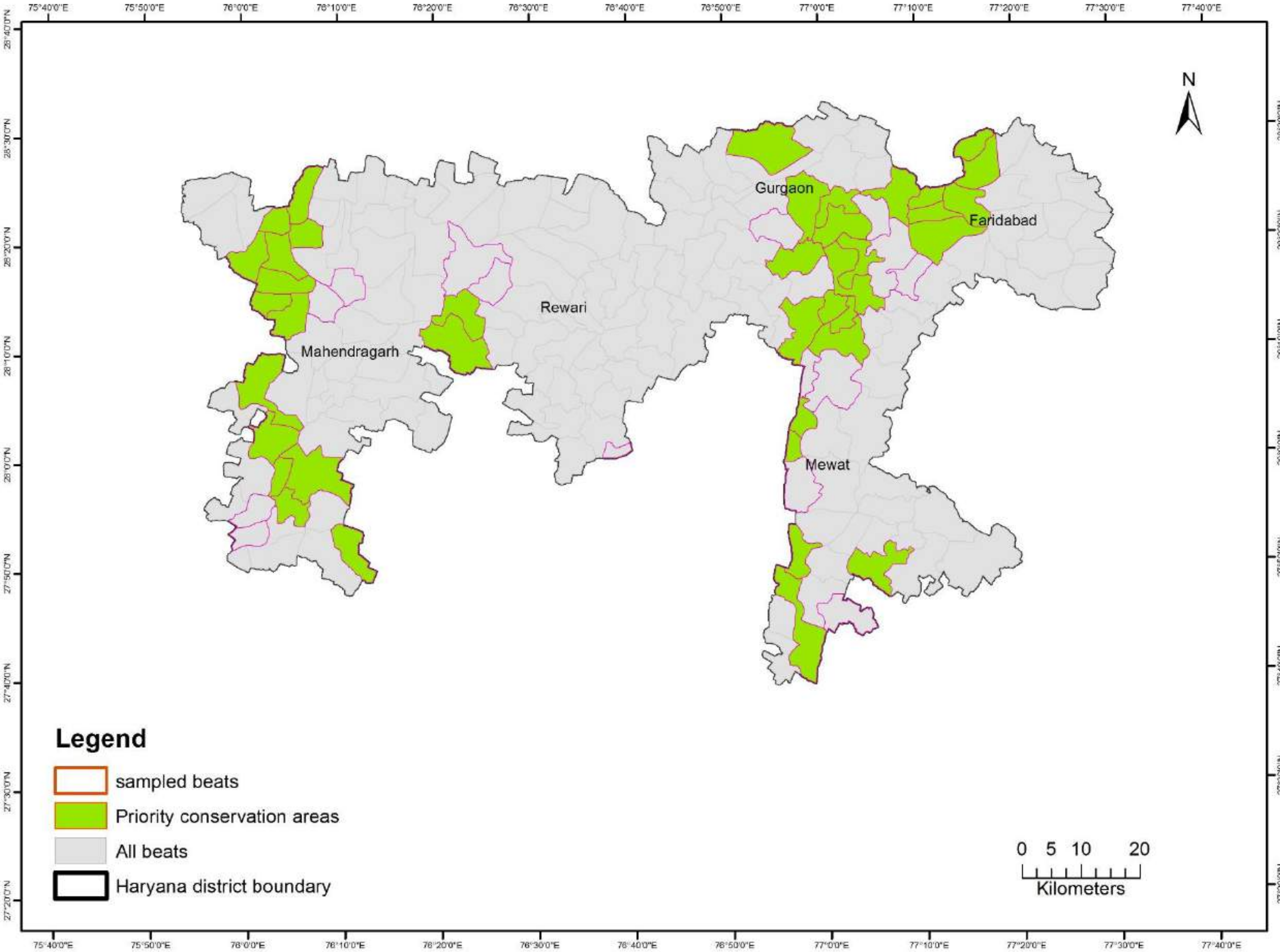


Figure 7.16: Priority Conservation Areas for Aravallis, Haryana India

Vinit Arora

CHAPTER 8
CAMERA TRAPPING
(OPPORTUNISTIC)

Opportunistic camera trapping was conducted in October 2016 for period of around 30 days. Twelve cameras were deployed in two districts – Gurgaon and Faridabad to get basic insights into the presence of animals. The sites selected to put cameras were Bhondsi (1), Gamroj (1), Manger (4), Bandhwari (2), Wazirabad (2), and Gothda (1) and Anagpur(1).

4 cameras were installed in Manger out of which one got vandalized by Nilgai. Wildlife species recorded (Figure 8.1), in Manger were Leopard, Striped hyena, Jackal, Nilgai, Porcupine, Palm civet, Indian grey mongoose, Ruddy mongoose, Peafowl, Hare and Rhesus macaque. In Bhondsi species recorded were the Nilgai, Palm civet, Peafowl and porcupine. Gamroj recorded species Hyena, Palm civet and sambar. In Anagpur species recorded were Leopard, Nilgai and Peafowl. In Mohtabad species recorded were Hare, Leopard, Nilgai, Peafowl, Porcupine, Ruddy mongoose and Small Indian civet. Bandhwari had two cameras deployed, which resulted in recorded species Nilgai, Palm civet, Peafowl, Wild pig and Porcupine. In Wazirabad also two camera were installed and species Jackal, Nilgai, Peafowl, Porcupine, Rhesus macaque, Wild pig, Hyena were recorded. Sambar recorded in camera traps is the first record of occurrence of the species in Gurgaon, Aravallis, Haryana.

Synthesis

The opportunistic camera trapping by placing only 12 camera traps has indicated presence of 14 species. This highlights the need for intensive camera trapping study across the landscape. The details of species recorded and capture rate for each species are provided in Table 8.1. Based on timing of capture we also evaluated the activity pattern of various species, the details are given in Figure 8.2 (Small dataset – need to be interpreted carefully).

Table 8.1: Species recorded during opportunistic camera trapping at Aravallis, Haryana, India

Species	Total No. of Captures	Capture Rate
Common Leopard	7	1.56 ± 0.74
Striped Hyena	7	2.94± 1.49
Golden Jackal	9	2.1± 0.70
Indian Hare	12	2.51± 1.50
Nilgai	55	11.27± 2.00
Sambar	6	2.27± 2.27
Small Indian civet	1	0.2± 0.20
Palm civet	7	3± 1.87
Indian grey mongoose	1	0.34± 0.34
Ruddy mongoose	1	0.2± 0.20
Wild pig	14	2.66± 2.66
Rhesus Macaque	55	15.3± 12.9
Peafowl	57	14.65± 5.92
Indian crested porcupine	12	14.65± 5.92


Ambush
10/31/2016 12:17 AM
Cuddeback
Ambush
11/6/2016 3:31 AM
Cuddeback
Ambush
10/14/2016 3:42 AM
Cuddeback
Ambush
11/16/2016 3:09 PM
Cuddeback
Ambush
10/6/2016 4:09 AM
Cuddeback
Ambush
10/19/2016 6:26 AM
Cuddeback
Ambush
11/16/2016 6:59 PM
Cuddeback
Ambush
10/19/2016 10:15 PM
Cuddeback

Figure 8.1: Animals captured in camera traps from left to right (A) Striped Hyena, (B) Common Leopard, (C) Golden Jackal, (D) Ruddy mongoose , (E) Indian Crested Porcupine (F) Indian Grey Mongoose, (G) Small Indian Civet, (H) Palm Civet, (I) Sambar, (J) Nilgai, (k) Peafowl, (L) Rhesus Macaque, (M) Wild pig, (N) Indian hare

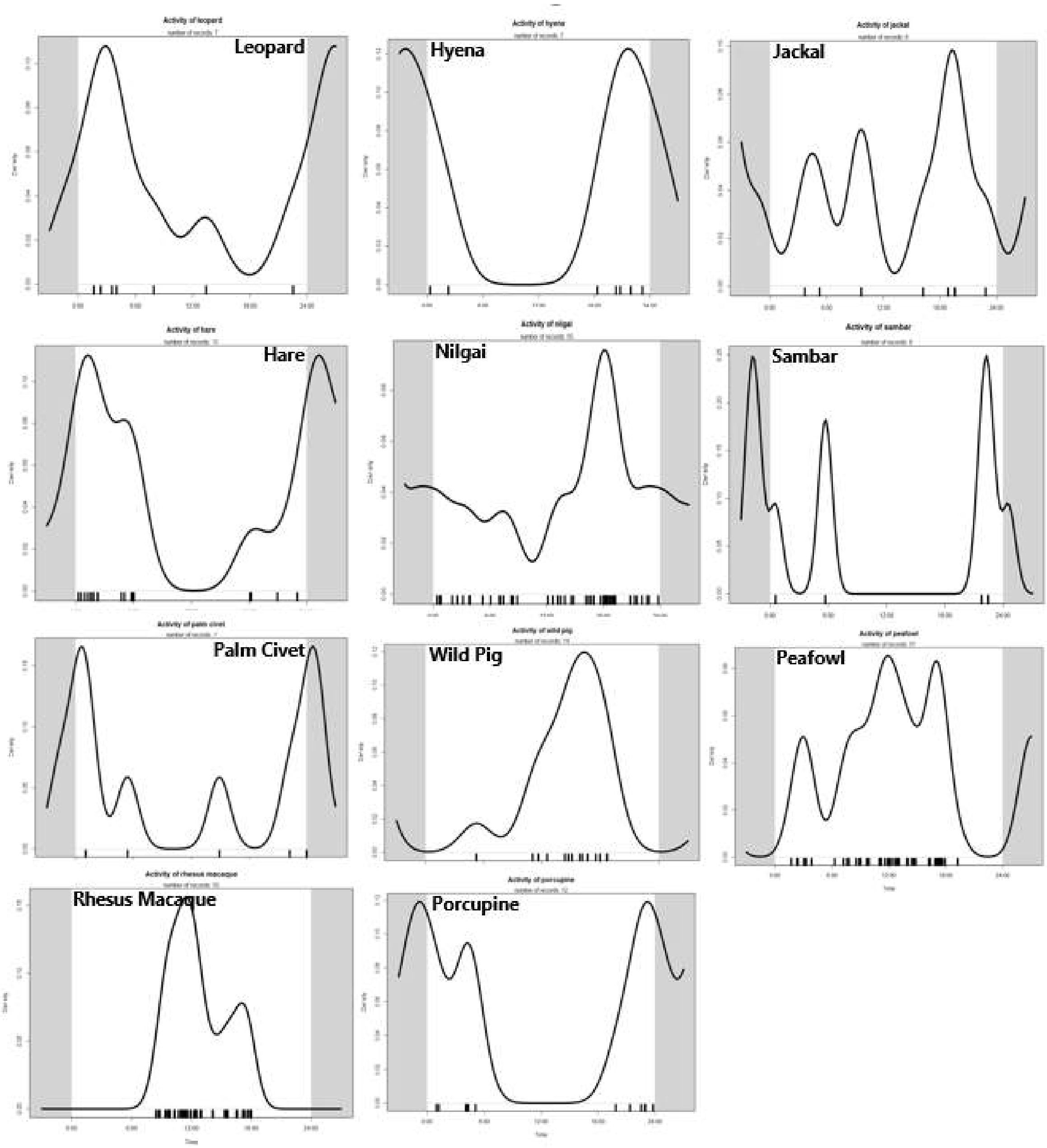


Figure 8.2: Kernel Density Activity Pattern of Species Reported from Aravallis based on Opportunistic Camera Trapping

G. S. Bhardwaj

CHAPTER 9
RECOMMENDATIONS

Priority Conservation Areas
Aravallis part of Haryana is a unique ecosystem in its self and is one of the oldest mountain range. There are serious issues that threaten the survival of Aravalli Hills. The most serious threat to wildlife and forests is developmental activities, which are gradually destroying the remnants of Aravallis left in the five districts of Gurgaon, Faridabad, Mahendragarh, Mewat and Rewari.

Highways passing through the wildlife habitats have adversely affected the fauna in these forests. Fast moving vehicles kill these animals when they are move across these road stretches. The Gurgaon Faridabad expressway is one such road in Aravallis. Tolerance by public for wildlife is decreasing and several examples narrate the story in which animals especially leopards are killed either in retaliation or lynched by public. The priory conservation areas as identified should be considered for effective conservation and management. The importance of few of them are again highlighted here.

Conservation Priority for Mangar Bani and Adjacent Forests of Kot and Damdama - Mangar Bani Forest grove on the Gurgaon-Faridabad highway can be considered priority conservation site, the fact that it is located amidst the reckless development in this region. They are the last remnant habitat for wildlife in this area. “Bani” means forest and Mangar is the name of the community, the forest is owned by the local Gujjar community and is a sacred grove. Most of the forest is dominated by *Angogeissus pendula* (Dhau) and is an excellent habitat for the faunal species.

Surendra Chauhan

Kot- Damdama forest and Mangar bani are all connected to each other thus forming a continuous stretch to be considered for long-term conservation of the area.

Raisina- Bhondsi - Gamroj Forest: The forest is extremely rich in both floral and faunal components. Shrub and tree cover is very dense, hence providing refuge to key predators like Leopard and Hyena. Covered with thick foliage and natural lakes it is home to several native tree species. The area is also at a distance from human habitation hence the disturbance index is very low and should be considered for priority conservation.

Nayaan (Nimatpur) Forest: Bestowed with wide variety of bird species, the area is ecologically rich. 13 sq km forest area is an excellent habitat for wildlife. The area has no disturbance from human encroachment and can be considered key area for conservation of Leopard and Hyena. The occupancy estimates for both key predators Leopard and Hyena were found to be very high.

Khudana: These Sandune hills are home to the antelope Chinkara. Largest population of this antelope was recorded in this area. The area is hilly with semi arid vegetation. Most of the landscape is sandy with numerous valleys supporting good biodiversity. It's also home to several other mammalian species recorded during the survey like Leopard, Hyena, Porcupine, Jackal, Nilgai etc.

Madhogarh: The habitat of madhogarh being similar to Khudana is covered with sandy hills and is home to Chinkara and some rare avian species like Eagle owl and Crested serpent eagle.

Khol Khaletha Forest: Most of the key species like Leopard, hyena and porcupine signs were found in this region, which is located in Rewari district. It is one of the best habitats observed in Rewari district. The region has semi arid with several native trees like *Butea monosperma* and *Acacia leucophloea.*

Recommendations

1. All priority areas identified in this report should be considered for long-term conservation and management. Site level conservation and management plans should be prepared in consultation with local stakeholders to make conservation effective in these remaining forest patches of Aravallis in the state of Haryana.

2. Opportunistic camera trapping has really given some interesting insights about the presence of the species in the landscape. There is need to conduct intensive camera trapping study across the landscape for evaluating the status and number of the wildlife species and their numbers in the area.

3. There is a need to identify road crossing zones for key wildlife species especially leopards to suggest mitigation measures. Radio-telemetry study will help in identifying critical leopard crossing zones.

4. Leopard as Predator and Hyena as scavenger should be considered for telemetry study in the landscape. The radio-telemetry study will help in understanding the fine scale movement pattern and landscape use by the species. It will provide data on how these species have adapted to this type of landscape, for their long-term conservation, which will provide insights in dealing with human – leopard conflict in much better way.

5. Habitat improvements in terms of removal of weeds, reducing pressures on forests should be taken on priority basis for the landscape.

6. Long term ecological monitoring should be initiated on the prioritized sites.

REFERENCES

Anonymous (2012): Ground water information booklet, central ground water board.

Anonymous (2010): National Wetland Atlas: Haryana, SAC/RESA/AFEG/NWIA/ATLAS/15/2010, Space Applications Centre (ISRO), Ahmedabad, India, 148p.

Anonymous (2010): Preparation of Sub Regional Plan for Haryana Sub-Region of NCR-2021, Department of town and country planning, September 2010, 71p

Buckland, S.T., Anderson, D.R., Burnham, K.P.,Laake, J.L., Borchers, D.L., & Thomas, L. (2001).Introduction to Distance Sampling, Oxford University Press, Oxford.

Donovan, T. M. and J. Hines. 2007. Exercises in occupancy modeling and estimation.

Gupta, S., 2011. Ecology of medium and small sized carnivores in Sariska Tiger Reserve, Rajasthan, India (Doctoral dissertation, PhD Thesis, Saurashtra University, Biosciences Department, India).

Gong, Im, Mountrakis (2011): An artificial immune network approach to multi-sensor land use/land cover classification. Remote Sens Environ.m115:600-614.

Habib, B., Talukdar, G. and Sapra, R. K. (2013): Status of Wildlife in Haryana State. Census Report 2013- Haryana Forest Department and Wildlife Institute of India, 63 Pp.

Kataria, R.K. District disaster management plan Gurgaon 2011

Kaur R, Gonza´les WL, Llambi LD, Soriano PJ, Callaway RM, et al. (2012) Community Impacts of Prosopis juliflora Invasion: Biogeographic and Congeneric Comparisons. PLoS ONE 7(9): e44966. doi:10.1371/journal.pone.0044966

Kidwai, Zaara., Sankar, K., Qureshi, Qamar. and Khan, J.A., 2011. Abundance and habitat utilization by Galliformes in the Sariska Tiger Reserve,Rajasthan, India. International Journal of Galliformes Conservation,2, pp.54-60.

Mondal, K., Gupta, S., Bhattacharjee, S., Qureshi, Q. and Sankar, K., 2012. Prey selection, food habits and dietary overlap between leopard Panthera pardus (Mammalia: Carnivora) and re-introduced tiger Panthera tigris (Mammalia: Carnivora) in a semi-arid forest of Sariska Tiger Reserve, Western India. Italian Journal of Zoology, 79(4), pp.607-616.

Rathore, N.S. and Verma, N., 2013. Impact of climate change in the southern Rajasthan, India. International Journal of Water Resources and Arid Environments, 39, pp.45-50.

Rathore, N.S., 2009. The study of the environment and its impact in the Aravalli Mountain Range in the study of the changing environment and its impact in the Aravalli Mountain Range in the western Region of India. Udaipur, Rajasthan.

Sati, J. and Sinha, N., 2004. Zoological Survey of India, Northern Regional Station, Dehra Dun-248 195. Gobind Pashu Vihar, p.55.

Shetty, B.V and Singh, V., 1987, Flora of India Series 2 Flora of Rajasthan Volume 1. Botanical Survey of India,Calcutta.

Singh, R., Ecological changes in Central Aravalli Hilly range: A case study of Tonk District, Rajasthan, India. International Journal of Research in Applied Natural and Social Sciences; Vol.3, Issue 4, Apr. 2015, 17-28.

Thomas M. Lillesand, Ralph W. Kiefer and Jonathan W. Chipman (2004): Remote Sensing and Image Interpretation, Fifth edition, reprint by Wiley India Pvt. Ltd., New Delhi, page 215, 2004

Verma K.P., Gaur M.P and Saini H.S. Geology and mineral resources of Haryana, Miscellaneous Publication no.30:Part XVIII,Geological Survey of India ,Order of Gov of India 2012

APPENDIX – I
SITE SPECIFIC PSI ESTIMATES

Study sites	Leopard	Nilgai	Porcupine	Hyena
Ankhir Mewla	0.4427	0.9147	0.8834	0.5462
Badkal	0.8763	0.9423	0.9997	0.3924
Bai Baruji	0.4426	0.6165	0.93	0.7553
Bandhwari 1	0.7979	0.955	0.9962	0.7553
Bhondsi	0.9784	0.9999	0.9999	0.3924
Damdama 1	0.8505	0.9991	0.9878	0.7553
Damdama 2	0.7424	0.9905	0.9787	0.7553
Damdama 3	0.7339	0.9302	0.9921	0.7553
Damdama 4 harchanpur	0.8681	0.8773	0.9995	0.7553
Dhauj Silakhedi	0.8195	0.6454	0.9993	0.7553
Firozpur Jirka 1	0.7003	0.96	0.9866	0.6593
Firozpur Jirka 2	0.2353	0.3302	0.6547	0.7553
Gehbar Nalhad	0.7631	0.7001	0.998	0.7553
Ghaghas Ghumat Bi	0.4859	0.3302	0.9762	0.7553
Ghaghas Khori	0.6225	0.3873	0.9939	0.7553
Ghata Shamshabad	0.5798	0.5867	0.9848	0.7553
Gothda	0.6507	0.9971	0.9008	0.6593
Jabua	0.9792	0.9999	0.9998	0.7553
Khol Khaletha 1	0.8725	0.9983	0.9947	0.7553
Khol Khaletha 2	0.63	0.9713	0.9527	0.7553
Khudana 1	0.291	0.9396	0.3854	0.7553
Khudana 2	0.214	0.8177	0.2875	0.7553
Kot	0.287	0.2967	0.8118	0.7553
Kota khandewla	0.4419	0.1054	0.9823	0.7553
Kotla Kansali	0.6927	0.9968	0.9281	0.7553
Madhogarh	0.3882	0.7193	0.8478	0.7553
Mahu Rawa	0.6384	0.5715	0.9924	0.7553
Manesar	0.157	0.2042	0.4072	0.7553
Mangar 1	0.8996	0.9996	0.9946	0.7553
Mangar 2	0.7729	0.9889	0.9875	0.7553
Maseet Siha	0.5458	0.9302	0.9282	0.7553
Mewla	0.6408	0.9464	0.99	0.2573
Mewli Mohammadpur	0.7609	0.8177	0.9971	0.7553
Mukundpura Rf	0.7147	0.9071	0.9914	0.7553
Nangal mala	0.5042	0.8773	0.9202	0.7553
Nangal Nawli	0.5061	0.4787	0.9732	0.7553
Nayaan	0.8789	0.9995	0.9911	0.7553
Pali Bhakhiri	0.6524	0.5176	0.9943	0.7553
Pali mohtabad	0.6591	0.8773	0.9853	0.7553
Panchgaon	0.1581	0.1054	0.5183	0.7553
Panchota	0.7791	0.8177	0.9978	0.7553
Pathkori	0.2632	0.1667	0.8241	0.7553
Raisina 1	0.9124	0.9996	0.9961	0.7553
Raisina 2	0.7672	0.9997	0.9088	0.7553
Rusulpur Rf	0.8307	0.9988	0.9846	0.7553
Sahsola	0.2297	0.4713	0.7925	0.2573
Sakatpur	0.7055	0.8773	0.9918	0.7553
Salimabad Rf	0.206	0.7934	0.2781	0.7553
Sohla Budin Rf	0.398	0.9849	0.5133	0.7553
Sultanpur	0.111	0.9095	0.1601	0.0781
Surajkund Lakadpur	0.599	0.9026	0.9903	0.2024

APPENDIX – II

LIST OF TREE, SHRUB AND GRASS SPECIES

Tree species	Shrub Species	Grass species
Acacia catechu	*Capparis sepiaria*	*Bothriochloa pertusa*
Acacia leucophloea	*Carissa spinarum*	*Cynodon dactylon*
Acacia nilotica	*Zizyphus nummularia*	*Apluda mutica*
Acacia senegal	*Justicia adhatoda*	*Cenchrus ciliaris*
Acacia tortilis	*Adhatoda vasica*	*Saccharum spontaneum*
Aegle marmelos	*Calotropis gigantea*	*Erianthus munja*
Albizzia amara	*Calotropis procera*	*Desmotychya bipinnata*
Albizzia lebbek	*Capparis zeylanica*	*Andropogon squarossus*
Albizzia odoratissima	*Capparis decidua*	*Cumbopogon martinii*
Alstonia scholaris	*Grewia tenax*	*Chrysopogon montanus*
Anogeissus pendula	*Lantana camara*	*Dichanthium antilatum*
Azadirachta indica	*Opuntia dilleni*	*Dactyloctenium sindicum*
Balanites roxburghii	*Indigofera oblongefolia*	
Capparis decidua	*Datura alba*	
Cassia fistula	*Xanthium strumarium*	
Commiphora wightii	*Nerium odorum*	
Crateva adansonii	*Tribulus terrestris*	
Dalbergia latifolia		
Dalbergia sissoo		
Diospyros cordifolia		
Ficus benghalensis		
Ficus racemosa		
Ficus religiosa		
Flacourtia indica		
Holoptelea integrifolia		
Maytenus senegalensis		
Mitragyna parvifolia		
Moringa concanensis		
Mucuna pruriens		
Phyllanthus emblica		
Pongamia pinnata		
Prosopis cineraria		
Prosopis juliflora		
Salvadora persica		
Syzygium cumini		
Tamarindus indica		
Tecomella undulata		
Wrightia arborea		
Wrightia tinctoria		
Zizyphus mauritiana		

We are thankful to Forest Department, Govt. of Haryana for financial assistance to the research project titled "Mapping Landuse/Landcover Pattern with reference to status of key wildlife species in Aravallis Landscape of Haryana" and permits for surveys, camera trapping and monitoring of the Landscape. We acknowledge the administrative support by Haryana Forest Department. We also thank following people for their involvement in this project.

Haryana Forest Department

Dr. (Mrs.) Amarinder Kaur, IFS
PCCF/MD, HFDC, Panchkula

Dr. P. P. Bhojvaid, IFS
PCCF (HoFF), Haryana

Sh. G. K. Ahuja, IFS
PCCF (WL), Haryana

Sh. Rambir Singh, IFS
CF (Wildlife) Gurgaon, Haryana

Sh. M.D. Sinha, IFS
CF (South) Gurgaon

Sh. R. Anand, IFS
DCF Gurgaon, Haryana
Wildlife Warden, Gurgaon

Mrs. Renjitha MH, IFS
DCF Faridabad, Haryana

Sh. Sunder Lal, HFS
DFO Rewari, Haryana

Sh. Shakti Singh, HFS
DFO, Mahendergarh, Haryana

Mrs. Vasvi Tyagi, IFS
DFO Palwal, Haryana

Sh. Ravinder Singh, HFS
DFO Mewat, Haryana

Sh. Kulwinder Singh
Former DFO (WL), Gurgaon

Wildlife Institute of India

Dr. V. B. Mathur
Director, WII

Dr. G. S. Rawat
Dean, WII

Dr. Bitapi C. Sinha
Researcher Coordinator, WII

Local Field Support

Sh. Chetan Agarwal
Gurgaon Haryana

Sh. Sunil Harsana
Gurgaon, Haryana

Dr. Bilal Habib
Department of Animal Ecology and Conservation Biology
Wildlife Institute of India, Chandrabani
Dehradun, India 248 001
Tell: 00 91 135 2646283
Fax: 00 91 135 2640117
E-mail: bh@wii.gov.in

भारतीय वन्यजीव संस्थान
Wildlife Institute of India