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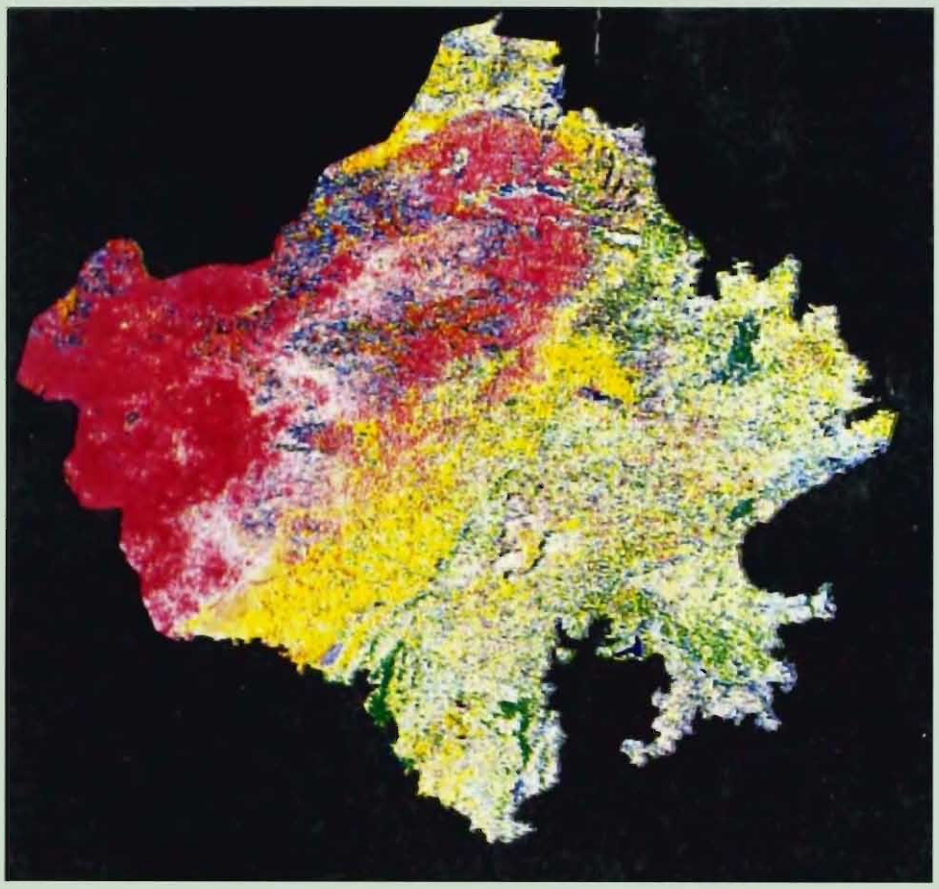
Habitat Suitability Analysis of Chinkara, *Gazella bennetti* in Rajasthan

A Remote Sensing and GIS Approach



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PREFACE

Global Biodiversity Convention (GBC) has put the highest priority on sustainable management of nature and natural resources for the very existence of the life on planet Earth. Judicious exploitation of these resources is being advocated globally. The delicate balance between the evolution of biological entities and extinction rate is dwindling more so in the recent past. Conservation efforts in India, being one of the 'mega-biodiversity' regions, have to play a very significant role at the regional/global level. Men play a very crucial role in destroying as well as saving biodiversity. Fragmentation and loss of habitats are seen as the major causes of biodiversity depletion. Thus there is urgent need to have basic information on flora and fauna – both historically and present.

India is one of the largest users of satellite data based information. Remote sensing (RS) technology has aptly supported traditional methods of surveying, inventorying and management. Indian space programme is committed to provide continuos data for updating and monitoring earth resources. Geographic Information System (GIS) provides ample opportunities to integrate, analyze and generate scenarios based on human knowledge and geophysical parameters. Combination of RS and GIS is making tasks of planning and decision making much easier. Foremost requirement for *in situ* or *ex situ* conservation is to understand complexities involved and then analyze their need in any ecosystem or habitat. Database, to meet such challenges can be huge and yet scarcely available. Habitat characterization for prioritization of potential conservation areas based on landscape parameters is necessary. Thus RS and GIS technologies are the ideal tools for geospatial data acquisition and handling.

Application of RS and GIS technologies has been skewed towards vegetation characterization. Present effort may be seen as an added dimension to the joint effort of Zoological Survey of India and Indian Institute of Remote Sensing in the field of faunal characterization/studies. A very innocent and attractive '*Chinkara*' is one of the endangered animals which require protection. Its population in the state of Rajasthan is declining in spite of efforts to protect both from government and communities. It is hoped that the present work will provide useful inputs for the conservation of 'Chinkara' *in situ* to wildlife managers and lovers.

I see this work as a very modest beginning and an excellent effort towards the cause of biodiversity conservation.

(P.S. ROY)
Dean
Indian Institute of Remote Sensing

Place: Dehradun
Dated: October, 2000

Records of the Zoological Survey of India

OCCASIONAL PAPER

No. 189 | 2001 | 1-73

CONTENTS

AZSI - IIRS Joint Project

How beautiful
the world be
if
the wilderness and development go together

INTRODUCTION

The importance of desert areas of India for the conservation of natural resources has been recognized nationally and internationally. Rajasthan is the major Desert State in India with about 60% of the Thar Desert lying within the western part of the state. Due to an admixture of Saharan, Turanian, Oriental and Peninsular elements the state exhibits excellent faunal diversity. Adams (1899), Blanford (1888-91) and Jerdon (1867) had recorded mammalian abundance in the desert region, a habitat preserved *in-situ*, due to low human density during late nineteenth century. On the other hand the eastern part of Rajasthan falls under semi-arid zone, that is a large transition area between the true desert and the seasonally wet peninsular India. Abundance of grasses and edible shrubs allow the development of relatively high ungulate densities, like the Black Buck, Cheetal, Nilgai and Sambhar.

Populations of several mammalian species of great conservation significance, though they are not restricted to the above-mentioned bio-geographic (arid and semi-arid) zone alone are also available. Species such as Caracal, Wolf, Fox, Jungle Cat, Desert Cat, Leopard, Tiger, Chowsingha, Black Buck and Chinkara can be observed here. The populations of many of these species are however, on the decline recently due to incessant anthropogenic pressures resulting in their habitat loss. Of late the impact has been acute and hence newer methodologies have been used to help in the conservation of the remaining faunal diversity in these areas.

1.1 Role of Geo-Informatics in Animal Resource Management:

Due to development of advanced satellite based Earth Observation System and extraordinary processing capabilities of computers to store and analyze large quantity of data geo-informatics nowadays is the most sought after technology in the management and conservation of natural resources. It operates basically on three components, viz., Remote Sensing data (which is acquired in different resolutions through Remote Sensing Satellites, such as IRS 1C & 1D), Image Processing and Geographic Information System [GIS], which are the processes executed through software's like ERDAS and ARC/INFO respectively. While Image processing, facilitates the remote sensing data ready for analysis, the GIS facilitates the storage and intelligent use of geographical data, i.e., topographic data about land and or hydrographic features, as well as descriptive/non-location data about these features including human activities at different points of time.

The Indian Remote Sensing Programme has demonstrated tremendous capabilities by successfully launching operational remote sensing satellites (the latest being state of art IRS-1C, 1D) providing images of resolution as high as 5.6m. It has opened up immense opportunities to utilize the voluminous information available on different scales and time on various aspects of environment and natural resources.

It would be appropriate to understand the basics of Remote Sensing techniques, before proceeding further, as how remote sensing data is used in the study of wildlife and it's management without any trace of animals on the images received from the satellites.

1.2 Remote Sensing:

Above absolute zero temperature all objects radiate electromagnetic energy by virtue of their atomic and molecular oscillations. The total amount of emitted radiation increases with the body's absolute temperature and peaks at progressively shorter wavelengths. Remote Sensing works on the above property, and defined as acquisition of information about the condition and/or the state of target at earth's surface by a sensor (placed on board in satellite) that is not in direct physical contact with it. The basic strategy for sensing electromagnetic radiation is that everything in nature has its own unique distribution of reflected, emitted and absorbed radiation. These spectral characteristics if ingeniously exploited can be used to distinguish one thing from another or to obtain information about shape, size and other physical and chemical properties. This is accomplished by measuring Electro Magnetic Radiation (EMR) emitted or reflected by the surface of earth. The interaction between sun's electromagnetic radiation and the earth surface modulates characteristics of emerging radiation from earth surface. The modulation may result in change in brightness, polarization and direction of radiation; it is wavelength dependent as well. This modulation serves as signal that is used for remote sensing of the target characteristics. Therefore, by measuring radiant energy (reflected or emitted) in different parts of electromagnetic spectrum, one can differentiate and distinguish features on the earth surface. The remotely sensed data contains both spatial (size, shape and orientation) as well as spectral information (tone, colour, spectral signature, etc.).

Various satellite sensors have been designed to capture the radiant energy reflected or emitted by objects on earth. Sensor is a device that gathers energy (EMR or other), converts it into a signal and presents it in a form suitable for obtaining information about the target under investigation. These may be active or passive depending on the source of energy. They are primarily designed to fulfil requirements of different resolutions and repetitively/ periodicity (duration of revisiting same part of the earth). While resolution capability is used for different levels of planning (such as district, state and country levels), the periodicity can be exploited for measuring changes through fixed intervals of time. The orbital characteristics of IRS series satellites and characteristics of different camera /sensors placed on them are given below (Table 1– 4).

Table 1 : Orbital characteristics of IRS series satellites

Features	IRS-1A/1B	IRS-P2
Altitude	904 km	817 km
Orbital period	103.2(min)	101.35(min)
Temporal resolution	22 days	24 days
Equatorial crossing time (local sun time)	10.00 AM	10.00 AM
Sensors	LISS-I LISS-II*	LISS-II*
Swath (km)	2 x 74 148	2 x 74 148
Resolution (m)	72.5 36.25	36.25

* LISS II has two cameras as A & B

Table 2 : Orbital characteristics of IRS-1C and IRS-1D

Features	IRS-1C	IRS-1D
Orbit type	Polar Sun synchronous	Polar Sun synchronous
Altitude	817 km	780 km (mean)
Inclination	98.69^0	98.53^0
Distance between adjacent tracks	117.5 km	111.94 km
Repetivity for LISS-3	24 days	25 days
Repetivity for WiFS	5 days	3 days
Revisit for PAN	5 days	3 days
Off-nadir coverage ± 26^0 for PAN	398 km	407 km
Stereo viewing capability	5 days	3 days

Table 3 : Characteristics of LISS-III Camera

Band 2	0.52-0.59 μm
Band 3	0.62-0.68 μm
Band 4	0.77-0.86 μm
Band 5	1.55-1.70 μm
Geometric resolution	23.5 m for bands 2,3,4 70.5 m for band 5
Equivalent focal length (bands 2, 3, 4/band 5)	347.5 mm/301.2 mm
Swath	141 km for bands 2,3,4 148 km for band 5
Radiometric resolution	7 bits
Band-to-band registration	±0.25 pixel

Table 4 : Characteristics of PAN Camera

Geometric resolution from altitude of 817 km	5.8 m
Effective focal length for optics	980 mm
Swath	70 km
Field-of-view for optics	$\pm 2.5^0$ (across track) $\pm 0.3^0$ (along track)
Spectral band	0.5-0.75 μm

Table 5 : Characteristics of WiFS Camera

Band 3	0.62-0.68 μm
Band 4	0.77-0.86 μm
Resolution	188.3 m
Swath	810 km
Radiometric resolution	7 bits
Band-to-band registration	±0.25 pixel

Hence, what we see in remote sensing images are mostly shapes, size and total variations of different kinds of vegetation and other large features like human settlements, forests, wetlands and hills, etc. constituting different macro habitat and their continuity in space and time. Animals have no specific reflectance values that can be recorded by the sensors placed in the satellite. However, animals are habitat specific that in turn can be identified by remote sensing. The combination of numerous factors like type of vegetation, altitude, latitude, longitude and various climatic factors together constitute diverse kinds of macro- and microhabitats. Therefore, if we precisely know that at a particular part of the earth's surface the type of habitat available, we can predict the kind of animals expected to occur there, and in turn help in habitat management which could become a very useful tool for species management.

The habitat suitability analysis of an animal is part of its habitat management strategy. A few studies using remote sensing techniques and GIS have been carried out recently on the habitat suitability analysis of Indian mammals such as Goral, *Nemorhaedus goral* (Roy, *et al.*, 1995); Sambar, *Cervus unicolor* (Porwal, *et al.*,1996); the Great Indian One-Horned Rhinoceros, *Rhinoceros unicornis* (Kushwaha, 1997) and Indian Elephant, *Elephas maximus* (Rout, *et al.*, 2000).

OBJECTIVES OF THE STUDY

2.1 Background:

A detailed project entitled "Status Survey of Chinkara and Desert Cat in Rajasthan" was recently carried out (1993-95) by Zoological Survey of India (Kankane, 2000). The study revealed that the present population of Chinkara has not only declined in approximately 47 development blocks of the state (out of a total 236 blocks), but has severely fragmented and shrunken round three nuclei, namely, Phalodi, Bassi and Dausa (l.c.). Therefore, these populations have little chance of exchange of individuals between them. The situation is so alarming that inbreeding cannot be ruled out in two of them, *viz.* Dausa and Bassi.

Another important finding of the project was the linking of relative abundance of Chinkara population to the characteristics of arid western plains agro-climatic zone which holds maximum wastelands (landuse under pasture, cultivable waste, with or without scrub, cultivable sandy areas and fallow land). The study also visualizes that with the development of technology such wasteland (the most suitable habitat available for Chinkara) are being and will continue to be treated as future land banks for local human populations. The best-known example in support of this kind of development is the present land use in Ganganagar district of Rajasthan. This was once part of the arid wasteland, till large-scale irrigation plans made it the greenery of Rajasthan, resulting almost in the total elimination of Chinkara from this district (Kankane, 2000), except for a few isolated groups around Bishnoi villages (because of the age old traditions and customs of protection they offer to these animals).

A mega irrigation project, i.e., Indira Gandhi Nahar Project (IGNP) is fast coming up in the area, which holds maximum concentration of Chinkara in the state at present.

The findings of Rahmani (1997) were also available for the period (1993-94) showing the density of Chinkara along the 176 survey routes covering nine districts of the western part of Rajasthan, which is the present stronghold of Chinkara in the state.

In light of the above and realizing the fact that the ground truth data generated on the relative abundance and distribution of the target species could be a useful tool for management of this typical beautiful desert dwelling animal, it was proposed to create a database and analyze the above information in GIS along with various life support systems, disturbance factors and data from Remote Sensing. The findings of this study are presented in this paper.

While comparing densities of various kinds of habitats and natural competitors with that of Chinkara density it has been noted that Chinkara has a positive relationship with higher densities of Fallow land, Grazing land, Salt effected land and Camel population. On the other hand Chinkara density has a negative relationship with the higher densities of Gullied and ravinous land, Cattle, Sheep, Goat and Human population (see maps at pages 63 to 68).

STUDY AREA

Rajasthan lies between 23° 30' and 30° 11' N latitude and 69° 29 and 78° 17' E longitude, in the track of the Arabian Sea branch of the south–west monsoon. However, the Aravalli, and in the south–east the plateau of Hadauti being the only highland channel, the SW monsoon coming from Kathiawar is stopped, creating the desert in the west. While the western boundary of the state is part of Indo-Pak international boundary, the Indian States of Punjab and Haryana surround Rajasthan in the north, Uttar Pradesh in the east, Madhya Pradesh in the southeast, and Gujarat in the southwest (Anon., 1994).

Physiography of Rajasthan is the product of long years of erosion and depositional processes. The present landforms and drainage systems have been greatly influenced and determined by the geological formation and structures. Four major physiographic regions can be identified within the state, namely,

1. The Western Desert (Thar),
2. The Aravalli Hills,
3. The Eastern plains and
4. The South – eastern plateau

The Aravalli hill ranges, running from northeast to southwest divides the state approximately into the western arid and eastern semi-arid regions. It is also a major water divide. The area, to its east, is well drained by integrated drainage systems, while the area, to the west, has only one integrated drainage system, *i.e.*, the Luni drainage system in the southeastern part of the desert (see map at page 47).

3.1 Life Support System :

3.1.1 Climate :

The climate of Rajasthan varies from arid to sub-humid. To the west of the Aravalli range low humidity and high wind velocity characterize the climate. The climate is semi–arid to sub–humid in the east of the Aravalli range and characterized by more or less the same extremes in temperature, but relatively lower wind velocity and high humidity with better rainfall.

A marked variation in diurnal and seasonal range of temperatures occur throughout the state that is the most characteristic phenomenon of warm–dry continental climate. The summer begins with the month of March with temperature rising progressively through April, May, June and reaches up to 49^0 C at some places (see map at page 59). The winter season remains from December through February with marked decline in minimum temperature in December and January (see map at page 60). A sharp decline in night temperatures is experienced throughout the arid and semi – arid zone of western Rajasthan on account of quick release of thermal radiation from sandy soil soon after the dusk.

The climate is marked by low rainfall with erratic distribution. The general trend of Isohytes is from NW to SE. There is a very rapid and marked decrease in rainfall west of Aravalli range making western Rajasthan the most arid part (see map at page 49).

Potential evapo-transpiration is higher than precipitation even during rainy months in the western part of Rajasthan, making these regions arid to extremely arid in climate with perpetual water deficit throughout the year. However, on the eastern side the rainfall is much higher during the rainy season than the potential evapotranspiration demands during that time, thus providing water surplus during the rainy season resulting in more vegetation and cultivation (see map at page 62).

Apart from the above prominent climatic factors, humidity, wind velocity and duration of sunshine, etc. affect the cropping pattern in such significant ways which in turn not only affects the agricultural practices but also the life style of the people. On the basis of climatic conditions and agricultural produce, Rajasthan has been divided into nine agro-climatic zones (see map at page 50).

3.1.2 Vegetation :

The state of Rajasthan is endowed with a wide range of vegetation that can broadly be categorized into two distinct groups. One comprising the arid vegetation, falling into the western part of the state, while the other belonging to semi–arid to sub–humid category in the eastern and southern Rajasthan.

Western Rajasthan, characterized by sparse vegetation, is neither barren nor uninhabited. It is covered with bushes and shrubs and even small trees which are well adapted to the arid conditions and show great modifications, but the species diversity and dominance is

well marked (see map at page 55). It is a great sandy tract with no streams and few rocks that protrude above the lower land now covered with sand apparent to be immobile sand dunes (see map at page 48). The grasses on these dunes grow in clumps, indicating the availability of water just beneath the sandy soil. Today what we observe is the degraded stage.

In contrast to the west, the eastern region receives 50-80 cm rainfall and largely constitutes the plains, deeply buried or exposed pediment plains or undulating rocky plains, valleys and Aravalli range which contain protected and reserve forest areas. The plains are largely under double cropping and hence the existing vegetation is very much modified due to agricultural operations.

3.1.3 Forests :

According to Champion & Seth (1968) a major part of Rajasthan falls under subgroup 6B- Northern Tropical Thorn Forest, with following types (see map at page 58) :

C1- Desert thorn forest

C2- Ravine thorn forest

C3- Rann thorn forest

DS1- Zizyphus scrub

DS2- Tropical Euphorbia scrub

The forests are unevenly distributed in various districts and most of these are over the hilly areas which make up for about 50% of the forests of the state (see map at page 57).

3.1.4 Wastelands :

Wastelands are lands which are degraded and at present lying unutilised or which are not being used to its optimum potential due to different constraints. Broadly these lands can be grouped as cultivable or non-cultivable. As per estimates Rajasthan has about 92.56 lakh hectares of wastelands of different types. Desertic sand cover constitutes about 49.69% of the total wastelands in Rajasthan (see map at page 56). The cultivable wastelands are capable of or have the potential for development of agricultural or pasture purposes or can be afforested. The non-cultivable wastelands on the other hand are barren lands that cannot be put to any productive use either for agriculture or to develop forests.

3.1.5 Protected Areas :

Rajasthan has a three tier conservation system with a large network of sanctuaries (23) and national parks (2) which is about 9250 km^2 and constitute about 2.7% of the total geographical area of the state. In addition to above, the government has declared 32 Closed areas of about 27950 km^2 for the purpose of giving added protection to individual species like Chinkara and Black Buck, as well the associated carnivores. The Closed areas are

typical scrubland, grazing and cropland, where villagers have traditionally protected wildlife. However, closed area status is not a long-term conservation measure because the government has no right over the land. Though the grasslands and scrubland of Rajasthan are valuable habitats for wildlife they also house large populations of resident and transient domestic livestock (see map at page 68). As a result, many wildlife areas are largely degraded in absence of effective core zone system and wildlife biomass is only a fraction of that of domestic stock.

At the same time change in land use practice leads to loss of wasteland and increased man–animal conflict. This problem is more pronounced in the western Rajasthan where most of the land is in private hands. However, the eastern part is relatively well protected which have almost all the national parks and sanctuaries of the state. Details of existing protected areas are given in the map (see map at page 61).

3.2 Man and his Activities :

3.2.1 Administrative Set-up :

The state of Rajasthan was constituted on November 1, 1956, comprising 23 erstwhile princely states and a centrally administrative province.

The state is divided into six divisions, with 31 districts in all (see map at page 43). The districts vary greatly in area and population. The western districts are generally much larger in size then the eastern and southern districts. Of the 31 districts four newly created districts, namely, Baran, Dausa, Hanumangarh and Rajsamand have been analysed along with Kota, Jaipur, Ganganagar and Udaipur respectively (27 Districts in all), since topographic and other features of these newly created districts are not available independently.

The smallest unit of administration in the state is the Development Block (Panchayat samitis), which comprises a cluster of gram panchayat. In all there are 236 blocks spread over the state (see map at page 44).

3.2.2 Land use Pattern :

Various land use patterns are in practice in the state, depending on the type of soil and water resources available.

Following six groups of land use classes are predominant in the state, namely, forest, land put to non agricultural uses, permanent pastures, gullied, salt affected and fallow land (see maps at pages 64 to 66).

3.2.3 Population Growth :

Rajasthan occupies 10.41% of the country's total geographical area yet its population is only 5% of the country. The population of the state has increased consistently from 30 to 128

persons/sq km, but still much lower than the country average of 267 persons/sq km (see maps at pages 45 & 63).

3.2.4 Infrastructure :

Rajasthan does not have a good network of roads due to its large desert area. The total length of roads in the state is 61,602 km of all types. The road density varies from 10.84 km/100 sq km to more than 30 km/100 sq km. Railways are the most important means of inland transportation in the state. The total length of railways in Rajasthan today is over 6227 km, extending into almost all districts (see map at page 46).

3.2.5 Indira Gandhi Nahar Pariyojana (IGNP) :

IGNP is a mega Irrigation project with the aim of fetching the river water to the waste stretches of desert in western Rajasthan from the Himalayas. The water is diverted from Hari-ke-barrage in Punjab and travels for about 650 km to Rajasthan. The project was initiated in 1958 and partial irrigation facility began in 1961. It comprises two stages, *viz.*; stage I and II. Stage I (phase I) comprises all command land whose canal system took from 0 to 74 km of main canal, while the phase II comprises from 74 to 189 km of main canal. By and large the work has been completed in Stage I (both phases), while Stage II was targeted to be completed by the year 2000 however, work in this Stage is still in progress. On completion of IGNP, it is expected to create irrigation potential of 24.65 lakh hectare (see map at page 73).

3.2.6 Livestock :

Rajasthan is rich in milch and non-milch animal wealth. It has the distinction of having the largest population of cattle, sheep and camels of different breeds. While the density of camel is greater in the western arid region, the eastern and southern parts of the state have greater population of goats while the sheep density is more in south central region of the state (see maps at pages 63, 66, 67 & 68).

3.2.7 Man – Animal Relationship :

Culturally the people of Rajasthan have over the centuries developed a dichotomous attitude towards wildlife. On the one hand, there are Rajputs – the princely caste – and their minions, besides a number of nomadic and forest dwelling tribes, who looked upon hunting of wildlife as their main pastime. They killed whatever game, came their way. On the other extreme, there are believers in total protection of nature, particularly those belonging to the trading communities, Brahmins, Jains and other religious sects (Prakash, 1980). The contribution of the Bishnoi community towards the cause of wildlife protection in general and Black Buck in particular in the states of Rajasthan and Haryana is unique and needs no elaboration. Though during princely days it was the prerogative of the *Rajas* and nobles to hunt in the state forests, they also undertook great efforts for general protection of wildlife.

Their love for wildlife speaks in some of their creations which are the best sanctuaries and national parks (Sariska, Gajneer, Sawai Madhopur and Bharatpur) we have today in Rajasthan. However, the situation gradually changed after independence. In the absence of any legislation thoughtless and ruthless killing of all kinds of wildlife became the order of the day till the Parliament enacted Wildlife (Protection) Act 1972.

3.3 The Target Species Chinkara or Indian Gazelle, *Gazella bennetti* Sykes, 1831 :

Gazelles (16 species) inhabit the desert and semi–desert regions of Africa, the Middle East and the Central Asia. They are adapted to subsist in arid conditions.

The Indian Gazelle, *Gazella bennetti* is a small, slender and gracefully built animal. Male bear annular horns (maximum length 40 cm), while females are normally with small, straight, smooth, thin spikes curving backward without any annulations. The Chinkara is light chestnut above, white on sides, buttocks, chin, breast and lower parts; tail black; knee brushes dark brown and dark rufous face with white streaks on it. During summer the coat colour is reddish buff with smooth and highly glossy fur. This is probably an important adaptation for reflecting back some of the sun rays and thus minimizing heat absorption during the very high day time temperature experienced in its habitat (Roberts, 1977).

3.3.1 Past Distribution of Chinkara :

The earliest distribution records of the Chinkara are available from Blanford (1873). He had defined its limits as (Quoted from Strendale, 1884) "throughout Punjab, North–West Provinces, Rajputana, Sind, Kutchh, Kathiawar, Guzerat and the whole Bombay Presidency, with exception of the Western Ghats and low land in Konkan along the western coast, south of the neighborhood of Daman" Blanford (l.c.) also reported its sightings in Narbada and Tapti valley and Rewah in Nagpur and Chanda country, Berar the Hyderabad territories and other parts of southern India, with a complete exception of the Malabar Coast and the adjacent hills. He further adds that "...from the evidence of Colonel Mc Master and Colonel Douglas Hamilton, it is not known to occur much south of Krishna river, nor it is found in the Ganges valley east of Benaras, in Eastern Bihar, the Santal Pergunnahse, Chota Nagpur, Birbhum Chhatisgurh, the Mahanadi valley, Orissa, Bastar and the east coast..." The distribution limits given by Blanford (1873) cover nine states of present India (Punjab, Haryana, Rajasthan, Gujarat, Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh and Uttar Pradesh), besides some parts of Pakistan. On the basis of available information Chinkara was once well distributed throughout the state of Rajasthan.

3.3.2 Habitat Requirement :

Jerdon (1874) recorded that "Chinkara is never found in forest country and districts having damp climate. They are often met with in low thorny jungle. However, as a rule it

prefers open bare plains or low rocky hills or sandy hills than richly cultivated and alluvial plains" Kankane (2000) made a detailed study on its occurrence in different habitats in Rajasthan, which include gullied land, grass land, fallow land, sandy area and open bare plains with scrub vegetation.

3.3.3 Brief Biology and Socio–biology :

The Chinkara is usually seen in small herds, rarely more than 7 or 8 individuals, except in extreme northwest where Jerdon (1867) and Prakash (1994) have recorded very large herds (up to 200 individuals). Young expelled bucks are often found in separate herds. Apart from this, single individuals are also of common occurrence. The Indian gazelle is very swift, not particularly wary and when alarmed stamps its fore feet and hisses through the nose hence named Chinkara – the Sneezer. The flesh is delicious and is considered better than the Black Buck.

The Chinkara, though seen roaming and feeding during daytime in the Thar area, the animals have been observed feeding as late as 0100 hrs. in the cultivated fields (Kankane, 2000). Bohra and Goyal (1991) while studying food and feeding habits of Chinkara and Black Buck concluded that during the post–monsoon and winter seasons, the Chinkara generally prefers the leaves of *Crotalaria burhia, Zizyphus nummularia* and flowers of *Tecomella undulata.* During summer *Eleusine compressa, Maytenus emerginata, Zizyphus nummularia, Prosopis cineraria* and *Heliotropium spp.* appear to be the most preferred food. Bohra *et al.* (1992) have listed about 13 species of plants, parts of which (containing 61 to 86% moisture) are consumed by Chinkara. This ensures reasonably large contribution of the preformed water of the feeds to their overall water balance. Sterndale (1884) had also pointed out that the Chinkara may not need any free water for drinking purposes, its food habit and physiological efficiency of water use is good enough to keep its water balance.

Prater (1971) did not record any particular season for breeding of Chinkara in India. Roberts (1977) reported two-rut seasons for Pakistan population of Chinkara. First such rut last from the end of the SW monsoon up to early October and second in the late spring from March to the end of April. Rahmani (1997) has reported SW monsoon period as breeding season of Chinkara in the Thar Desert. The gestation period is about five to five and half months, twins have been noticed frequently (Dunbar Brander, 1923). Peak littering rate is reported during February–March and August–September. The young do not follow mother until they are two to three days old. Roberts (1977) reported that they are not sexually mature till two years of age and frequency of oestrous cycle is 28 days (as observed in captive females).

Nothing is known about their predation from Jackal and Wolves. However, Kankane (2000) reported an important aspect of predation in the cultivated areas of Ganganagar and Bikaner districts (where Wolves and Jackals have been either eliminated or are very rare due to extensive agriculture), the land–owners in these areas keep good breed pet dogs to keep the Chinkara and Black Bucks away from their crop fields. This does not only play an

effective role in checking the antelope population but also save their masters from the litigation of the Wildlife (Protection) Act, 1972 and also the anger of neighboring *Bishnois*.

3.3.4 Present Distribution :

Recently Rahmani (1990, 1990b & 1997) and Kankane (2000) dealt with distribution, density, and group size and conservation issues of the Chinkara in Rajasthan. Kankane (*l.c.*) records that Jodhpur ranks first in the relative abundance of Chinkara, out of fifteen districts (with positive reports), with about 30% of population. This cluster along with seven other adjoining districts in western Rajasthan (Barmer, Bikaner, Jaisalmer, Jalore, Nagaur, Churu and Pali) hold about 89% of population of the total Chinkara counted during the survey. The nucleus of this population is at Phalodi (a tehsil of Jodhpur district). The next stronghold of Chinkara population is around Bassi in Chittaurgarh district that holds about 9% of the total Chinkara's from Kota, Baran, Bhilwara and Udaipur districts; while the third nucleus of Dausa holds only about 1% of the population from Dausa, Sawai Madhopur, Jhunjhunun and Jaipur districts (see map at page 69).

4.0 METHODOLOGY

4.1 Ground truthing of Chinkara :

For the period during 1993–1995 findings of two studies by Rahmani (1997) and Kankane (2000) on the distribution and density of Chinkara are summarised below.

Results of Kankane (2000) are based on two years of field study on Chinkara from March 1993 to April 1995 covering the whole of Rajasthan. During the survey each district headquarters was visited to contact forest officials for inquiries concerning the availability of the Chinkara in their districts. In addition to the above, locality responses from knowledgeable villagers, shepherds, old *shikaris* and NGOs and queries based on coloured photographs of the target animal were recorded. Subsequently, survey routes were designed to cover maximum possible potential Chinkara localities in the above updated list. The surveys were carried on vehicle and data recorded in Transect Data Sheet (TDS) designed for this purpose. These records include herd size, sex–ratio whenever possible, and number of young's. As the development activities (irrigation, electricity, roads, industry, etc.) and wildlife dispersal are inversely related; development blocks (total 236) were adopted as unit for displaying the results of field survey (see map at page 44). During surveys, localities (as above) were the target for search of animals and not the entire block. The animal count of the present study does not represent census of Chinkara. The author (*l.c.*) did not report any density figures, hence they were calculated during the analysis of current study.

Rahmani (1997) carried out three field surveys in the nine districts of the western part of the state from February 1993 to 1994. The author recorded date, time, distance covered, type of road, number and sex of animals, herd size and dominant human communities in the

area. Based on 176 counts, the author reported overall density of Chinkara as 0.88/km^2 (ranging from 0 - 24.40/km^2)

Use of Data :

Survey routes (total 176) taken by Rahmani (1997) were digitized on screen using SOI Toposheets in 1:1,000,000 scale (Table 8) as base map, except 11 untraceable routes. Thereafter development block theme was overlaid on the route map. ArcView-Identify option was used for preparing a block wise list indicating number of times a specific block was surveyed and analogous densities reported. The routes partially falling in a block were also taken into account. The density of Chinkara in a specific block was calculated taking the average of the total reported densities. This can be described in mathematical terms as :

$$\mathbf{dn\ (R)} = \frac{\mathbf{\Sigma dn\ (r)}}{\mathbf{n}}$$

where
dn(R) = Average density of Chinkara in a block after Rahmani (1997)
Σdn (r) = Sum of densities reported for a particular block
n = Number of times densities reported for the block

Survey routes undertaken by Kankane (2000) were also digitized as above. The density of Chinkara was calculated based on Transect Data Sheet (TDS) using transects length and total number of animals sighted. These density figures were tabulated block wise and were used after averaging as in the above study. However, seldom repeat surveys were carried out. These can be described in mathematical terms as :

$$\mathbf{dn\ (K)} = \frac{\mathbf{\Sigma dn\ (k)}}{\mathbf{n}}$$

where :
dn(K) = Average density of Chinkara in a block after Kankane (2000).
Σdn (k) = Sum of densities reported for a particular block
n = Number of times densities reported for the block

Finally, average density of Chinkara for a particular block was reached by taking corresponding averages of the two studies (details at Annexure-I). The final density figures are absolute and cannot be used for census of Chinkara in the state as the animal is not randomly distributed. These can be described in mathematical terms as :

$$\mathbf{dn(K+R)} = \frac{\mathbf{dn(K) + dn(R)}}{\mathbf{S(k) + S(r)}}$$

where
dn(K+R) = Final average density of Chinkara in a block
dn(K) = Average density for a block after Kankane (2000)
dn(R) = Average density for a block after Rahmani (1997)
S(k) = Surveyed by Kankane, *if yes = 1; if no = 0*
S(r) = Surveyed by Rahmani, *if yes =1; if no = 0*

The results of the final average density were plotted in a map (see map at page 69). It ranges from 0.0 to 6.55 individuals /km^2 with 32 classes in between. These 34 classes were clubbed into five, ranging from 0-0.19, 0.19-0.57, 0.57-0.97, 0.97-1.76 and 1.76-6.55 individuals/km^2, for the purpose of meaningful analysis. The results of the analysis are plotted blockwise as relative average density of Chinkara in the state (see map at page 70). This map is used for all the practical purposes of analysis during present study.

4.2 Creation of Database:

Habitat suitability analysis requires generation of accurate database on various life support systems as well as potential disturbance factors in the habitat. A total of 19 maps were digitized to create the spatial vector layers (coverage's) required for digital analysis under Geographic Information System (GIS). The details of base maps used, soft and hard copies generated and their associated attributes are given in the Table 6.

On screen digitization was carried out using Window based ArcView 3.0b GIS software, editing was done by using ARCEDIT 7.1.2. and final layouts were prepared using ArcView 3.1. Two layers (Human settlements and Infrastructure) have been prepared to create zone of influence of roads and settlements on the habitat suitability of the target species. Based on norms different values were assigned for creation of buffer (see maps at pages 45 & 46) around above human activities. Though in the arid areas where the vehicular traffic is very low (due to comparatively lower human density), the buffer zone concept plays a limited role since most of the animals were sighted during roadside surveys.

4.3 Digital Image Processing:

ERDAS Imagine software was used for generating False Color Composites (FCC) of the IRS 1C & 1D WiFS data of bands 3 & 4 using Digital Personal Workstation (tables 8 and 9). Geo-referencing of images was carried out by extracting GCP's from 1:1,000,000 scale Survey of India topo sheets using image rectification model. Later all the eight scenes of WiFS data were correspondingly used for preparation of mosaic images for four different periods of the year viz., January, April, October and December.

Table 6 : Data Preparation

S. N.	Title/Name of File	Base map/s	Attributes	Code	Hard copy at page
1.	State *arc_state*	SOI Topo sheets (Ref. Table 8)		170000	43
2.	Districts *arc_dist*	SOI Topo sheets (Ref. Table 8)		See map	43
3.	Development Blocks *arc_blocks*	Resource Atlas of Rajasthan		See Ann exure I	44
4.	Human Settlements *Setlmnts.shp*	SOI Topo sheets (Ref. Table 8)			45
5.	Railways *railways*	SOI Topo sheets (Ref. Table 8)			46
6.	National Highways *nh*	SOI Topo sheets (Ref. Table 8)			46
7.	State Highways *sh*	SOI Topo sheets (Ref. Table 8)			46
8.	Major Roads *majroads*	SOI Topo sheets (Ref. Table 8)			46
9.	Sandy Area *arc_sand*	SOI Topo sheets (Ref. Table 8)	Sand	poly_id	48
				Sand	
			Non-sand	Non-sand	
10.	Rainfall *arc_rainfall*	Resource Atlas of Rajasthan		rainfall_ code	49
		Sh. S. S. Bhandari Former Director & Sh. H. R. Solanki Director Meterological Centre, GOI, Jaipur	< 10	10	
			10-20	9	
			20-30	8	
			30-40	7	
			40-50	6	
			50-60	5	
			60-70	4	
			70-80	3	
			80-90	2	
			> 90	1	

S. N.	Title/Name of File	Base map/s	Attributes	Code	Hard copy at page
11.	Agro-climatic Zones *agroclzones*	Resource Atlas of Rajasthan Sh. K. L. Vyas Retired Professor (Plant Breeding) Rajasthan Agriculture Univ., Jodhpur		zone_code	50
			Arid Western Plains	11	
			Irrigated North Western Plains	12	
			Transitional Plains of Inland Drainage	21	
			Transitional Plains of Luni Basin	22	
			Semi-arid Eastern Plains	31	
			Flood Prone Eastern Plains	32	
			Sub-humid Southern Plains	41	
			Humid Southern Plains	42	
			Humid South-eastern Plains	50	
12.	Wasteland *arc_ wasteland*	Resource Atlas of Rajasthan Dr. N. C. Gautam Group Director Land use, Cartography and Printing Div. NRSA, Hyderabad		wasteland_code	56
			Gullied and/or Ravinous Land	1	
			Undulating Upland with or without Scrub	2	
			Water Logged	3	
			Salt-affected Land	4	
			Degraded Forest	5	
			Sandy Area	6	
			Baren Rocky/Stony/Waste Sheet Rock area	7	
			Non Waste	8	
			Forest	9	
13.	Vegetation (trees & shrubs) *vegetation*	Resource Atlas of Rajasthan		vegetation_code	55
			Acacia nilotica	01	
			Suaeda fruticoa salsola bryosma	02	

S. N.	Title/Name of File	Base map/s	Attributes	Code	Hard copy at page
		Shri S. K. Saxena Principal Scientist CAZRI, Jodhpur	*Acacia senegal Euphorbia caducifolia*	04	
			Anogeissus pendula Euphorbia caducifolia Rhusmysorensis	05	
			Butea monosperma Madhuca indica ziziphus mauritiana	06	
			Anogessus pendula Boswellia seratta	07	
			Mangifera indica syzgium cumini	09	
			Calligonum-Haloxylon Leptadenia	10	
			Ziziphus-capparis	11	
			Salvadora-Euphorbia	12	
			Prosopis-capparis -ziziphus	13	
			Prosopis-Acacia	14	
			Proscopis-Tecomella	15	
			Salvadora-Proscopsis-Capparis	08	
			Acacia nilotica-Acacia cupressiformis	17	
			Acacia leucphloea - P. cineraria - A. nilotica	16	
14.	Forest Type *arc_fortype*	Resource Atlas of Rajasthan		fortype_code·	58
			Tropical Dry deciduous Forest	0	
			Tropical Thorn Forests	10	
		Sh. S. K. Verma IFS, Retd. PCF, GOR, Udaipur	Sub tropical Hill forests	20	
		Sh. S. K. Srivastava IFS, Project Director, DRDA, Jodhpur	Non Forests	30	
		Sh. O. S. Kachhwaha DCF, GOR, Jaipur			

S. N.	Title/Name of File	Base map/s	Attributes	Code	Hard copy at page
15.	Forest Cover *arc_forcov*	do		cover_code	57
			Dense Forest	11	
			Open Forest	21	
			Non Forest	31	
16.	Protected Areas *arc_pacwlw*	Resource Atlas of Rajasthan Sh. S. S. Bhandari CCF (Wildlife), GOR, Jaipur		Pa_Code	61
			National Parks	1	
			Sanctuaries	2	
			Closed Areas	3	
17.	Temperature Regimes *temp_jan* *temp_jun*	Resource Atlas of Rajasthan Shri S. S. Bhandari Former Director & Sh. H. R. Solanki Director Meterological Centre, Jaipur		jan_code	60
			January		
			< 6° C	1	
			6° - 8° C	2	
			8° - 10° C	3	
			> 10° C	4	
			June	june_code	59
			< 42° C	1	
			40° 38° C	2	
			38° - 36° C	3	
			36° - 32° C4	4	
			> 32° C	5	
18.	Mean Annual Potential Evapo-transpiration *arc_state*	do		color_code	62
			> 200 cm	1	
			190 - 200 cm	2	
			180 - 190 cm	3	
			170 - 180 cm	4	
			160 - 170 cm	5	
			150 160 cm	6	
			140 - 150 cm	7	
			130 - 140 cm	8	
			< 130 cm	9	
19.	Human Population Density *Landuse.shp*	Resource Atlas of Rajasthan Census of India 1991	Districtwise Persons / km^2 1981 1991		63

S. N.	Title/Name of File	Base map/s	Attributes	Code	Hard copy at page
20.	Population Growth *Landuse.shp*	Resources Atlas of Rajasthan Dr. M. S. Mathus Retd. Professor (Geography) Rajasthan University Jaipur	**Districtwise Persons / km²**		
			1901-11		
			1911-21		
			1921-31		
			1931-41		
			1941-51		
			1951-61		
			1961-71		
			1971-81		
			1981-91		
21.	Density of animals (1992) *Landuse.shp*	Resources Atlas of Rajasthan Dr. A. K. Purohit Director	**Districtwise Camels / km²**		63 & 66 to 68
			0.322 0.417		
			0.417 - 0.974		
			0.974 - 1.706		
			1.706 - 3.222		
			3.222 - 5.567		
			Districtwise Sheep / km²		
			3.055 - 5.274		
			5.274 16.757		
			16.757 - 40.222		
			40.222 - 64.058		
			64.058 - 111.165		
			Districtwise Cattles / km²		
			2.448 - 19.062		
			19.062 - 29.993		
			29.993 - 37.333		
			37.333 59.549		
			59.549 - 106.214		
			Districtwise Goats / km²		
			0.04 - 22.148		
			22.148 - 43.369		
			43.369 - 54.711		
			54.711 - 66.005		
			66.005 - 81.48		

S. N.	Title/Name of File	Base map/s	Attributes	Code	Hard copy at page
22.	Net Sown Area *Landuse.shp*	Resource Atlas of Rajasthan Dr. N. C. Gautam Group Director Land use, Cartography and Printing Div. NRSA, Hyderabad	**District wise Net Sown Area/km²**		64
			0.049 - 0.053		
			0.053 - 0.479		
			0.479 - 0.632		
			0.632 - 0.729		
			0.729 - 0.799		
			District wise Fallow Area/km²		64
			0 - 0.016		
			0.016 - 0.078		
			0.078 - 0.135		
			0.135 - 0.267		
			0.267 - 0.567		
			District wise Pasture/ Grazing Land/km²		65
			0 - 003		
			0.003 0.012		
			0.012 0.019		
			0.019 - 0.061		
			0.061 - 0.087		
			District wise Gulliede/ Ravinous Land/km²		65
			0 - 0.003		
			0.003 - 0.018		
			0.018 - 0.028		
			0.028 - 0.079		
			0.079 - 0.174		
			District wise Salt Affected Land/km²		66
			0 - 0.001		
			0.001 - 0.004		
			0.004 - 0.008		
			0.008 - 0.011		
			0.011 0.033		
23.	Indira Gandhi Nahar Project (IGNP) Command Area *Arc_ignpcomnd*	do	Comnd_ref		73
			Stage I		
			Stage II		
			Bangarsar lift Scheme		
			Bhakra Canal Area		

S. N.	Title/Name of File	Base map/s	Attributes	Code	Hard copy at page
			Gang canal area		
			Phalodi lift scheme		
			Pokaran lift scheme		
			Sahawa lift scheme		
			Under sidhmukh area		
24.	Vegetation *Semi-final.img*	WiFS data (for details see table 7)	**Dry Deciduous Forest**		54
			Teak and kardhai		
			Kardhai and Sal		
			Kardhai and Babool		
			Thorn Forest		
			Acacia mixed		
			Ravine scrub		
			Sand Dunes		
			Calligonum-Haloxylon-Leptadenia		
			Suaeda-Salsola Prosopis-		
			Capparis-Ziziphus		
			Desert		
			Prosopis-Acacia		
			Sand Dunes		
			Calligonum-Euphorbia-Acacia		
			Agriculture		
			Double Crop		
			Single Crop		
			Water Body		

The state area mask was created by transforming the state boundary on the mosaic images (see FCC's at pages 51 to 53). As a first step the enhancement techniques were used extensively in digital image processing after verifying the scene to improve the quality of an image. The *Neutral Density Vegetation Index (NDVI)* was prepared using above four seasons images. This image was visually interpreted and a vegetation map showing spatial distribution of dry deciduous forest, thorn forest, sand dunes, double and single crop agriculture areas and water bodies was prepared (see image at page 54).

Table 7 : Hardware and Software Used

A. Hardware	Digital Personal workstation (with UNIX version 5.60) 4.3 GB Ultra SCSI HDD (7200 rpm) 256 MB RAM 16 MB VRAM 500 MHz CPU 256 MB ECC SDRAM 2 MB 13B CACHE 21" colour Monitor 104 Keys (keyboard) 600 MB, 12 Speed IDE CD ROM Drive 4D50T Graphic 1.44 MB FDD Internal 16 bit Sound Blasters compatible Blaster 2 PAR & 4 Serial ports
B. Software	ARC View GIS version 3.0b & 3.1 **GIS** : ARC/ INFO version 7.1.2. ARCTOOLS version 7.1.2 ARCPLOT Version 7.1.2. ARCEDIT version 7.1.2 ArcView version 3.0b & 3.1 **O.S.** : UNIX & PC **DIP** : ERDAS / Imagine 8.3

Table 8 : Primary Source of Data

A. Survey of India Topo sheets (Scale 1:1,000,000) used

S. N. Reference	Title Name	Year of Publication
1 NG 43	Rajasthan	1986
2. NG 43	Delhi	1965/1978
3. NF 43	Satpura Mountains	1965
4. NG 42	Sindh	1976
5. State Map of Rajasthan	Rajasthan	1978

B. Resource Atlas of Rajasthan, Department of Science and Technology, Govt. of Rajasthan.

Table 9 : Remote Sensing Data Used

	Scene I	*Scene II*
January, 1998	S : 04388 B : 34 P : 04680 R : 180 Wif ACQ 13-1- 98 DPC – 2 : UCT 000214 Vol 01/01	Row : 98242 – 01 –1 IRS – 1C WiFS 92 –57 17-1-98 05:58:39 STLC 0026J
April, 1998	**IRS – 1C** IC Wif 92-57 23 APR 98 STLC 0026J	**IRS – 1C** 98/391 22-1 1C Wif 93 –52 4 APR 98 STLC 0026J
October, 1998	**IRS – 1D** GEN : 16-4-99 19 : 21 PR–1 STLC 0026J 093/052 Wif ACQ 18 OCT 98 S : 04336 P 05040 B : 34 R: 180-00 ACT CD ROM # 1 DPC – 1 : : UCT : 000737 Vol 01/01	**IRS – 1D** GEN : 16-4-99 18 18 PR–1 STLC 0026J 092/057 Wif ACQ 21 OCT 1998 S : 04343 P : 05040 B : 34 R : 180-00 ACT CD ROM # 1 DPC – 1 : : UCT : 000729 Vol 01/01
December, 1998	**IRS – 1D** GEN : 16-4-99 20 : 32 PR–1 STLC 0026J 093/052 Wif ACQ 07 DEC 98 S : 04441 P 04500 B : 34 R 180-00 ACT CD ROM DPC – 1 : : UCT : 000737 Vol 01/01	**IRS – 1D** GEN : 16-4-99 20 : 32 PR–1 STLC 0026J 092/057 Wif ACQ 10 DEC 98 S : 04446 P : 04500 B : 34 R : 180-00 ACT CD ROM DPC – 1 : : UCT 000737 Vol 01/01

4.4 Spatial Analysis/Modeling:

Spatial analysis involves interaction of a variety of data and derived parameters in a desired fashion. The geographic analysis allow us to study and understand the real world processes by developing and applying manipulation analysis criteria and models and to carry out integrated modeling. These criteria illuminate underlying trends in Geographic data, making new information available. Spatial analysis in GIS also provides us tool to reveal new or previously unidentified relationships within or between data sets, thus increasing better understanding of real world phenomenon. Integration involves bringing together diverse

information from a variety of sources and analysis of multiparameter data to provide answers and solutions to defined problems. Out of three modeling approaches *viz.*, area based modeling, point modeling and attribute modeling available, area based modeling was used.

Area based modeling involves selecting features based on locations or spatial relations. It relates new maps based on mathematical concepts that are used to stimulate real world phenomenon. It can also be used to explore statistical relationships that exist between classes of different input maps and then combine the individual relationship into single equation for modeling. The first step in modeling is to define the relationship between spatial variables. The next step is to select those maps that are spatial variables in the model. Either class number or the attribute value associated with the class number can be used in the model. The modeling equation assigns a value to each unique condition / combination.

In this study overlay approach of the area-based modeling was followed. The complete analysis was done systematically in stages. Initially two layers (Agro-climatic zone and wasteland) were selected and a composite layer (Agrwate) was created by union using ARCTOOLS, ARC/INFO GIS software. Similarly all the listed layers were merged to create one union file (Table 10).

Table 10 : Creation of union file

Input file-I	Input file-II	Union file
1. Agroclzones	Arc_wasteland	Agrwaste
2. Arc_forcov	Arc_fortype	Forcov_type
3. Arc_sand	Arc_ignpcommd	Sand_ignp
4. Vegetation	Arc_blocks	Veg_blocks
5. Arc_state	Arc_pacwlw	Evapo_pa
6. Temp_June	Temp_Jan	Jan_june
7. Rainfall	Jan_June	Temp_rain
1. Agrwaste	Forcov_type	Union1
2. Sand_ignp	Veg_blocks	Union2
3. evapo_pa	Temp_rain	Union3
1. Union1	Union 2	Union_a
2. Union_a	Union3	Union_f

The final layer (Union_f) thus generated was used for deriving suitability maps by reclassification of the resultant classes by using query building option of ArcView 3.1. Overall habitat suitability for Chinkara was depicted in three categories ranging from highly suitable to not suitable. Area under each suitability class was estimated.

As far as the scale is concerned, block level scale is most appropriate and practically possible at the moment. But, it is always better to go for finer scale because it gives more accurate area of occupancy figures. The area of occupancy is the smallest area essential at any stage for the survival of a taxon (i.e. colonial nesting sites, feeding/breeding sites for migratory taxon). The size of the area of occupancy will be a function of the scale at which it is measured and should be at a scale appropriate to relevant biological aspects of the taxon. The criteria includes value in km^2 and thus to avoid errors in classification the area of occupancy should be measured on grid squares or equivalent, which are sufficiently small. In contrast to area of occupancy, the area of extent of occurrence does not take into account of discontinuities of disjunction's in the spatial distribution and often be measured by a minimum convex polygon (the smallest polygon in which no internal angle exceed 180^0 and which contains all the sites of occurrence).

RESULTS

On the basis of general habitat requirements of the Chinkara *vis-a-vis* other restrictive factors and pattern of relative abundance emerged through ground survey all the 46 development blocks in which Chinkara is present in different densities (Annexure I) were categorised as follows, namely :

(i) Highly Suitable

(ii) Moderately Suitable and

(iii) Least Suitable

ArcView Query building option was applied on Union file (as above) to determine and demarcate the above suitability categories. The flow diagram for indentifying the above categories is as follow :

(i) Highly Suitable category (present)

```
zone_code = 11,22
wasteland_code = 6
poly_id = "sand"
vishnois = 1
Pa_code = 3
vegetation_code 2, 11, 15
```

Add to set

```
cover_code = 31
fortype_code = 30
([colour_code] = 4) and ([ rainfall_code] = 8) and ([june_code] = 2) and (not
    [wasteland_code] = 7) and (not([comnd_ref] = "stage I")))
```

Select from set

(ii) Highly Suitable category (after commencement of Stage II of IGNP)

```
zone_code = 11, 22
wasteland_code = 6
poly_id = "sand"
vishnois = 1
Pa_code = 3
vegetation_code 2, 11, 15
```

Add to set

```
cover_code = 31
fortype_code = 30
([colour_code] = 4) and ([rainfall_code] = 8) and ([june_code] = 2) and (not
[wasteland_code] = 7) and (not([comnd_ref] = "stage II")))
```

Select from set

(iii) Moderately Suitable (Category)

```
zone_code = 21, 31, 32, 50
wasteland_code = 1, 2
Pa_code = 1, 2
vegetation_code = 10, 13, 14
(rainfall_code = 7) and (colour_code = 5)
(rainfall_code = 7) and (colour_code = 4)
(rainfall_code = 7) and (colour_code = 3)
```

Add to set

```
(rainfall_code = 7) and (colour_code = 4)
(rainfall_code = 7) and (colour_code = 3)
(rainfall_code = 7) and colour_code = 5)
and (not([comnd_ref] = "sahawa lift scheme"))
```

Select from set

(iv) Least Suitable category

```
colour_code = 4, 5, 6, 7
```

Add to set

```
([cover_code] = 31) and ([Pa_code] = 2)
```

Select from set

Output of this exercise are in maps at pages 71 and 72, and statistics for area (predominant) analysis in Tables 11 to 13. As per the present study the suitability analysis are 22% under Highly Suitable (present), 11.5% Moderately Suitable and 0.8% Least Suitable categories.

On completion of stage II of IGNP the Category of Highly Suitable area would further be reduced to 18% (see maps at pages 71 & 72).

Table 11. Chinkara Habitat : Highly Suitable Blocks

Block	Area	K+R	Agroclimatic Zone Code	Agroclimatic Zone Area	Forest Cover Code	Forest Cover Area	Forest Type Code	Forest Type Area	Sand	Non Sand	IGNP Area	Vegetation Code	Vegetation Area	Evapotranspiration Code	Evapotranspiration Area	Temp. (Jan.) Code	Temp. (Jan.) Area	Temp. (June) Code	Temp. (June) Area	Rainfall Code	Rainfall Area	Wasteland Code	Wasteland Area
171802 Phalodi	4773	6.55	*11*	4766	*31*	4773	*30*	4773	4484	289	0	*13*	4547	*2*	3117	*2*	3131	*2*	4773	*8*	4082	*6*	3422
170404 Balotra	3333	5.77	*11*	3333	*31*	3333	*30*	3297	2326	1007	0	*13*	3123	*3*	2746	*4*	3281	*2*	3333	*7*	2014	*8*	1661
170405 Chotan	3721	5.72	*11*	3701	*31*	3721	*30*	3721	3721	0	0	*15*	3054	*4*	2118	*4*	3541	*2*	2563	*8*	3031	*6*	363
170401 Shiv	6258	1.76	*11*	6258	*31*	6258	*30*	6258	5914	344	495	*11*	2607	*2*	3825	*4*	4729	*2*	6258	*8*	4977	*6*	5861
170703 Kolayat	7026	1.62	*11*	7026	*31*	7026	*30*	7026	6258	768	2690	*13*	4087	*2*	3117	*2*	3131	*2*	4773	*8*	4082	*6*	3422
171805 Osian	2665	1.6	*11*	2664	*31*	2665	*30*	2665	1936	729	0	*13*	2597	*3*	1890	*3*	2063	*2*	2665	*7*	2651	*8*	1969
171402 Jaisalmer	8366	1.25	*11*	8365	*31*	8365	*30*	8365	6171	2195	2431	*4*	2992	*1*	7919	*2*	7855	*2*	8365	*9*	6202	*6*	5995
170704 Nokha	3965	1.15	*11*	3892	*31*	3965	*30*	3965	3965	0	0	*16*	3965	*4*	2488	*2*	2323	*2*	3825	*7*	2489	*6*	3714
171403 Sankra	8047	0.9	*11*	8047	*31*	8004	*30*	8047	5327	2720	5910	*16*	5587	*1*	4942	*2*	5657	*2*	8047	*9*	4909	*6*	4949
171401 Sam	20397	0.73	*11*	20391	*31*	20391	*30*	20391	18563	1834	5482	*11*	16315	*2*	12401	*3*	11054	*2*	20398	*9*	'—'	*6*	17802
170408 Dhorimanna	2885	0.56	*11*	2852	*31*	2885	*30*	2825	2445	440	0	*13*	1814	*5*	2142	*4*	1989	*4*	1278	*7*	1524	*6*	2362
171801 Bap	5359	0.51	*11*	5356	*31*	5359	*30*	5359	4127	1232	988	*13*	5012	*1*	2334	*2*	5359	*2*	5359	*8*	4045	*6*	4780
170702 Bikaner	9353	0.48	*11*	9308	*31*	9353	*30*	9353	8335	1018	4596	*13*	5201	*4*	5830	*3*	8004	*2*	8834	*8*	4860	*6*	7338
170402 Bayatu	2323	0.19	*11*	2323	*31*	2323	*30*	2323	2323	0	0	*13*	2323	*3*	1278	*4*	636	*2*	2323	*8*	2323	*6*	2323
171804 Balesar	1342	0.01	*11*	1342	*31*	1342	*30*	1342	1059	283	0	*13*	1342	*3*	786		'—'	*2*	1342	*3*	1245	*7*	961
170406 Sindari	3645	0.05	*11*	3642	*31*	3645	*30*	3626	3275	370	0	*15*	2709	*4*	3040	*4*	3574	*2*	3471	*8*	2621	*6*	2726

Table 12. Chinkara Habitat : Moderately Suitable Blocks

Block	Area	K+R	Agroclimatic Zone Code	Agroclimatic Zone Area	Forest Cover Code	Forest Cover Area	Forest Type Code	Forest Type Area	Sand	Non Sand	IGNP Area	Vegetation Code	Vegetation Area	Evapotranspiration Code	Evapotranspiration Area	Temp. (Jan.) Code	Temp. (Jan.) Area	Temp. (June) Code	Temp. (June) Area	Rainfall Code	Rainfall Area	Wasteland Code	Wasteland Area
171808 Luni	1841	1.3	*11*	1839	*31*	1841	*30*	1841	143	1698	0	*16*	1294	*4*	1500	*3*	1711	*2*	1698	*7*	1841	*8*	1642
171506 Sanchore	2614	1	*11*	2585	*31*	2614	*30*	2614	2444	170	0	*13*	2611	*5*	1409	*3*	2614	*5*	1333	*7*	2309	*6*	2181
171504 Bhinmal	1496	0.7	*22*	1484	*31*	1496	*30*	1440	799	697	0	*10*	1403	*6*	915	*6*	1496	*4*	744	*7*	947	*8*	1281
171807 Mandore	929	0.6	*11*	929	*31*	929	*30*	929	464	465	0	*16*	810	*3*	466	*3*	929	*2*	929	*7*	929	*8*	640
171806 Bhopal Gr	2045	0.5	*11*	2001	*31*	2045	*30*	2045	947	1102	0	*15*	1762	*4*	1138	*2*	1576	*2*	1196	*7*	2045	*8*	1311
171809 Bilara	1580	0.5	*11*	1529	*31*	1580	*30*	1580	0	1580	0	*16*	1545	*5*	1441	*2*	1040	*3*	1534	*7*	1182	*8*	1308
70701 Karansar	5901	0.3	*11*	5844	*6*	5901	*30*	590	5901	0	1315	*10*	5014	*5*	5901	*1*	5901	*2*	4657	*8*	5270	*6*	5859
172707 Sujangarh	2870	0.3	*21*	2869	*6*	2870	*30*	2870	2870	0	0	*13*	2746	*6*	2107	*1*	2870	*3*	2816	*7*	2870	*6*	2622
172705 Sri Dungar	3179	0.1	*21*	3109	*31*	3179	*30*	3179	3179	0	0	*13*	3178	*5*	2791	*1*	3179	*2*	2246	*7*	3179	*6*	3179
172103 Rohit	1296	0	*22*	1195	*31*	1296	*30*	1296	0	0	0	*16*	1296	*5*	872	*3*	1296	*3*	833	*7*	1154	*8*	1066
172005 Mundwa	1845	0	*21*	1809	*31*	1845	*30*	1845	950	895	0	*13*	1622	*4*	944	*2*	1845	*2*	1173	*7*	1845	*8*	1449
171503 Jalore	989	0	*22*	989	*31*	989	*30*	943	0	46	0	*16*	877	*6*	989	*3*	989	*5*	630	*6*	978	*8*	612

Table 13. Chinkara Habitat : Least Suitable Blocks

Block	Area	K+R	Agroclimatic Zone Code	Agroclimatic Zone Area	Forest Cover Code	Forest Cover Area	Forest Type Code	Forest Type Area	Sand	Non Sand	IGNP Area	Vegetation Code	Vegetation Area	Evaptranspiration Code	Evaptranspiration Area	Temp. (Jan.) Code	Temp. (Jan.) Area	Temp. (June) Code	Temp. (June) Area	Rainfall Code	Rainfall Area	Wasteland Code	Wasteland Area
171903 Ladpura	1719	1.2	*50*	1719	*31*	1171	*30*	1232	0	1719	0	*10*	1197	*6*	1365	*4*	1439	*2*	1651	*2*	963	*8*	906
171902 Sultanpur	906	1.2	*50*	9061	*31*	9061	*30*	8236	0	906	0	*16*	553	*5*	784	*4*	9061	*2*	9061	*2*	8899	*1*	3797
171507 Raniwara	1133	0.35	*22*	1133	*31*	1133	*30*	1097	1119	14	0	*16*	9099	*6*	1133	*3*	1133	*7*	8126	*6*	1099	*8*	711
171306 Jam. R'Grh	645	0.3	*31*	632	*31*	522	*30*	526	0	645	0	*1*	4081	*4*	645	*3*	645	*3*	645	*4*	645	*8*	455
170403 Barmer	2738	0.22	*11*	2738	*31*	2738	*30*	2738	2738	0	0	*15*	2150	*3*	2726	*4*	2738	*2*	2738	*8*	2738	*6*	2441
170611 Mandal G'rh	1373	0.16	*41*	1359	*31*	1241	*0*	701	0	1373	0	*7*	572	*7*	1373	*3*	1373	*3*	809	*3*	1361	*8*	1360
170606 Jahazpur	1175	0.11	*41*	1081	*31*	1175	*30*	1076	0	1175	1625	*16*	1101	*7*	551	*3*	1175	*3*	1042	*4*	886	*8*	831
171206 Suratg'rh	3032	0.1	*12*	2983	*31*	3032	*30*	3032	2802	230	58	*14*	2979	*5*	3032	*1*	3032	*1*	3032	*8*	3032	*6*	2554
170407 Siwana	2440	0.1	*11*	2397	*31*	2412	*30*	2274	1402	1038	0	*16*	1041	*4*	1626	*3*	1767	*2*	672	*7*	2440	*8*	2000
171706 Nawalg'rh	558	0.03	*21*	559	*31*	539	*30*	525	498	60	0	*14*	222	*6*	559	*1*	500	*3*	559	*6*	559	*6*	465
172109 Desuri	673	0.01	*22*	658	*31*	549	*0*	406	0	267	0	*7*	365	*7*	643	*2*	439	*5*	562	*5*	661	*9*	341
172008 Kuchaman	1816	0.01	*21*	1807	*31*	1816	*30*	1696	1561	255	0	*9*	1452	*6*	1685	*2*	1266	*3*	1816	*6*	1308	*8*	898
172001 Ladnum	1443	0.01	*21*	1443	*31*	1443	*30*	1443	1429	14	0	*14*	1002	*6*	1443	*1*	1443	*3*	1443	*7*	1406	*6*	1178
172006 Degana	864	0.01	*21*	864	*31*	864	*30*	864	404	460	0	*14*	842	*6*	753	*2*	820	*3*	864	*6*	466	*8*	423
171909 Baran	626	0.01	*50*	626	*31*	626	*30*	543	0	626	0	*1*	444	*5*	621	*4*	626	*2*	626	*7*	625	*1*	332
172609 Salunber	805	0.01	*41*	805	*31*	616	*0*	552	0	805	0	*1*	572	*9*	413	*3*	885	*4*	805	*2*	532	*8*	449
172206 Karauli	1491	0.01	*32*	1491	*31*	1154	*30*	879	0	1491	0	*7*	718	*4*	1491	*3*	1491	*2*	1491	*3*	1378	*8*	956
172211 Khandar	1214	0.01	*50*	932	*31*	850	*30*	771	0	1214	0	*1*	797	*4*	107	*4*	1148	*2*	1214	*2*	1212	*8*	600

DISCUSSION

Wildlife habitat analysis has always been considered important for any wildlife management and planning. It includes a wide variety of factors like soil, topography, water availability, vegetation and land cover characteristics including human interference on all of these and incorporate several interrelated concepts dealing with space, time and functions. Basically habitat is the place occupied by a specific population within a community of populations (Smith,1994). The findings of the present study are discussed in the light of the above factors.

The Chinkara population of Rajasthan was found to be distributed in at least 46 development blocks out of total 236 in the state (Annexure I).

The distribution of Chinkara is uneven in Rajasthan, comprising three major sub-populations (Kankane, *l.c.*). There is very little chance of exchange of individuals between these sub-populations due to fragmentation of habitat. Other than the southwest population, in the remaining two areas, *viz.*, eastern and southeastern the populations are so fragmented that even after hours of search (accompanied by experience local guide) one can see only a group of 2 to 3 individuals. In the above two areas Chinkara is either confined to newly developed plantations in the periphery of sanctuaries or in the closed areas.

The results of the present study indicate that abundance of Chinkara has a clear inclination towards arid western plains, with higher evapotranspiration, lower rainfall, higher diurnal temperature and sandy areas with vegetation combination of *Prosopis-Capparis-Ziziphus spp*. These together constitute the highly suitable areas in Rajasthan (Table 11). This area is generally without surface and ground water, therefore harvest is single, irregular Kharif crop. Consequently, the rate of human settlements is also comparatively low.

The above inferences testify that scrub and sandy wasteland are the primary habitats for Chinkara in Rajasthan, and its occurrence in other habitats is secondary. As a result of gradual introduction of better facilities for agriculture, like ground water exploration, development of canal system, tube wells, etc. supplemented by motorized irrigation, the wastelands become the first and easy target for reclamation. The best example to illustrate the above is the present status of Chinkara in Ganganagar district. Earlier the district was a part of arid wasteland till large-scale irrigation made it the greenery of Rajasthan. This change has almost eliminated Chinkara from the district, except for limited and isolated groups and that too around *Bishnoi* villages.

In order to save animals of scrub-waste and desert land, the government has drawn up a mega plan to create a Desert Biosphere Reserve with a proposed area of about 3,100 km^2 in Jaisalmer and Barmer districts in the heart of the Rajasthan desert. It is also projected as a refuge for wildlife displaced through upcoming Indira Gandhi Nahar Irrigation Project. The proposed Biosphere Reserve is fragmented into pockets, as branches of a man-made

canal will bisect the originally planned Biosphere Reserve. Thus, it is a typical example of the outcome of the direct conflict between developmental activities and wildlife conservation.

The extent of area covered by southwest population has no protected area other than Desert and Tal Chappar wildlife sanctuaries. Tal Chappar sanctuary is over populated with Black Buck. Thus, under the circumstances Desert sanctuary is the only refuge for Chinkara population, which is a nonstarter so far. The state government has declared a number of closed areas in the above habitat as an alternate measure to protect wildlife in this area, but it has no administrative control over the land (except for few enclosures). Therefore, the closed area approach cannot be considered as an effective long-term conservation measure. Hence the largest assemblage of the Chinkara population of the state is susceptible to any change in the land use pattern in future.

In conclusion, it is not always necessary to use GIS to undertake spatial modelling and integrating the two will not necessarily lead to any greater insights into the problem (Fotheringham,1999). However, for certain aspects, integration will lead to greater probability of producing insights that would otherwise be missed if spatial models were not integrated within GIS.

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Annexure I

Block-wise Density of Chinkara in Rajasthan

Block_name	Block_code	dn(R)	dn(K)	dn(K+R)
Abu road	172405	0.00	0.00	0.00
Ahore	171501	0.00	0.00	0.00
Ajmer	170105	0.00	0.00	0.00
Alsisar	171701	0.00	0.00	0.00
Amber	171305	0.00	0.00	0.00
Amet	172614	0.00	0.00	0.00
Anandpuri	170306	0.00	0.00	0.00
Anupgarh	171208	0.00	0.00	0.00
Arain	170104	0.00	0.00	0.00
Arnaud	170911	0.00	0.00	0.00
Asin	170601	0.00	0.00	0.00
Aspur	171103	0.00	0.00	0.00
Atru	171910	0.00	0.00	0.00
Bagidora	170305	0.00	0.00	0.00
Bahror	170202	0.00	0.00	0.00
Balesar	171804	0.00	0.01	0.01
Bakani	171604	0.00	0.00	0.00
Bali	172110	0.00	0.00	0.00
Balotra	170404	7.05	3.50	5.77
Bamanwas	172208	0.00	0.00	0.00
Bandi kui	171314	0.00	0.00	0.00
Banera	170605	0.00	0.00	0.00
Bansur	170206	0.00	0.00	0.00
Bap	171801	0.62	0.40	0.51
Baran	171909	0.00	0.00	0.01
Bargaon	172602	0.00	0.00	0.00

Block_name	Block_code	dn(R)	dn(K)	dn(K+R)
Bari	171002	0.00	0.00	0.00
Bari sadri	170908	0.00	0.00	0.00
Barmer	170403	0.45	0.00	0.22
Baseri	171001	0.00	0.00	0.00
Bassi	171311	0.00	0.00	0.00
Bayana	170509	0.00	0.00	0.00
Baytu	170402	0.19	0.00	0.19
Begun	170912	0.00	0.00	0.00
Bhadesar	170905	0.00	0.00	0.00
Bhadra	171210	0.00	0.00	0.00
Bhainsrorgarh	170913	0.00	0.00	0.00
Bhim	172612	0.00	0.00	0.00
Bhinani	170107	0.00	0.00	0.00
Bhinder	172606	0.00	0.00	0.00
Bhinmal	171504	0.00	0.65	0.65
Bhopalgarh	171806	0.00	0.00	0.53
Bhupalsagar	170902	0.00	0.00	0.00
Bichhiwara	171101	0.00	0.00	0.00
Bikaner	170702	0.97	0.00	0.48
Bilara	171809	0.16	0.77	0.46
Bonli	172207	0.00	0.00	0.00
Buhana	171705	0.00	0.00	0.00
Chaksu	171313	0.00	0.00	0.00
Chechat (ramganj mandi)	171905	0.00	0.00	0.00
Chabra	171912	0.00	0.00	0.00
Chhipa barod	171911	0.00	0.00	0.00
Chhoti sadri	170909	0.00	0.00	0.00
Chirawa	171702	0.00	0.00	0.00

Block_name	Block_code	dn(R)	dn(K)	dn(K+R)
Chittaurgarh	170904	0.00	0.00	0.00
Chohtan	170405	0.00	5.72	5.72
Churu	172704	0.00	0.00	0.00
Dag	171606	0.00	0.00	0.00
Dahod	172303	0.00	0.00	0.00
Danta ramgarh	172305	0.00	0.00	0.00
Dausa	171315	0.00	0.00	0.00
Deeg	170503	0.00	0.00	0.00
Degana	172006	0.00	0.01	0.01
Deogarh	172613	0.00	0.00	0.00
Desuri	172109	0.00	0.01	0.01
Devli	172505	0.00	0.00	0.00
Dhariwad	172610	0.00	0.00	0.00
Dhaulpur	171003	0.00	0.00	0.00
Dhorimanna	170408	0.51	0.62	0.56
Didwana	172004	0.00	0.00	0.00
Dudu	171308	0.00	0.00	0.00
Dungarpur	171102	0.00	0.00	0.00
Dungla	170906	0.00	0.00	0.00
Fatehpur	172301	0.00	0.00	0.00
Ganganagar	171201	0.00	0.00	0.00
Gangapur	172205	0.00	0.00	0.00
Garhi	170303	0.00	0.00	0.00
Ghatol	170301	0.00	0.00	0.00
Girwa	172605	0.00	0.00	0.00
Gogunda	172601	0.00	0.00	0.00
Govindgarh	171304	0.00	0.00	0.00
Govindgarh	170213	0.00	0.00	0.00

Block_name	Block_code	dn(R)	dn(K)	dn(K+R)
Hanumangarh	171207	0.00	0.00	0.00
Hindaun	172203	0.00	0.00	0.00
Hindoli	170802	0.00	0.00	0.00
Hurrda	170602	0.00	0.00	0.00
Itawa (pipalda)	171901	0.00	0.00	0.00
Jahazpur	170606	0.00	0.11	0.11
Jaisalmer	171402	1.87	0.54	1.25
Jaitaran	172101	0.00	0.00	0.00
Jalor	171503	0.00	0.01	0.01
Jamwa ramgarh	171306	0.00	0.30	0.30
Jaswantpura	171505	0.00	0.00	0.00
Jawaja	170105	0.00	0.00	0.00
Jayal	172003	0.00	0.00	0.00
Jhadol	172607	0.00	0.00	0.00
Jhalrapatan	171602	0.00	0.00	0.00
Jhotwara	171310	0.00	0.00	0.00
Jhunjhunun	171704	0.00	0.00	0.00
Kaman	170501	0.00	0.00	0.00
Kapasan	170903	0.00	0.00	0.00
Karanpur	171202	0.00	0.00	0.00
Karauli	172206	0.00	0.01	0.01
Kathumar	170214	0.00	0.00	0.00
Kekri	170108	0.00	0.00	0.00
Keshorai patan	170803	0.00	0.00	0.00
Khairwara	172611	0.00	0.00	0.00
Khamnor	172617	0.00	0.00	0.00
Khandar	172211	0.00	0.01	0.01
Khandela	172306	0.00	0.00	0.00

Block_name	Block_code	dn(R)	dn(K)	dn(K+R)
Khanpur	171601	0.00	0.00	0.00
Kharchi	172106	0.00	0.00	0.00
Khetri	171708	0.00	0.00	0.00
Kisangarh bas	170207	0.00	0.00	0.00
Kishanganj	171907	0.00	0.00	0.00
Kolayat	170703	1.24	2.00	1.62
Kot putli	171301	0.00	0.00	0.00
Kot qasim	170204	0.00	0.00	0.00
Kotra	172604	0.00	0.00	0.00
Kotri	170610	0.00	0.00	0.00
Kuchaman	172008	0.00	0.01	0.01
Kumbhalgarh	172615	0.00	0.00	0.00
Kumher	170505	0.00	0.00	0.00
Kushalgarh	170308	0.00	0.00	0.00
Lachhmangarh	172302	0.00	0.00	0.00
Ladnum	172001	0.00	0.01	0.01
Ladpura	171903	0.00	1.20	1.20
Lalsot	171317	0.00	0.00	0.00
Luni	171808	1.58	1.08	1.33
Lunkaransar	170701	0.34	0.34	0.34
Mahwa	172201	0.00	0.00	0.00
Makrana	172007	0.00	0.00	0.00
Malpura	172501	0.00	0.00	0.00
Mandal	170604	0.00	0.00	0.00
Mandalgarh	170611	0.00	0.16	0.16
Mandawar	170203	0.00	0.00	0.00
Mandore	171807	0.59	0.54	0.57
Mangrol	171906	0.00	0.00	0.00

Block_name	Block_code	dn(R)	dn(K)	dn(K+R)
Manohar thana	171603	0.00	0.00	0.00
Masuda	170106	0.00	0.00	0.00
Mavli	172603	0.00	0.00	0.00
Merta	172009	0.00	0.00	0.00
Mundwa	172005	0.00	0.01	0.01
Nadbai	170504	0.00	0.00	0.00
Nadoti	172204	0.00	0.00	0.00
Naenwa	170801	0.00	0.00	0.00
Nagar	170502	0.00	0.00	0.00
Nagaur	172002	0.00	0.00	0.00
Nawalgarh	171706	0.00	0.03	0.03
Neem ka thana	172308	0.00	0.00	0.00
Nimbahera	170907	0.00	0.00	0.00
Nimrana	170201	0.00	0.00	0.00
Niwai	172502	0.00	0.00	0.00
Nohar	171209	0.00	0.00	0.00
Nokha	170704	0.71	1.57	1.15
Osian	171805	1.60	0.00	1.60
Padampur	171203	0.00	0.00	0.00
Pali	172105	0.00	0.00	0.00
parvatsar	172011	0.00	0.00	0.00
Peepalkhoont	170302	0.00	0.00	0.00
Phagi	171312	0.00	0.00	0.00
Phalodi	171802	6.61	6.50	6.55
Pindwara	172403	0.00	0.00	0.00
Piprali	172304	0.00	0.00	0.00
Pirawa	171605	0.00	0.00	0.00
Pisangan	170102	0.00	0.00	0.00

Block_name	Block_code	dn(R)	dn(K)	dn(K+R)
Pratapgarh	170910	0.00	0.00	0.00
Railmagra	172618	0.00	0.00	0.00
Raipur	172102	0.00	0.00	0.00
Raipur	170607	0.00	0.00	0.00
Raisinghnagar	171205	0.00	0.00	0.00
Rajakhera	171004	0.00	0.00	0.00
Rajgarh	172703	0.00	0.00	0.00
Rajgarh	170211	0.00	0.00	0.00
Rajsamand	172616	0.00	0.00	0.00
Ramgarh	170208	0.00	0.00	0.00
Rani	172107	0.00	0.00	0.00
Raniwara	171507	0.00	0.35	0.35
Rashmi	170901	0.00	0.00	0.00
Ratangarh	172706	0.00	0.00	0.00
Reni	170212	0.00	0.00	0.00
Revdar	172404	0.00	0.00	0.00
Rian	172010	0.00	0.00	0.00
Rohit	172103	0.00	0.01	0.01
Rupwas	170508	0.00	0.00	0.00
Sadulshahar	171204	0.00	0.00	0.00
Sagwara	171104	0.00	0.00	0.00
Sahara	170608	0.00	0.00	0.00
Saila	171502	0.00	0.00	0.00
Sajjangarh	170307	0.00	0.00	0.00
Salumber	172609	0.00	0.01	0.01
Sam	171401	0.07	1.41	0.73
Sambhar	171307	0.00	0.00	0.00
Sanchore	171506	0.21	1.73	0.97

Block_name	Block_code	dn(R)	dn(K)	dn(K+R)
Sanganer	171309	0.00	0.00	0.00
Sangod	171904	0.00	0.00	0.00
Sankra	171403	0.31	1.50	0.90
Sapotra	172209	0.00	0.00	0.00
Sarada	172608	0.00	0.00	0.00
Sardarshahar	172701	0.00	0.00	0.00
Sawai madhopur	172210	0.00	0.01	0.01
Sewar	170506	0.00	0.00	0.00
Shahbad	171908	0.00	0.00	0.00
Shahpura	171303	0.00	0.00	0.00
Shahpura	170603	0.00	0.00	0.00
Shergarh	171803	0.00	0.00	0.00
Shiv	170401	0.07	3.50	1.76
Shivganj	172401	0.00	0.00	0.00
Sikrai	171316	0.00	0.00	0.00
Silora	170101	0.00	0.00	0.00
Simalwara	171105	0.00	0.00	0.00
Sindari	170406	0.00	0.10	0.05
Sirohi	172402	0.00	0.00	0.00
Siwana	170407	0.00	0.10	0.10
Sojat city	172104	0.00	0.00	0.00
Sri dungargarh	172705	0.15	0.11	0.13
Sri madhopur	172307	0.00	0.00	0.00
Srinagar	170103	0.00	0.00	0.00
Sujangarh	172707	0.07	0.55	0.31
Sultanpur	171902	0.00	1.20	1.20
Sumerpur	172108	0.00	0.00	0.00
Surajgarh	171703	0.00	0.00	0.00

Block_name	Block_code	dn(R)	dn(K)	dn(K+R)
Suratgarh	171206	0.00	0.20	0.10
Suwana	170609	0.00	0.00	0.00
Salera	170804	0.00	0.00	0.00
Salwara	170304	0.00	0.00	0.00
Taranagar	172702	0.00	0.00	0.00
Thana gazi	170209	0.00	0.00	0.00
Tijara	170205	0.00	0.00	0.00
Toda rai singh	172504	0.00	0.00	0.00
Todabhim	172202	0.00	0.00	0.00
Tonk	172503	0.00	0.00	0.00
Udaipurwati	171707	0.00	0.00	0.00
Umrain	170210	0.00	0.00	0.00
Uniara	172506	0.00	0.00	0.00
Viratnagar	171302	0.00	0.00	0.00
Wer	170507	0.00	0.00	0.00

Administrative Districts

70 E 30 N

78 E 30 N

Ganganagar
Bikaner
Churu
Jhunjhunun
Sikar
Alwar
Jaisalmer
Nagaur
Jodhpur
Jaipur & Dausa
Bharatpur
Dhaulpur
Ajmer
Tonk
Sawai Madhopur
Barmer
Pali
Bhilwara
Bundi
Jalore
Kota & Baran
Sirohi
Chittaurgarh
Udaipur & Rajsamand
Jhalawar
Dungarpur
Banswara

70 E 23 N

78 E 23 N

200 0 200 400 Kilometers

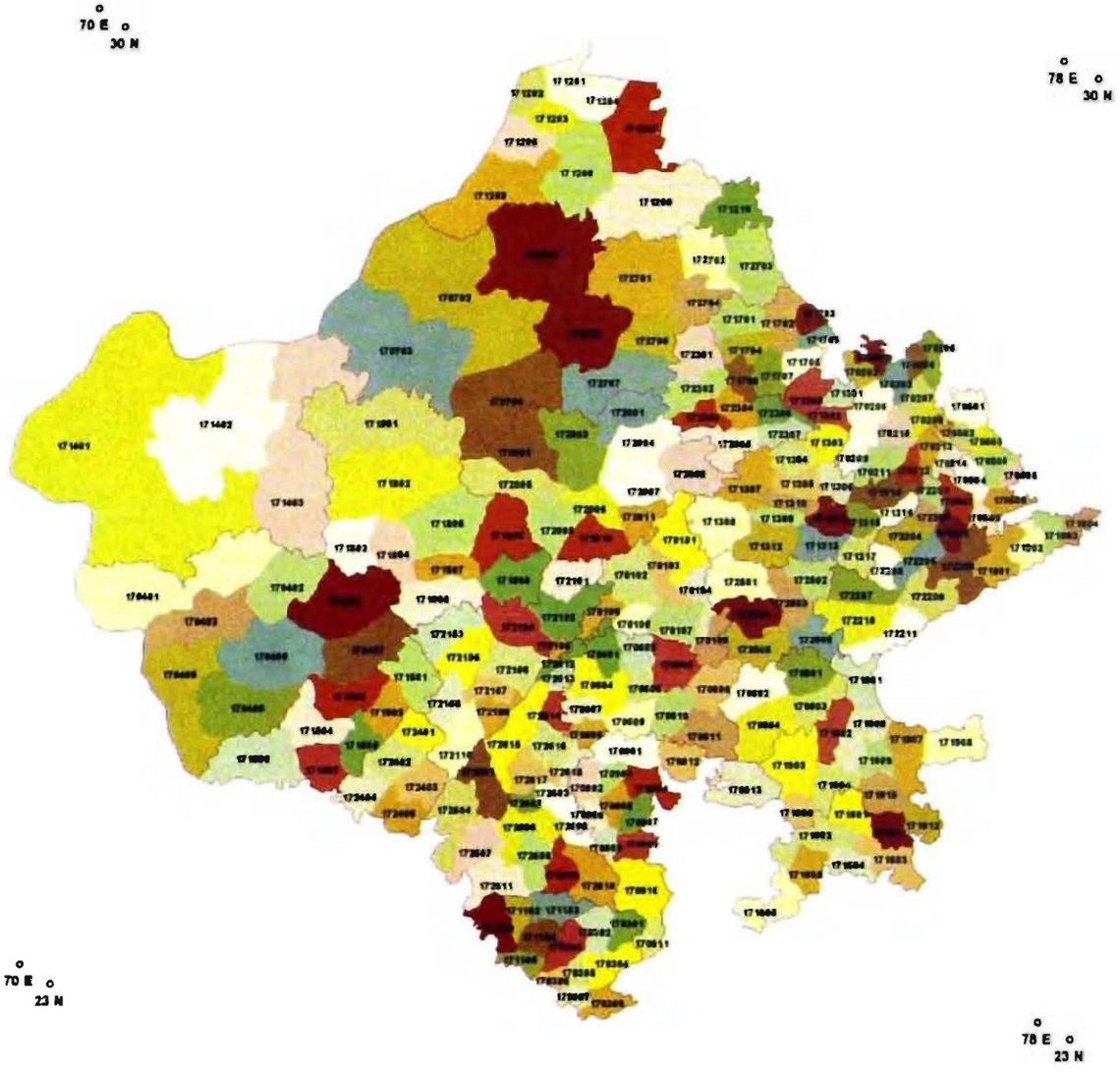
Administrative Districts

Code	Name
	State Boundary
170100	Ajmer
170200	Alwar
170300	Banswara
170400	Barmer
170500	Bharatpur
170600	Bhilwara
170700	Bikaner
170800	Bundi
170900	Chittaurgarh
171000	Dhaulpur
171100	Dungarpur
171200	Ganganagar
171300	Jaipur & Dausa

Code	Name
171400	Jaisalmer
171500	Jalore
171600	Jhalawar
171700	Jhunjhunun
171800	Jodhpur
171900	Kota & Baran
172000	Nagaur
172100	Pali
172200	Sawai Madhopur
172300	Sikar
172400	Sirohi
172500	Tonk
172600	Udaipur & Rajsamand
172700	Churu

Projection : Lambert Conformal Conic

Development Blocks



Development Blocks

State Boundary

District Boundary

See Annexure I for Name of the Blocks

Projection : Lambert Conformal Conic

Buffer Around Human Settlements

70 E 30 N

78 E 30 N

70 E 23 N

78 E 23 N

100 0 100 200 Miles

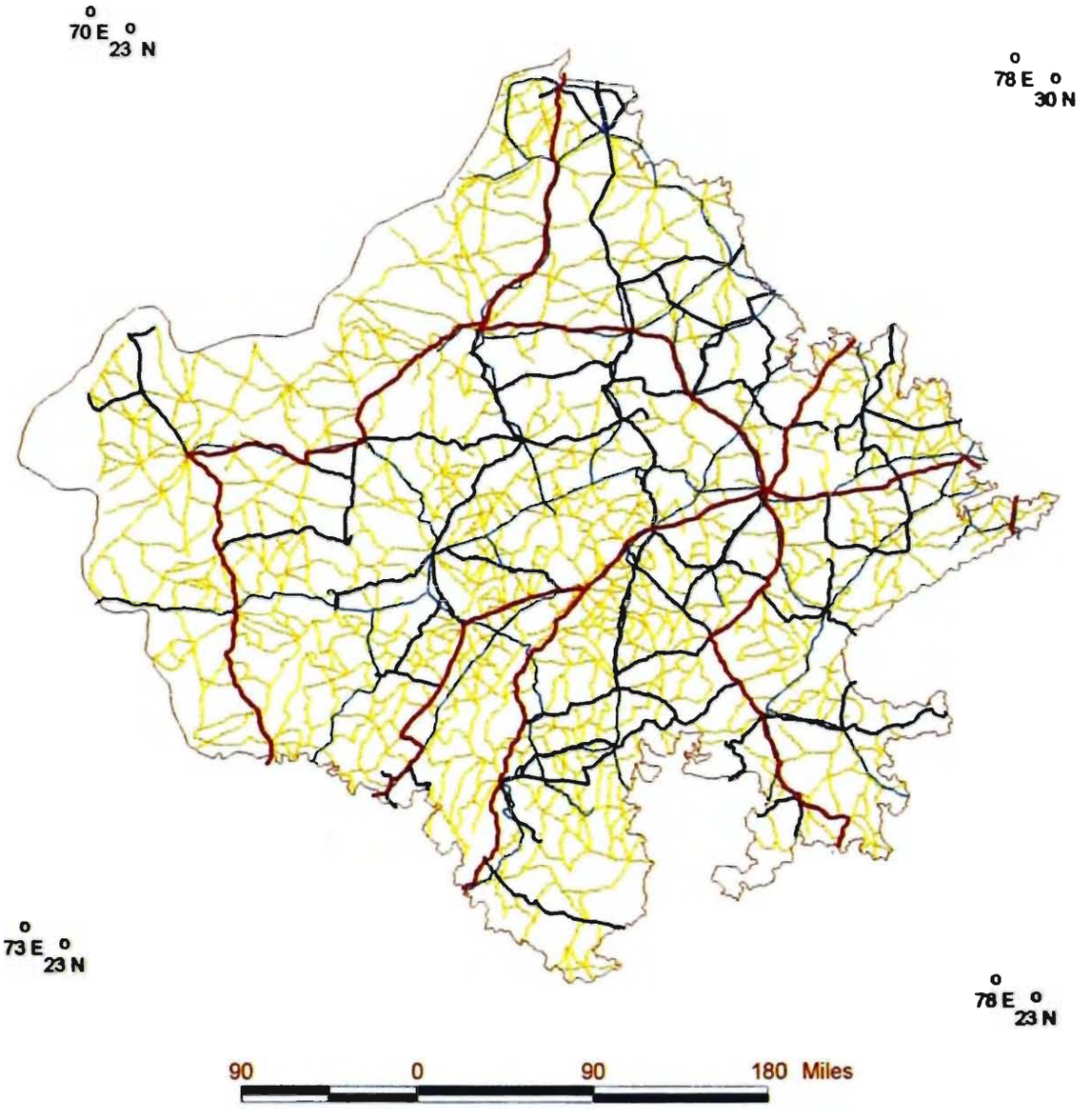
Agglomerations/Cities with Population > 100,000

(1991 Census)

- Ajmer (401, 930) ; Bikaner (415,355) : Buffer 6,000 m
- Alwar UA (211,162) : Buffer 4,200 m
- Beawar UA (106,715); Tonk UA (100,176) : Buffer 1,500 m
- Bharatpur UA (156,844) ; Sikar (148,235); Pali (136,797) : Buffer 2,250 m
- Bhilwara (183,791) : Buffer 3,000 m
- Ganganagar (161,377) : Buffer 2,400 m
- Jaipur (1,514,425) : Buffer 15,600 m
- Jodhpur_bufr.shp
- Kota (536,444) : Buffer 8,000 m
- Other Settlements (< 100,000) : Buffer 1,000 m
- Udaipur (307,682) : Buffer 4,600 m

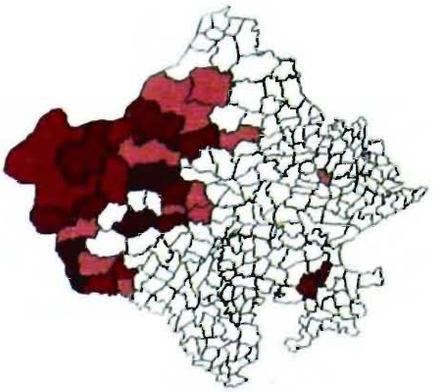
Projection : Lambert Conformal Conic

Buffer Around Infrastructures



Projection : Lambert Conformal Conic

Surface Water Resources

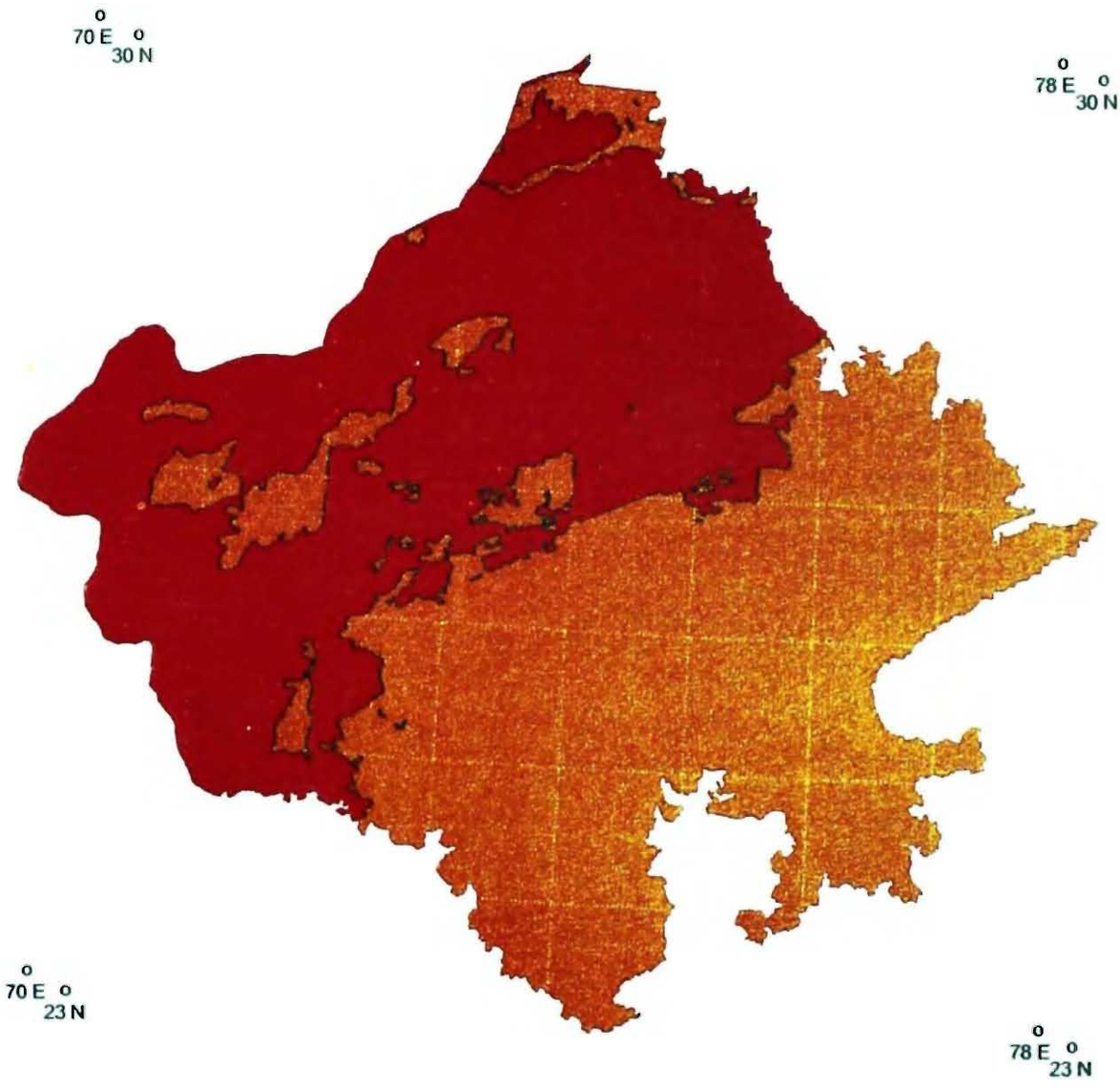


Surface Water Resources

Indira Gandhi Nahar
Rivers, Streams &
Waterbodies

Projection : Lambert Conformal Conic

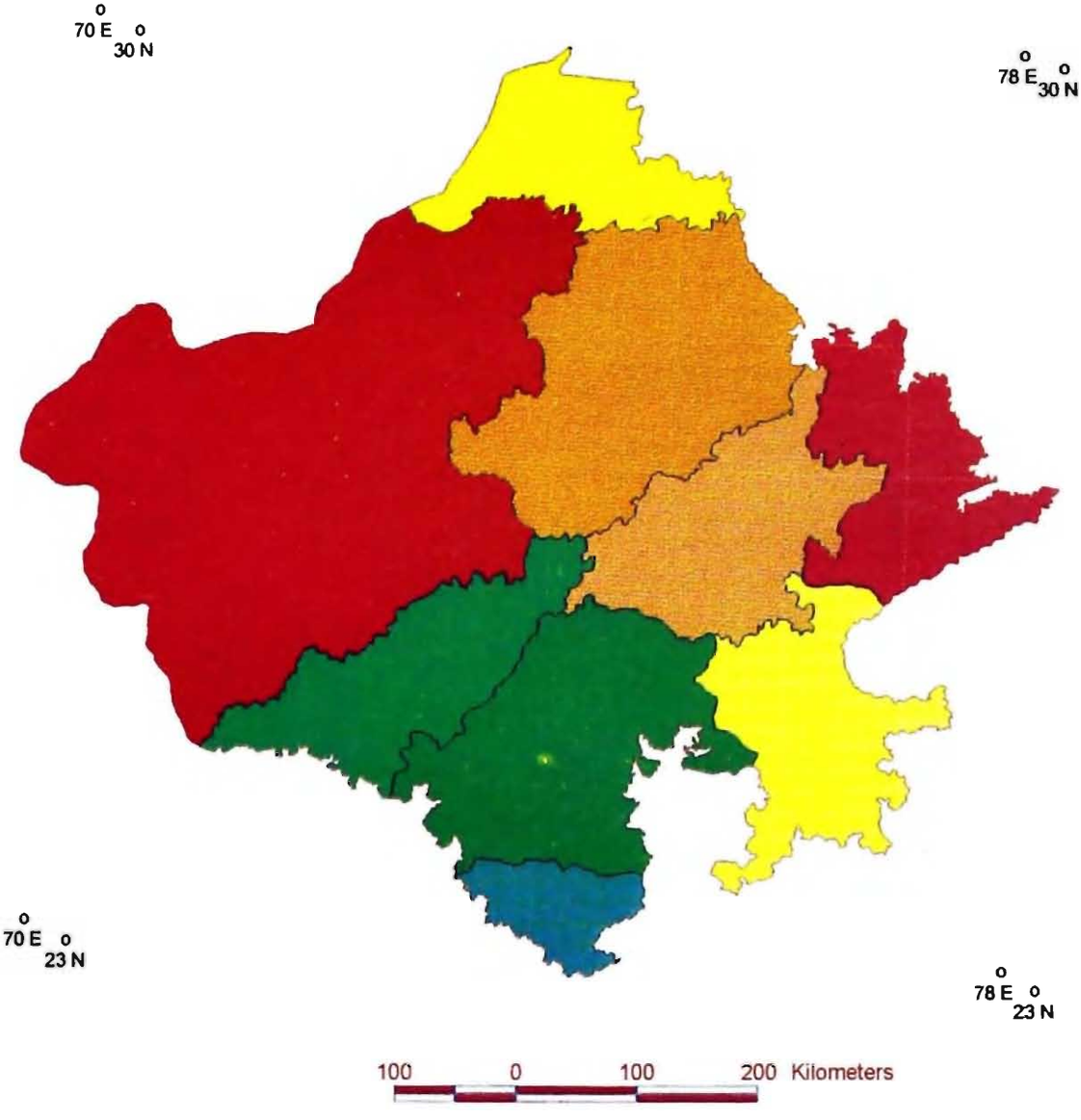
Sandy Areas



Projection : Lambert Conformal Conic

Rainfall Pattern
N
W
E
S
70 E 30 N
78 E 30 N
70 E 23 N
78 E 23 N
100 0 100 200 Kilometers
Rainfall Zones (cm.)
<10
10_20
20_30
30_40
40_50
50_60
60_70
70_80
80_90
90_100
90_120
120_150
> 160
Projection : Lambert Conformal Conic

Agro-climatic Zones

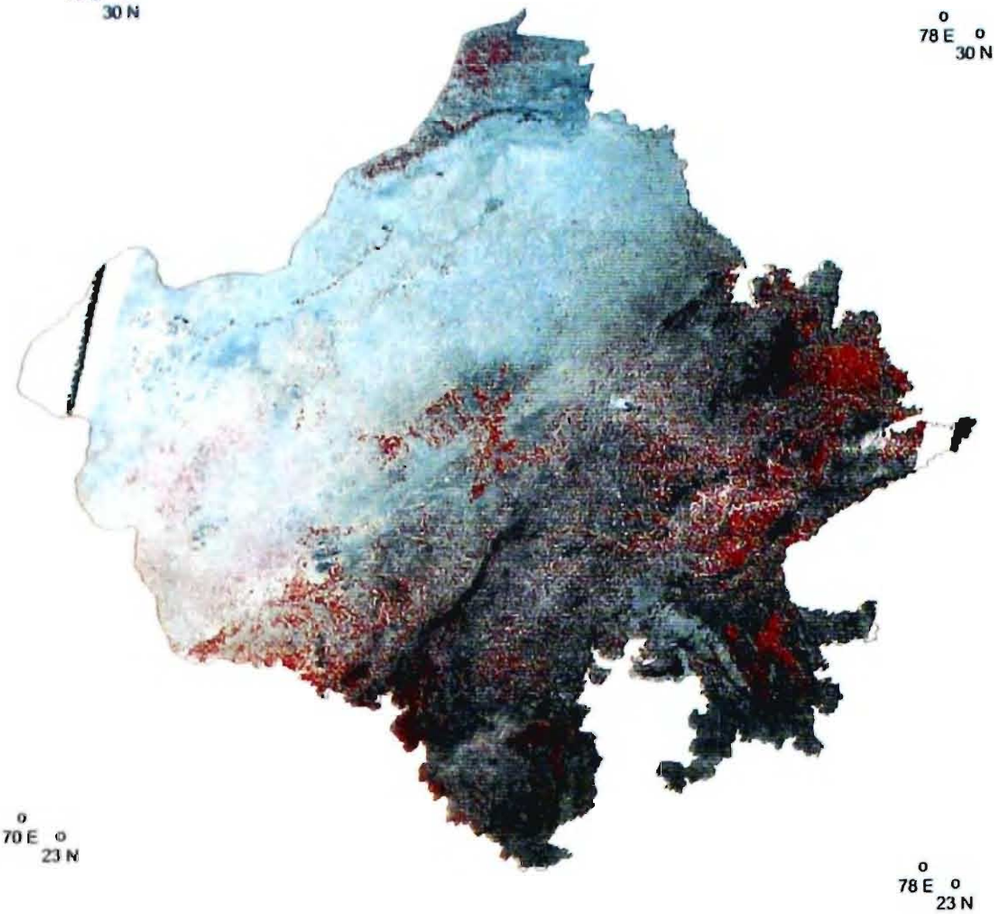


Agro - climatic Zones

- Arid Western Plains
- Irrigated North - western Plains
- Transitional Plains of Inland Drainage
- Transitional Plains of Luni Basin
- Semi - arid Eastern Plains
- Flood Prone Eastern Plains
- Sub - humid Southern Plains & The Aravalli Hills
- Humid Southern Plains
- Humid South - eastern Plains

Projection : Lambert Conformal Conic

False Color Composit (December,1998) [IRS-1D WiFS Data]



90 0 90 180 Kilometers

State Boundary

Projection : Lambert Conformal Conic

False Color Composit (January,1998) [IRS-1C WiFS Data]

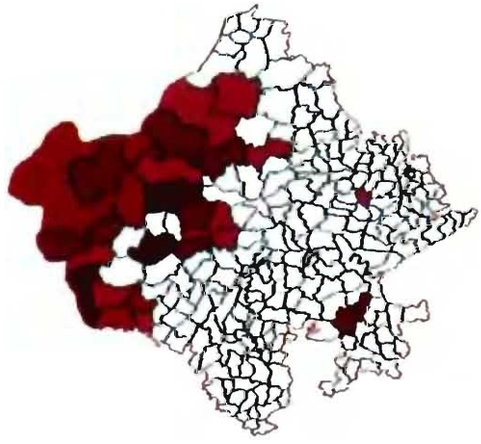
70° E 30° N

78° E 30° N

70° E 23° N

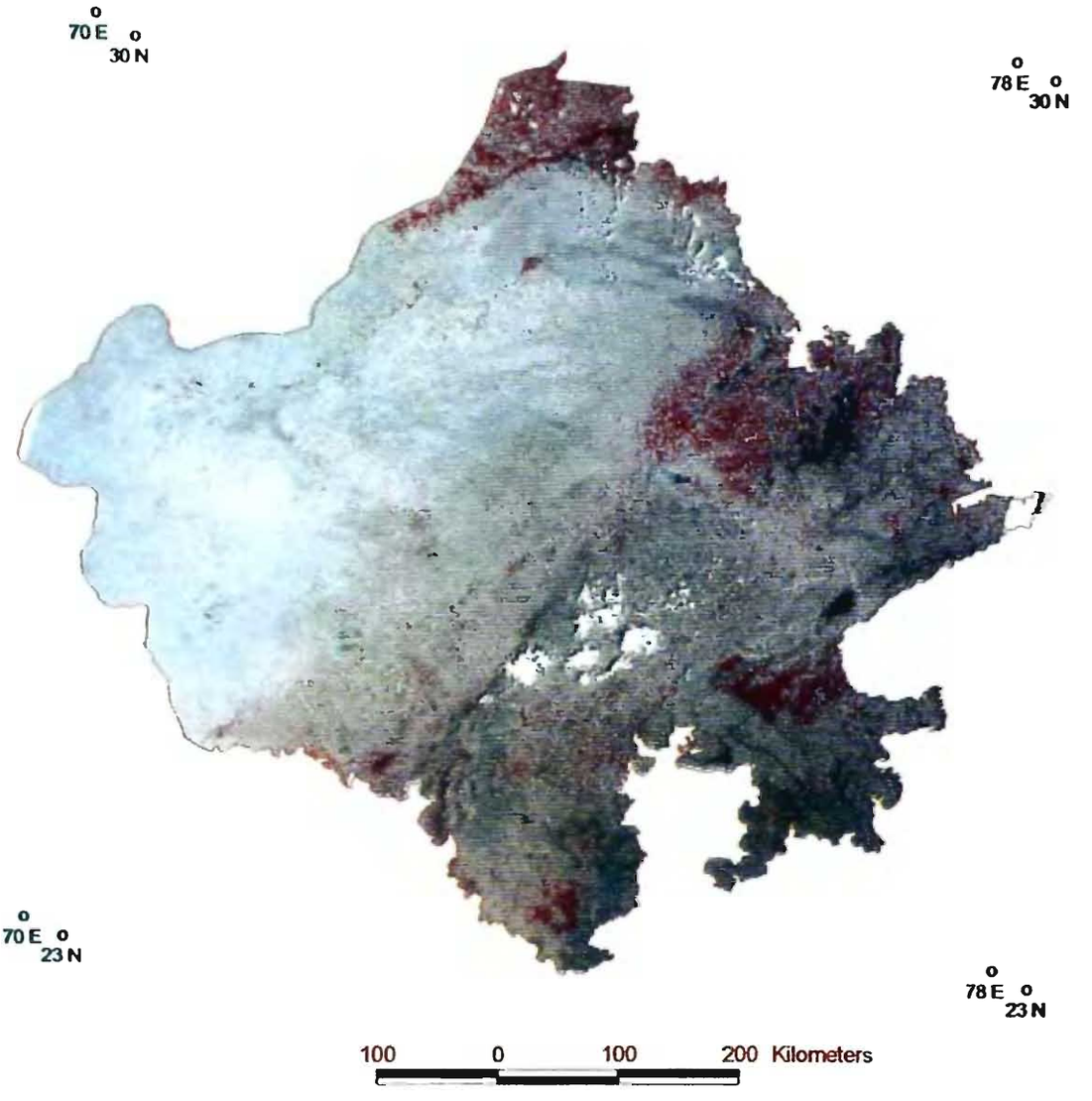
78° E 23° N

100 0 100 200 Kilometers



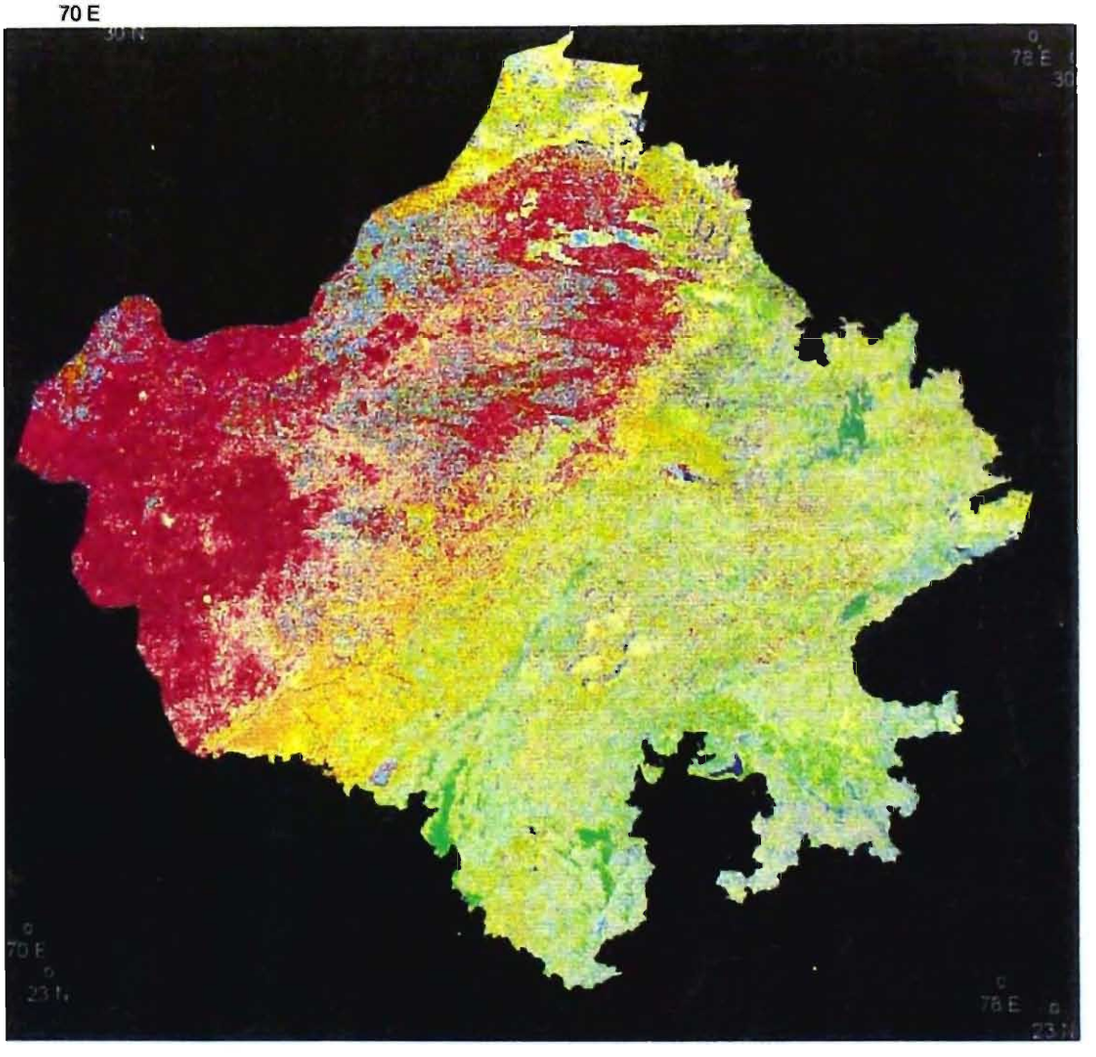
State Boundary

Projection : Lambert Conformal Conic



Projection : Lambert Conformal Conic

Classified Image (WiFS Data)

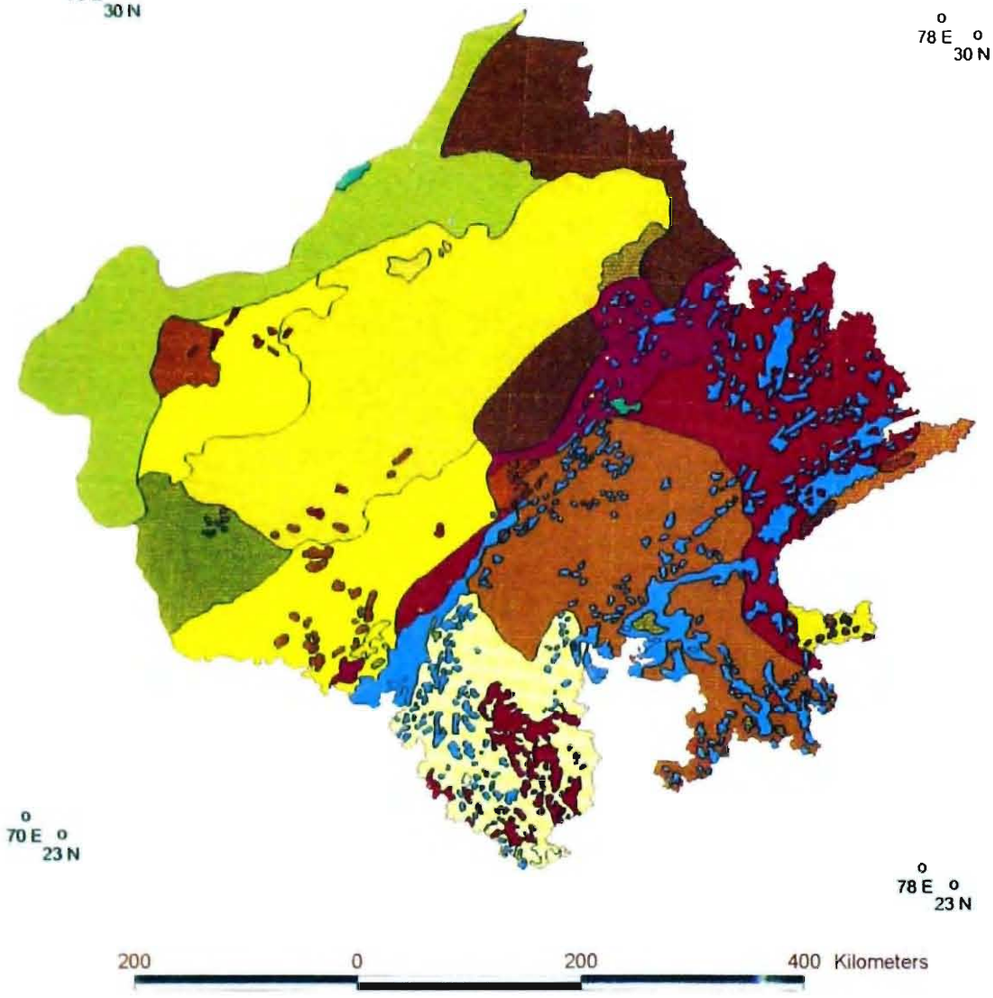


200 0 200 400 Kilometers

- Dry Deciduous Forest (Teak and Kardhai)
- Dry Deciduous Forest (Kardhai and Salai)
- Dry Decicuous Forest (Kardhai and Babool)
- Thorn Forest (Acacia mixed)
- Thorn Forest (Ravine scrub)
- Sand Dunes Calligonum-Haloxylon-Leptadenia
- Sand Dunes (Suaeda -Salsola)
- Sand Dunes (Prosopis-Capparis-Ziziphus)
- Desert (Prosopis - Acacia)
- Desert (Calligonum - Capparis)
- Sand Dunes (Calligonum- Euphorbia--Acacia)
- Agriculture (Double Crop)
- Agriculture (Single Crop)
- Water Body

Projection : Lambert Conformal Conic

Vegetation (Trees & Shrubs)

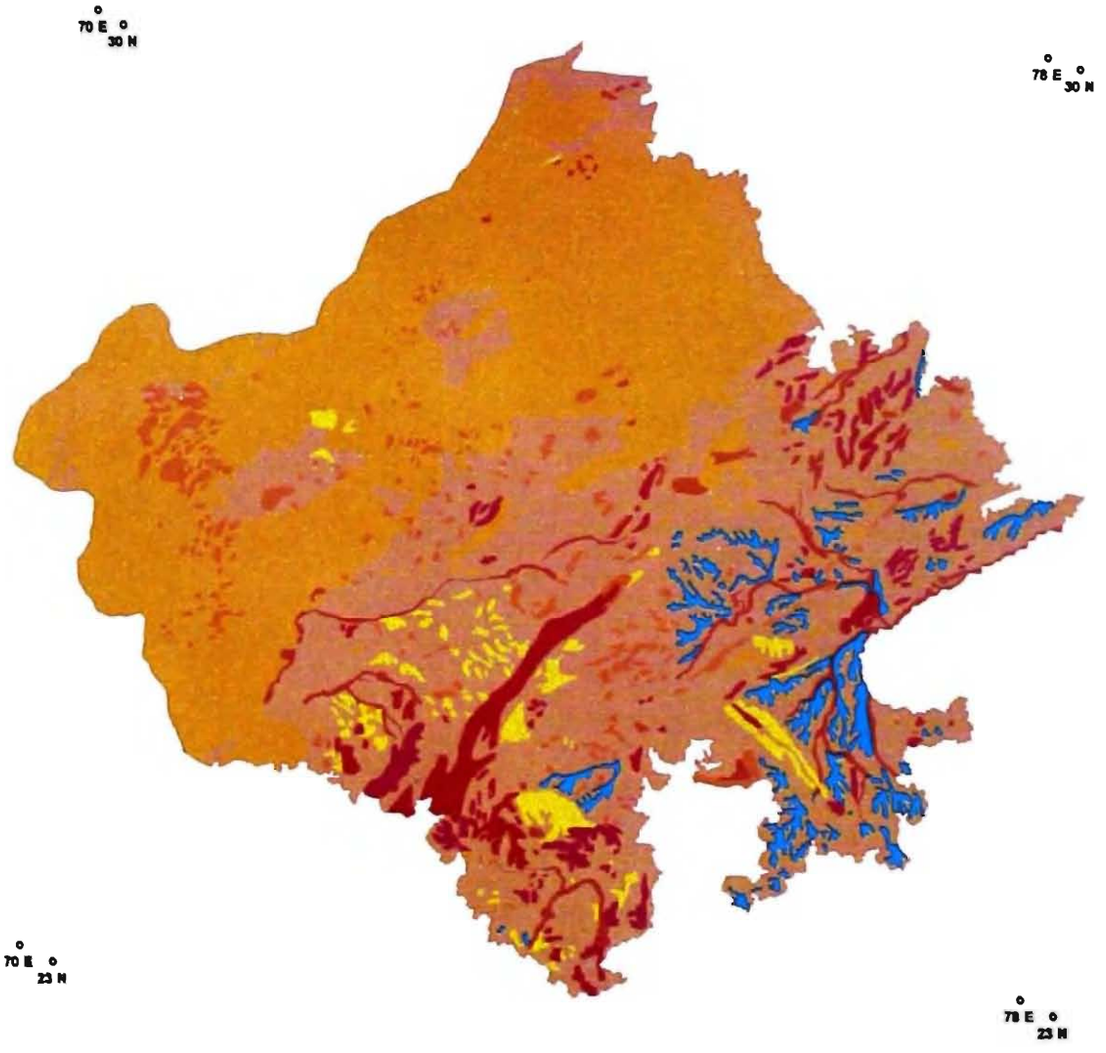


Vegetation Types

- *Acacia nilotica*
- *Suaeda fruticosa - Salsola baryosma*
- *Acacia nilotica - Capparis decidua*
- *Acacia senegal - Euphorbia caducifolia*
- *Anogeissus pendula - Euphorbia caducifolia - Rhusmysorensis*
- *Butea monosperma - Madhuca indica - Ziziphus mauritiana*
- *Anogeissus pendula - Boswellia serrata*
- *Salvadora - Prosopis - Capparis*
- *Mangifera indica - Syzgium cumini*
- *Calligonum - Haloxylon - Leptadenia*
- *Ziziphus - Capparis*
- *Prosopis - Capparis - Ziziphus*
- *Prosopis - Acacia*
- *Prosopis - Tecomella*
- *Acacia leucophloea - Prosopis cineraria - Acacia nilotica*
- *Acacia nilotica - Acacia cupressiformis*

Projection : Lambert Conformal Conic

Wastelands



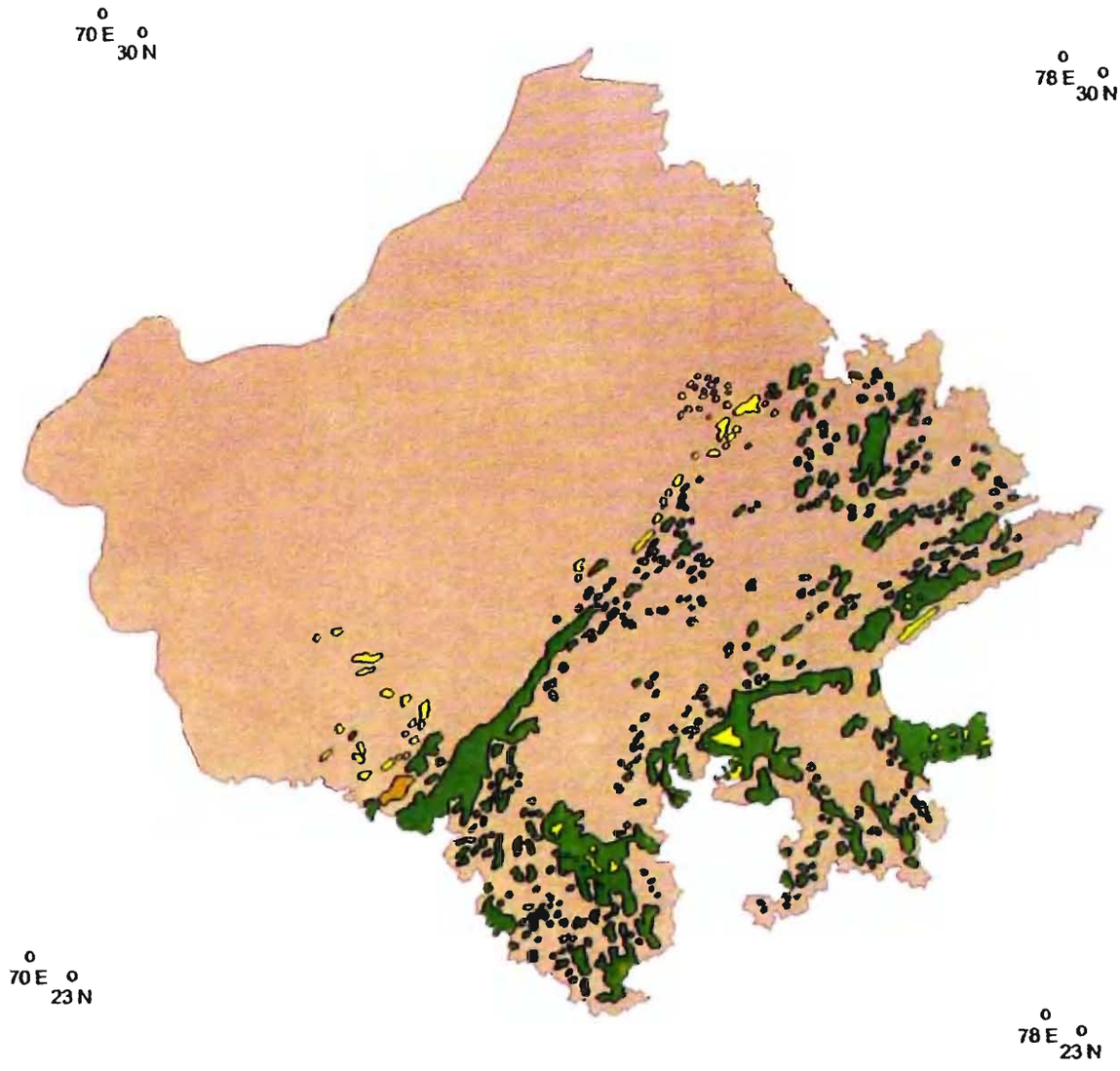
Wasteland Categories

- Gullied and Ravinous Land
- Undulating Upland with or without Scrub
- Water Logged
- Salt-affected Land
- Degraded Forest
- Sandy Area
- Barren Rocky/Stony/Waste Sheet Rock Area
- Other Non Waste Land
- Forest

Projection : Lambert Conformal Conic

Forest Cover
N
W
E
S
70 E 30 N
78 E 30 N
70 E 23 N
78 E 23 N
100 0 100 200 Kilometers
Cover Type
Dense Forest
Open Forest
Non Forest
Projection : Lambert Conformal Conic

Forest Types



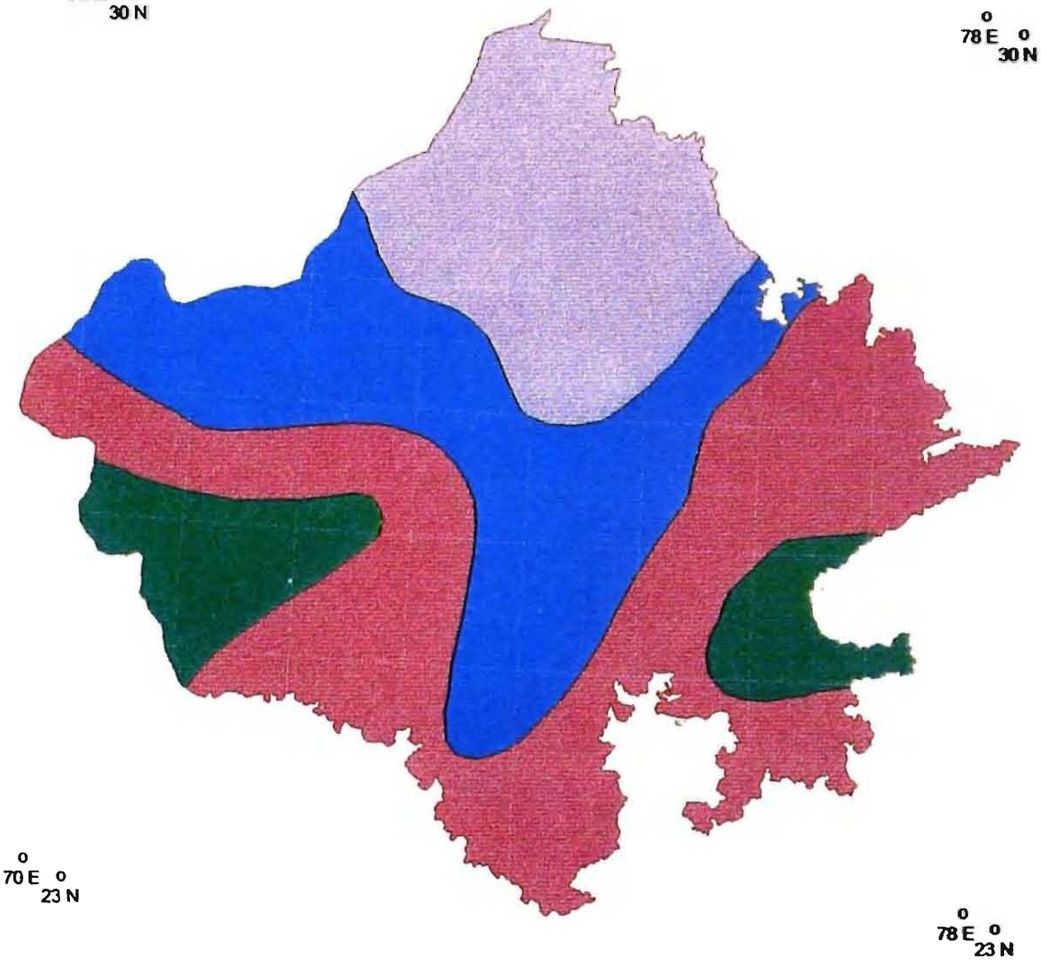
Forest Types

- Tropical Dry Deciduous Forest
- Tropical Thorn Forest
- Subtropical Hill Forest
- Non Forest

Projection : Lambert Conformal Conic

Temperature (June)
(Isotherms)
N
W
E
S
70 E 30 N
78 E 30 N
70 E 23 N
78 E 23 N
80 0 80 160 Kilometers
Temperature
(Degree Centrigrades)
> 42
42_40
40_38
38_36
36_32
<32
Projection : Lambert Conformal Conic

Temperature (January)
(Isotherms)



Temperature
(Degree Centrigrade)

- > 10
- 10_8
- 8_6
- < 6

Projection : Lambert Conformal Conic

Protected Area Network

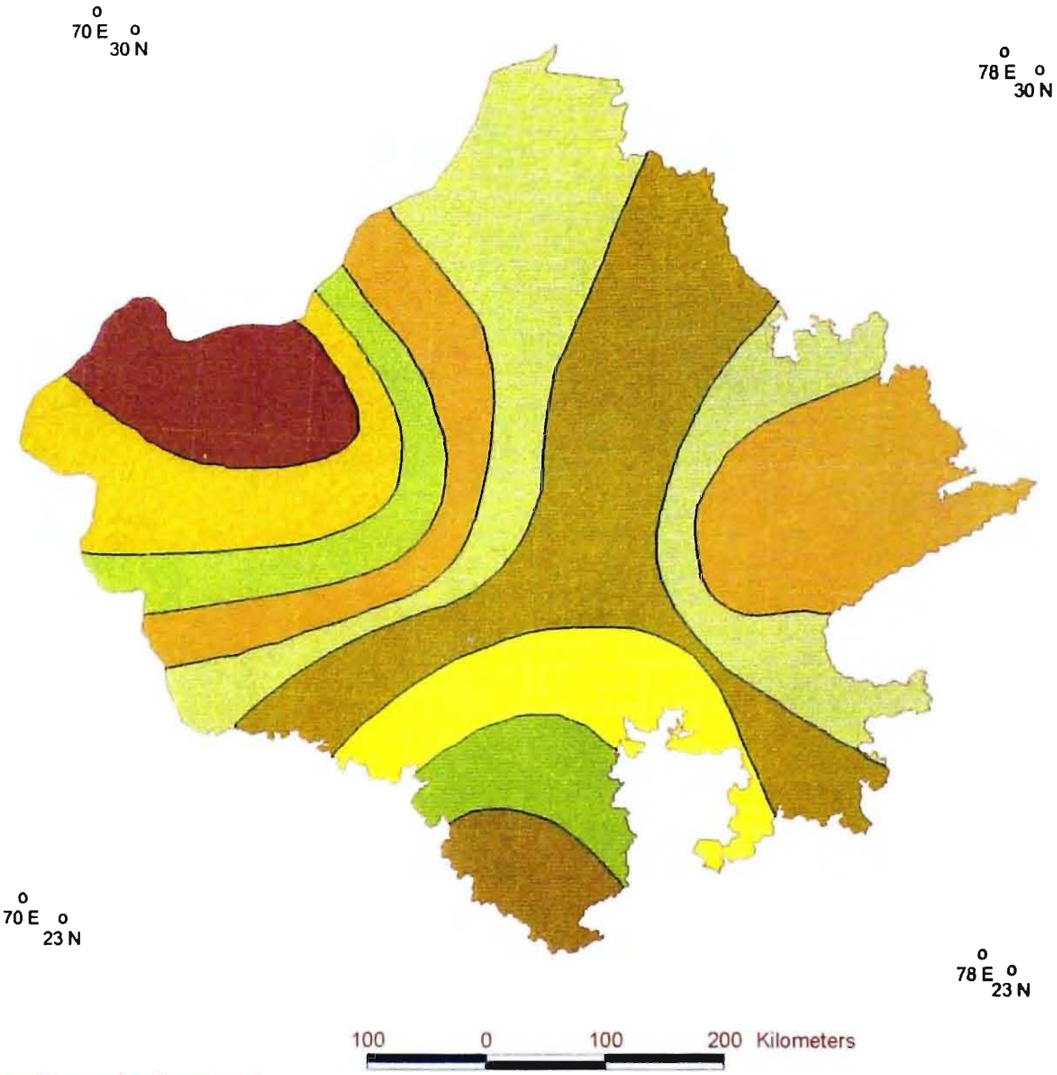
Protected Areas

- National Parks
- Sanctuaries
- Closed Areas

The Protected Area Ploygons are approximate and not to the scale but are as per information available with State Forest Department

Projection : Lambert Conformal Conic

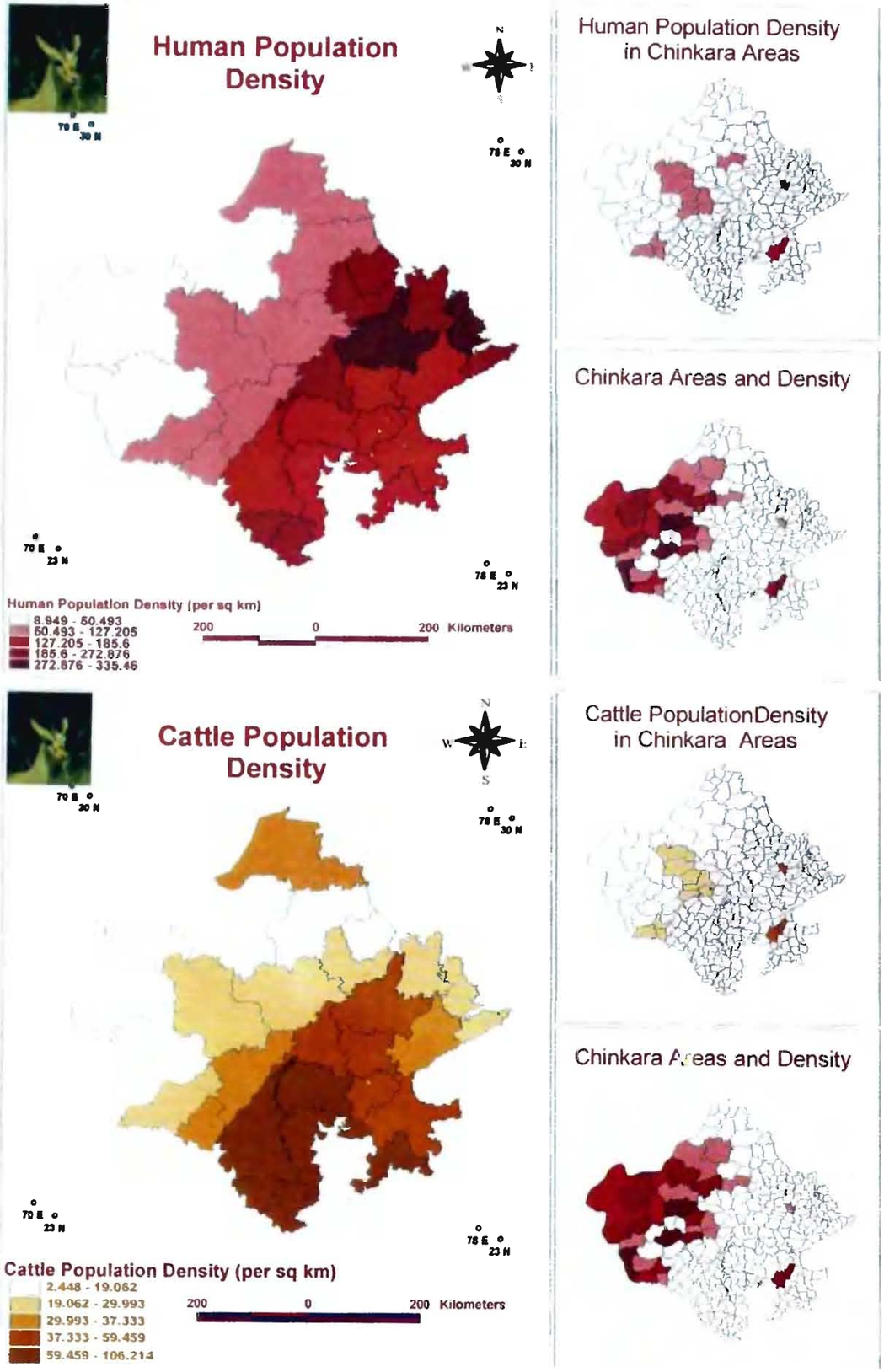
Mean Annual Potential Evapotranspiration

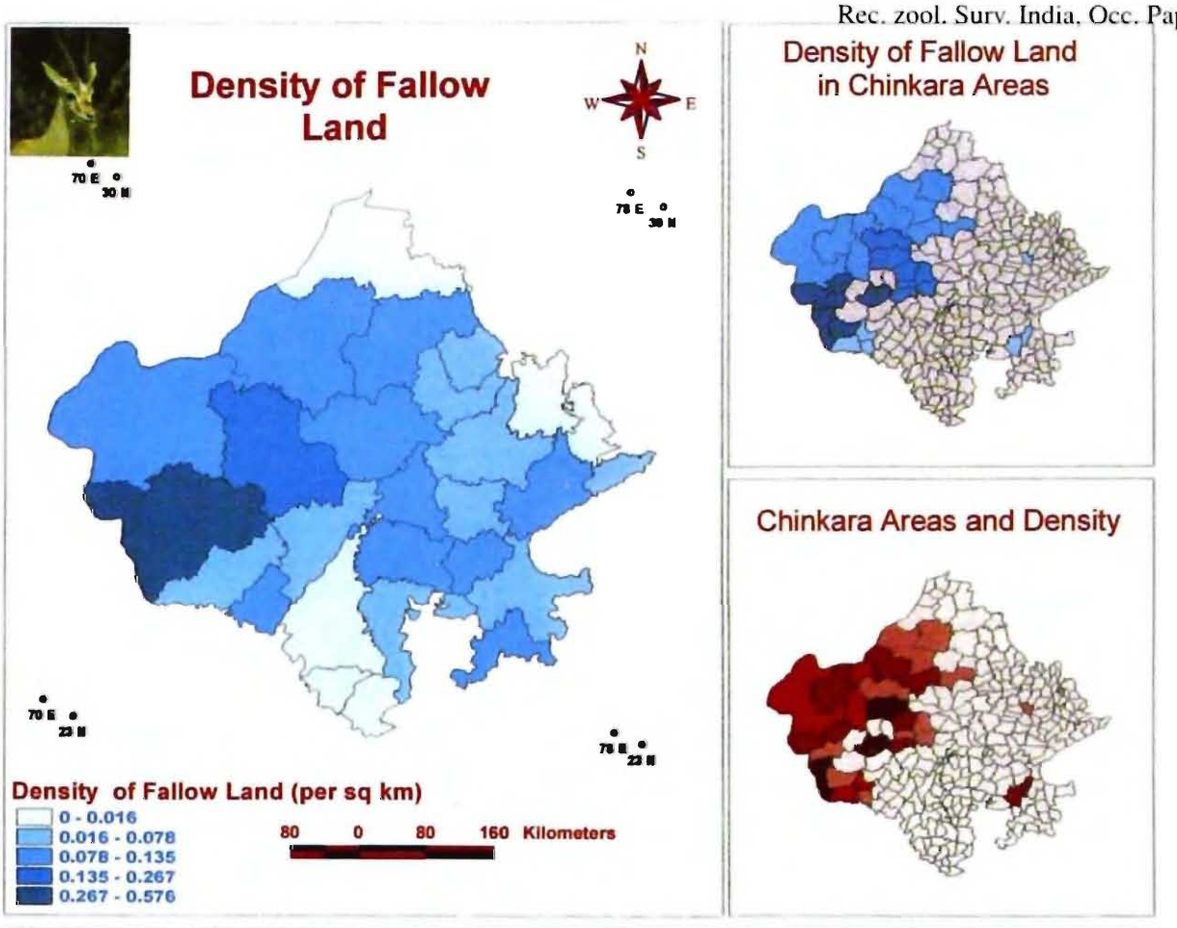


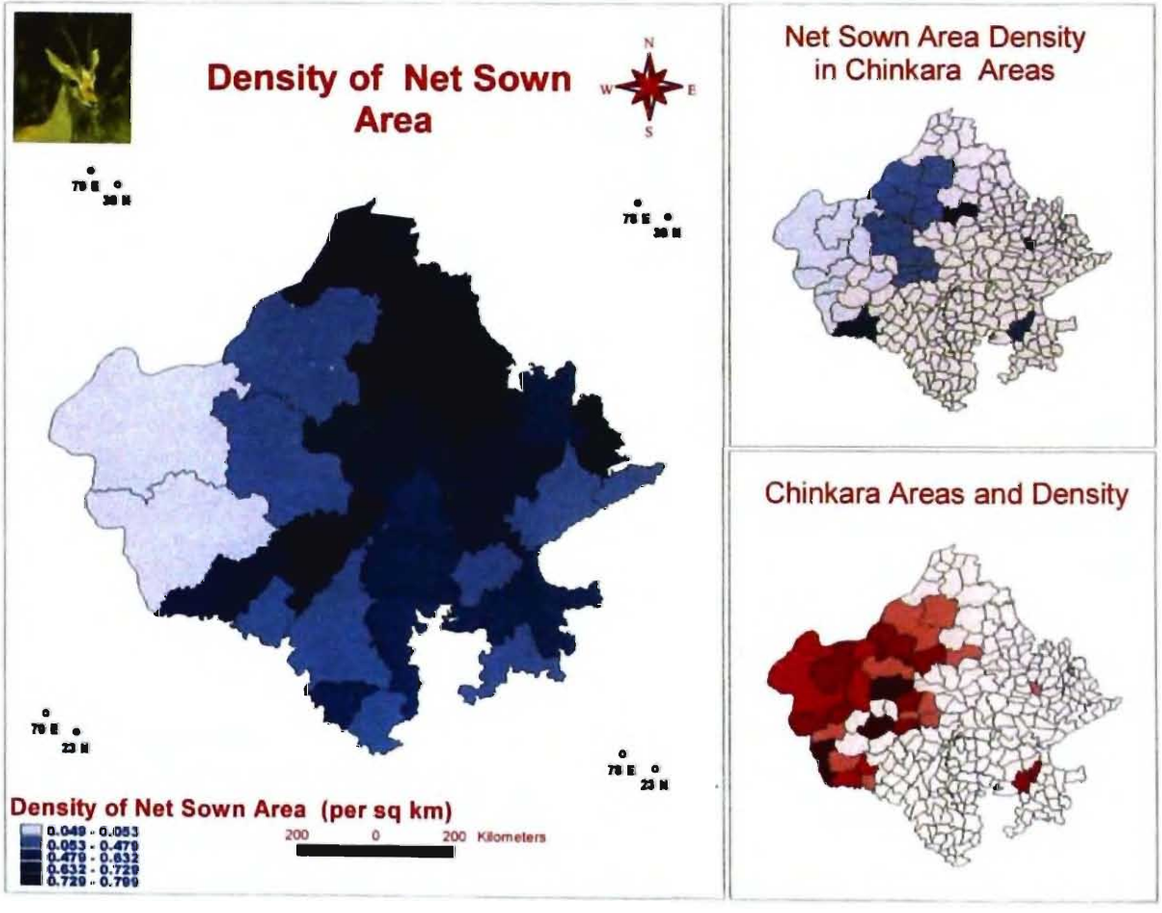
Evapotranspiration (cm)

- >200
- 190_200
- 180_190
- 170_180
- 160_170
- 150_160
- 140_150
- 130_140
- <130

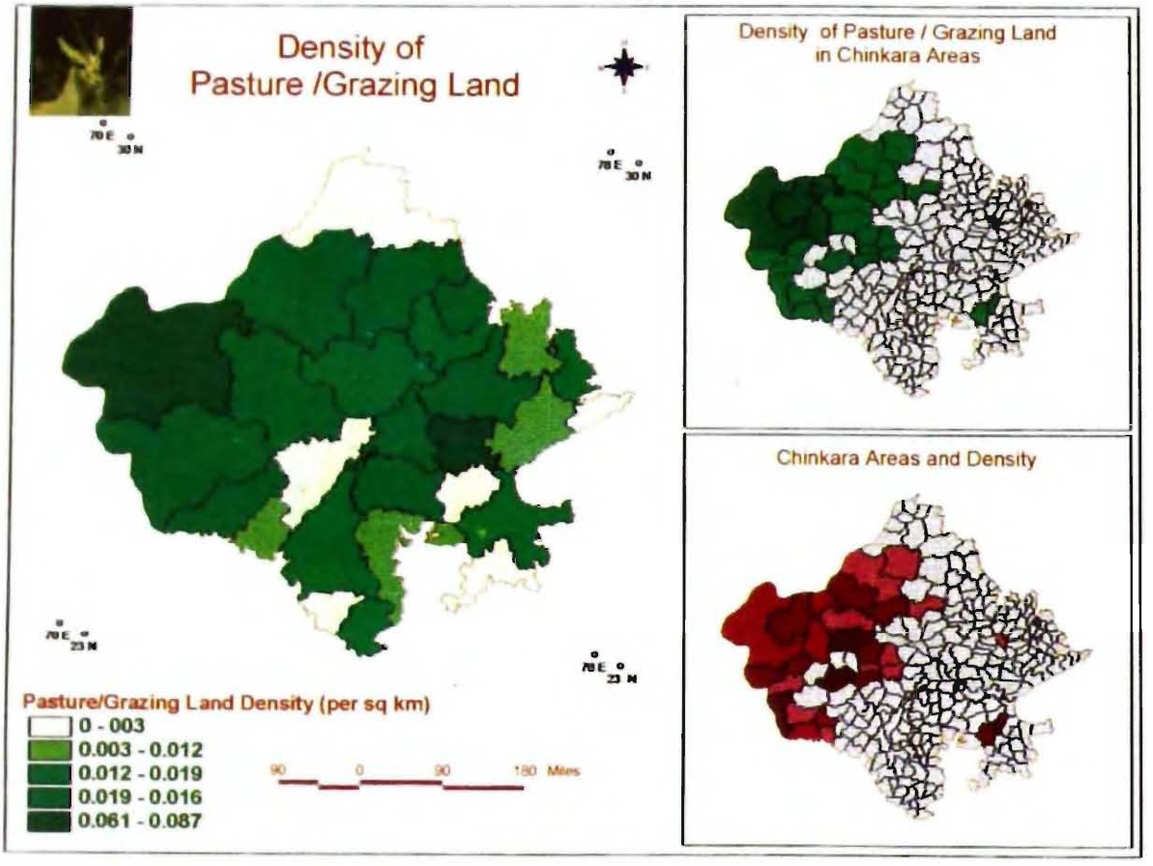
Projection : Lambert Conformal Conic

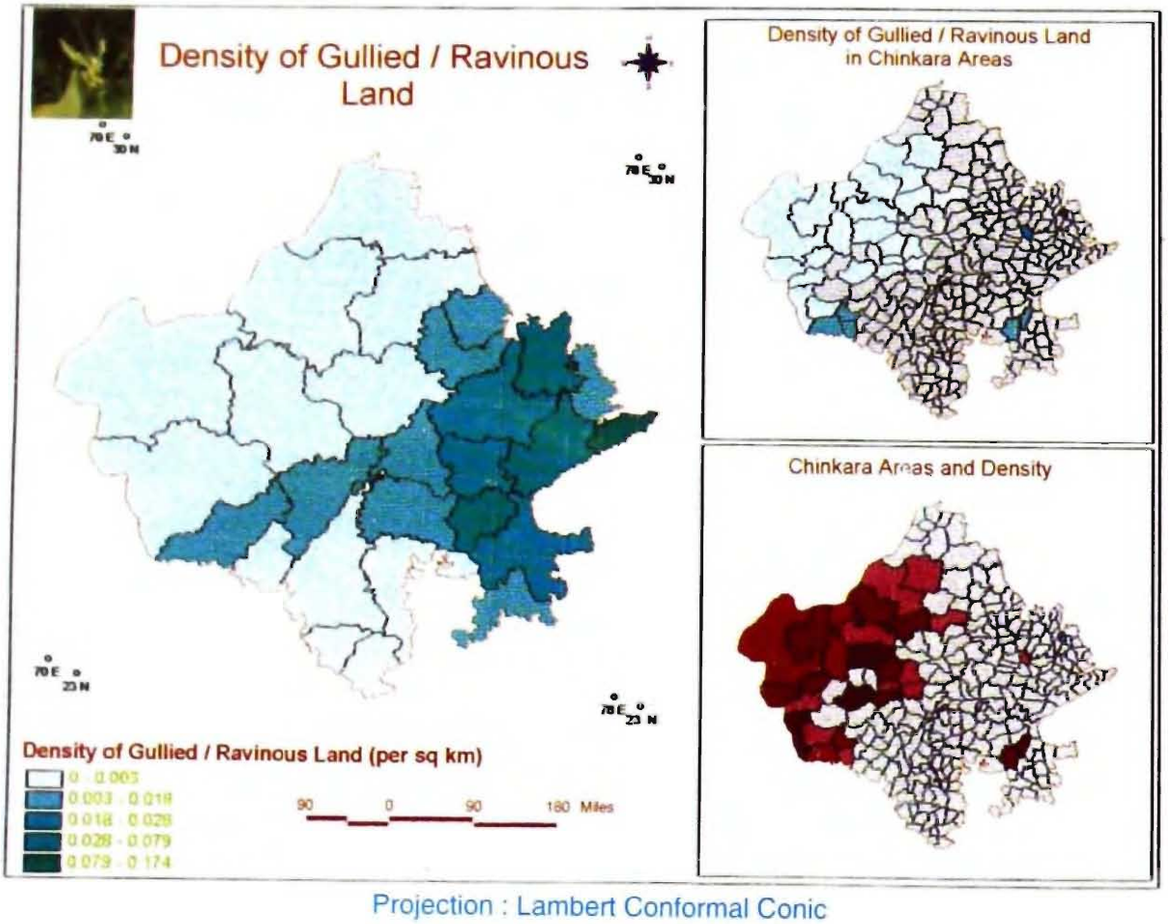

Human Population Density
70 E 30 N
78 E 30 N
70 E 23 N
78 E 23 N
Human Population Density (per sq km)
8.949 - 50.493
50.493 - 127.205
127.205 - 185.6
185.6 - 272.876
272.876 - 335.46
200 0 200 Kilometers
Human Population Density in Chinkara Areas
Chinkara Areas and Density
Cattle Population Density
70 E 30 N
78 E 30 N
70 E 23 N
78 E 23 N
Cattle Population Density (per sq km)
2.448 - 19.062
19.062 - 29.993
29.993 - 37.333
37.333 - 59.459
59.459 - 106.214
200 0 200 Kilometers
Cattle PopulationDensity in Chinkara Areas
Chinkara Areas and Density
Projection : Lambert Conformal Conic



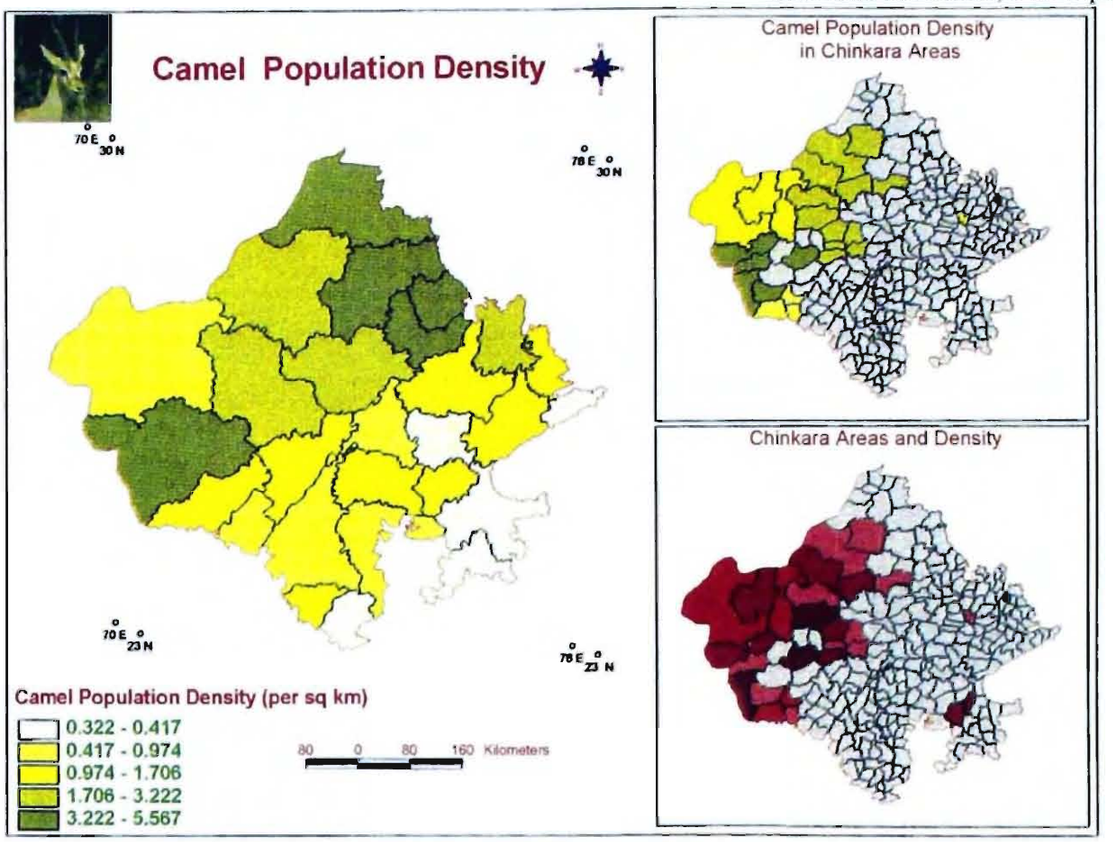


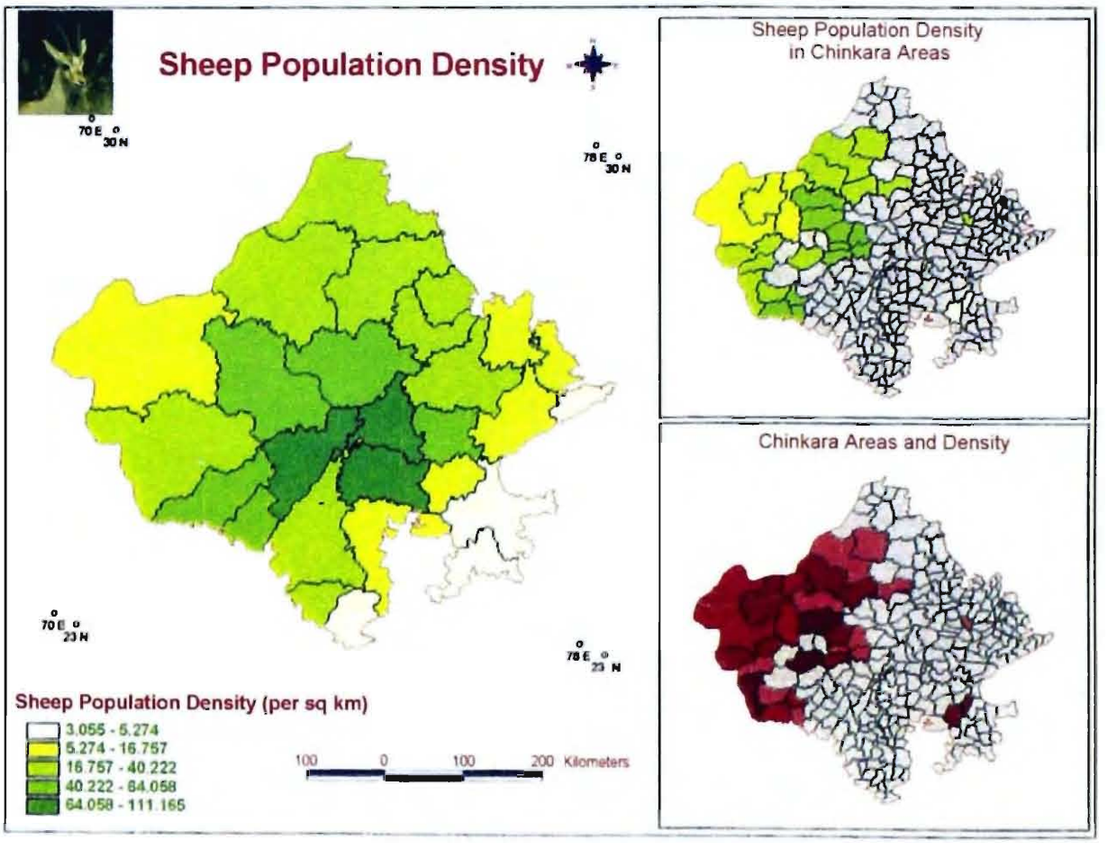
Projection : Lambert Conformal Conic



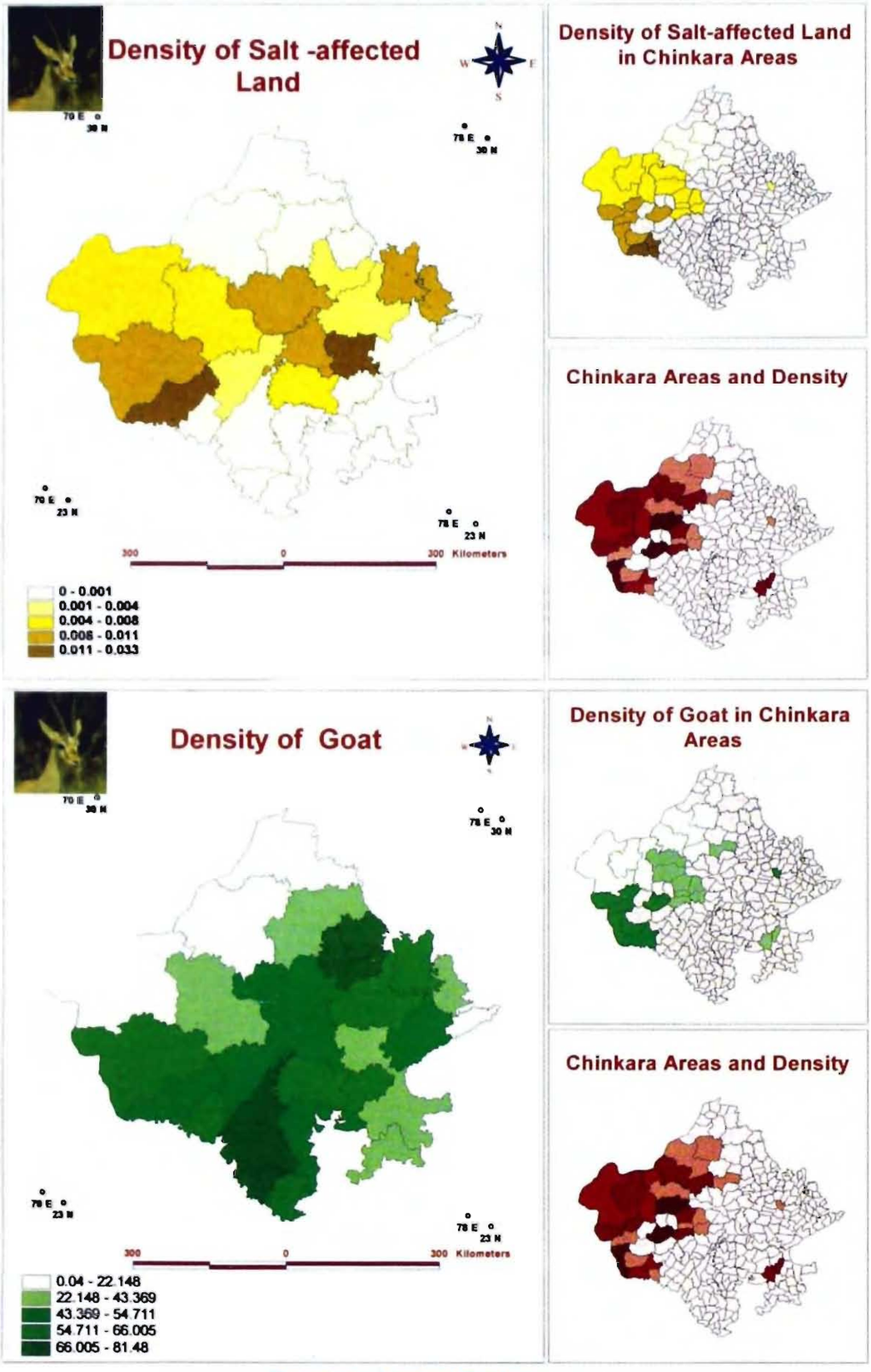


Projection : Lambert Conformal Conic



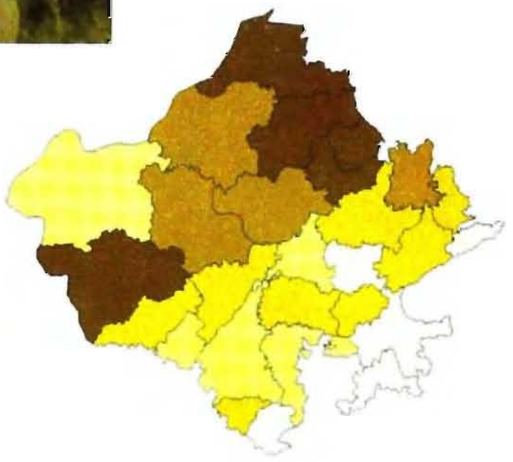


Projection : Lambert Conformal Conic

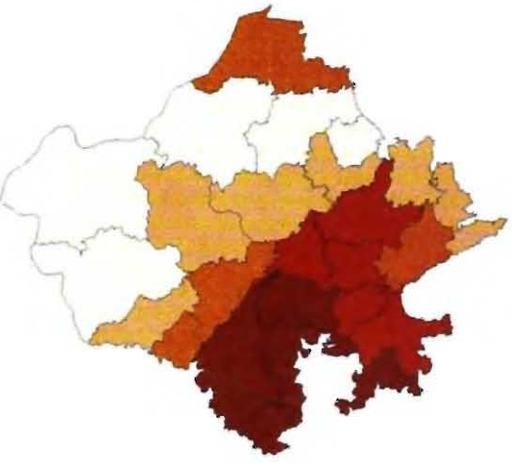


Projection : Lambert Conformal Conic

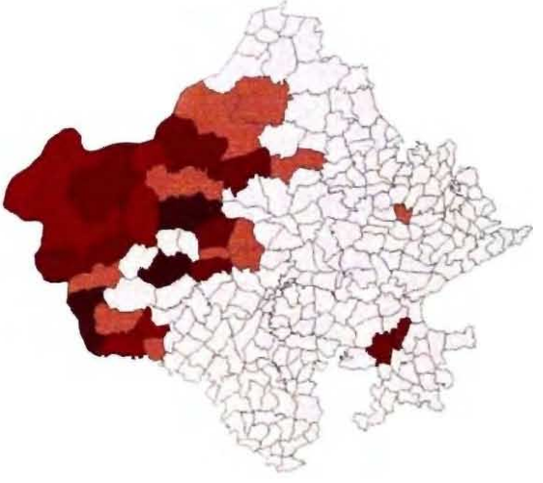
Livestock Density vis-a-vis Chinkara Areas and Density



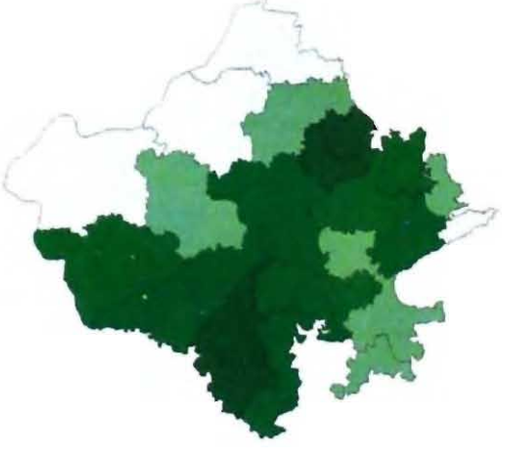
Camel



Cattle



Chinkara

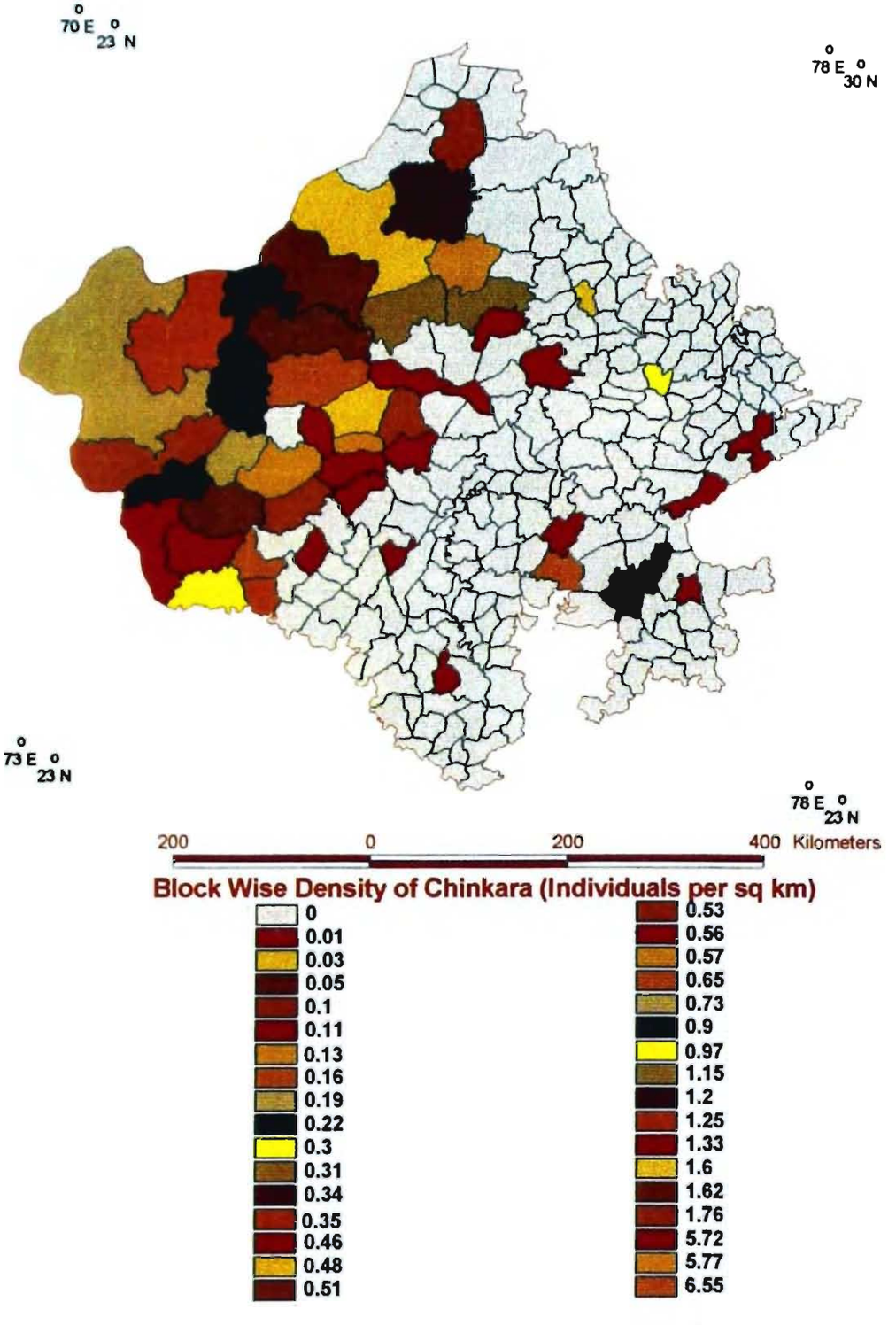


Goat

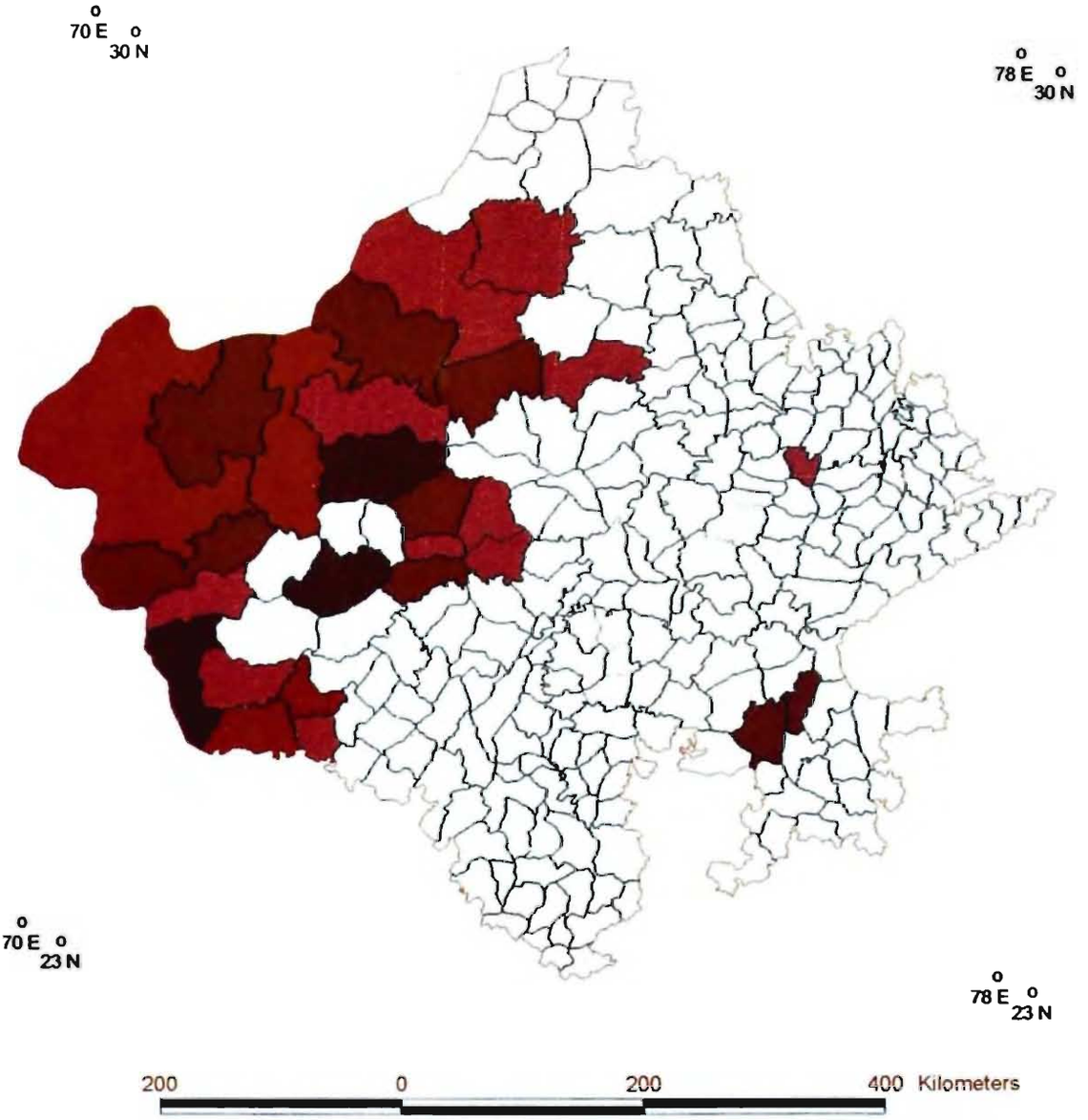
Sheep

Projection : Lambert Conformal Conic

Post Survey Status of Chinkara (Kankane, Rahmani, 1993-95)



Relative Average Density of Chinkara



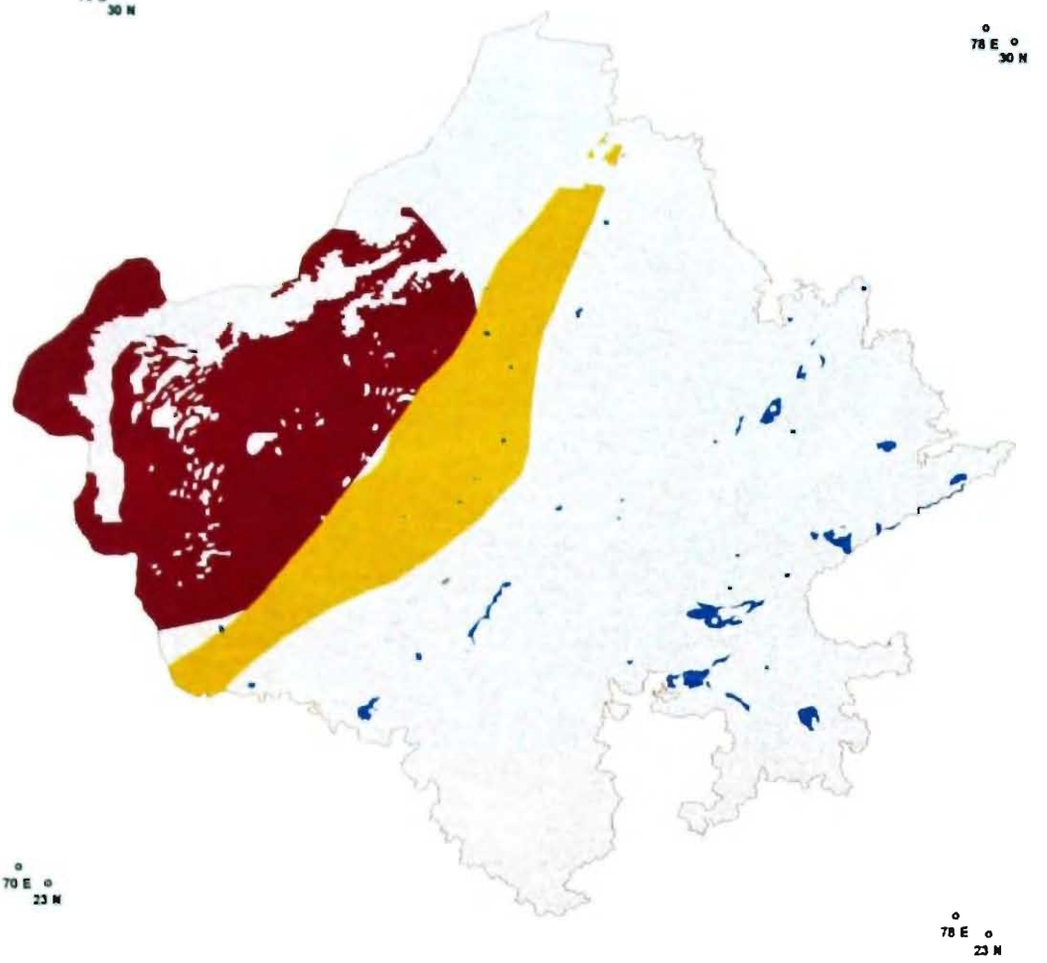
Chinkara Density (Individuals per sq km)

- 0 - 0.19
- 0.19 - 0.57
- 0.57 - 0.97
- 0.97 - 1.76
- 1.76 - 6.55

Projection : Lambert Conformal Conic

Habitat Suitability Map of Chinkara

(After Commencement of Stage - II of IGNP)



80 0 80 160 Kilometers

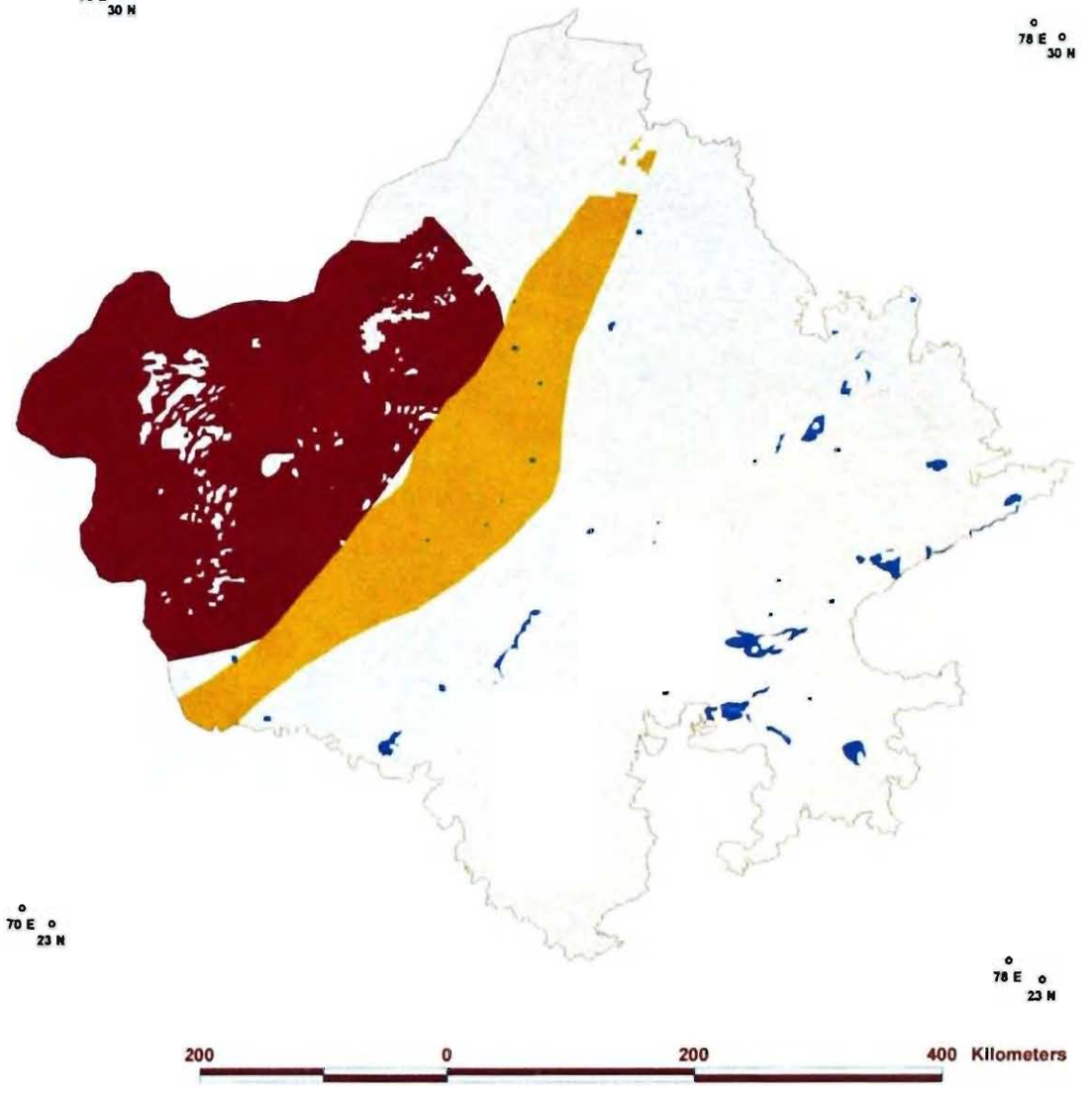
Suitability Criteria

- Highly Suitable
- Moderately Suitable
- Lowest Suitable
- Not Suitable

Projection : Lambert Conformal Conic

Habitat Suitability Map of Chinkara

(Present)



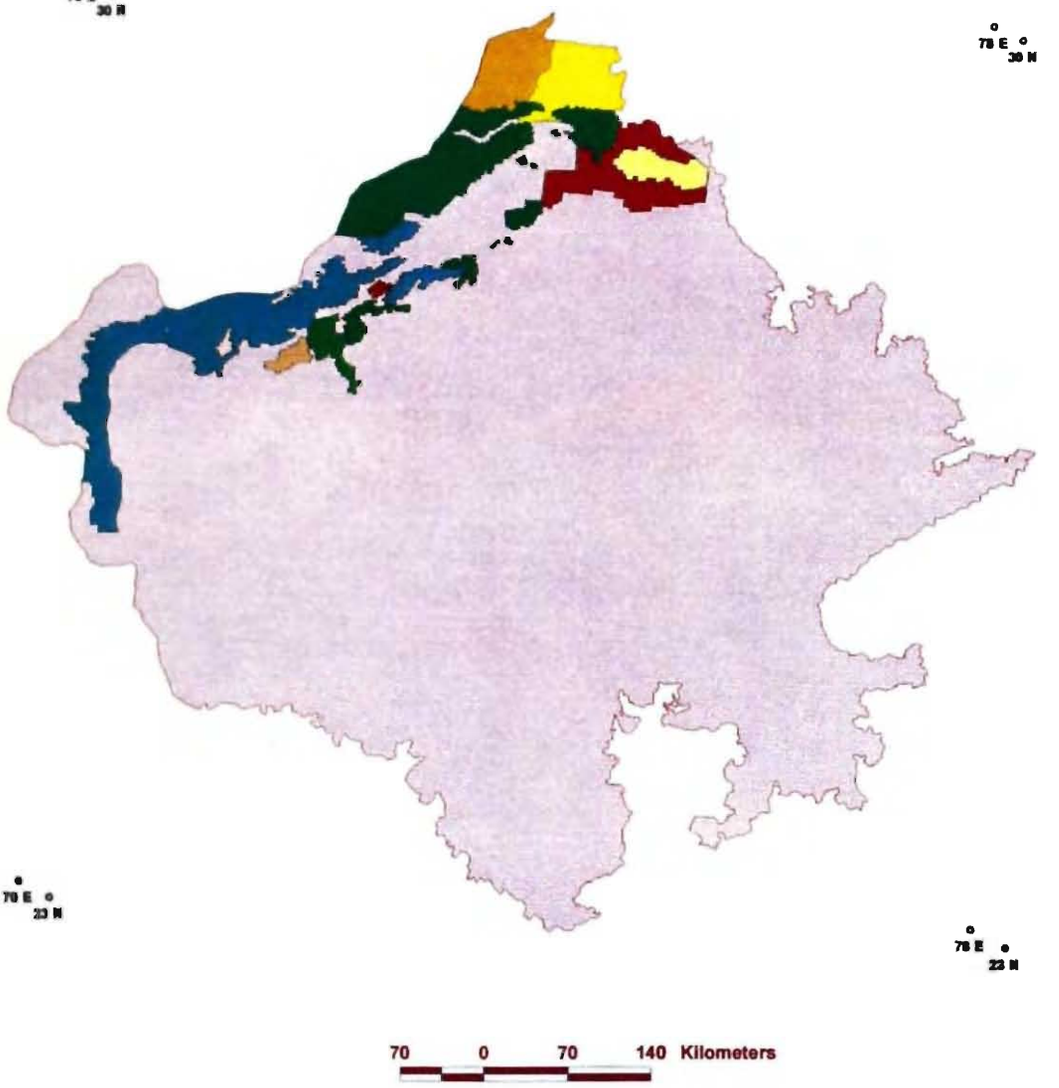
Suitability Criteria

- Highly Suitable
- Moderately Suitable
- Lowest Suitable
- Not Suitable

bangarsar lift scheme
bhakra canal area
gang canal area
phalodi lift scheme
pokaran lift scheme
sahawa lift scheme
stage 1
under sidhmukh area

Projection : Lambert Conformal Conic

Indira Gandhi Nahar Project (IGNP)



IGNP Command Area

- Stage 1
- Stage 2
- Bangarsar lift scheme
- Bhakra canal area
- Gang canal area
- Phalodi lift scheme
- Pokaran lift scheme
- Sahawa lift scheme
- Under Sidhmukh area

Projection : Lambert Conformal Conic

Chinkara or Indian Gazelle, Gazella bennetti Sykes, 1831