IMPACT OF LAND USE CHANGES ON THE HABITAT, BEHAVIOUR AND BREEDING BIOLOGY OF THE INDIAN SARUS CRANE (*Grus antigone antigone*) IN THE SEMI-ARID TRACT OF RAJASTHAN, INDIA

THESIS
SUBMITTED TO THE
FOREST RESEARCH INSTITUTE UNIVERSITY
DEHRADUN

UTTARAKHAND

For
THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY IN FORESTRY
(Forest Ecology and Environment)

By

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Wildlife Institute of India,
Dehradun,
2007

DECLARATION

I hereby declare that the thesis entitled "**Impact of Land use changes on the habitat, behaviour and breeding biology of the Indian Sarus Crane (*Grus antigone antigone*) in the semi-arid tract of Rajasthan, India.**" submitted for the award of Doctor of Philosophy in Forestry (Forest Ecology & Environment) to Forest Research Institute University, Dehradun is a record of original research work done by me under the supervision Mr. B.C. Choudhury, Professor, Wildlife Institute of India, Dehradun and it has not formed the basis for the award of any other degree or diploma. I also declare that the thesis embodies the result of my own work and observations and in that respect the investigation appears to advance knowledge in the subject.

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Place: Dehradun

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CERTIFICATE

This is to certify that the thesis entitled "**Impact of Land use changes on the habitat, behaviour and breeding biology of the Indian Sarus Crane (*Grus antigone antigone*) in the semi-arid tract of Rajasthan, India.**" submitted for the award of Doctor of Philosophy in Forestry (Forest Ecology & Environment) to Forest Research Institute University, Dehradun is a record of original research work done by Ms. **JATINDER KAUR** at Wildlife Institute of India, Dehradun under our guidance and supervision. I further certify that this research work has not previously formed the basis for the award of any other degree or diploma and it fulfils all the requirements laid down in the Ordinance governing award of Ph.D. degree of Forest Research Institute University.

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SUMMARY

1. Sarus Crane needs no introduction to most people from northern India. They have always been part of the agricultural landscape and have been known to live in harmony with farmers. The Sarus Crane has been recorded all over the northern India and central region of the Indian sub-continent historically. However, this once abundant tallest flying bird species has now become threatened. The post–independence rise of human population, the ensuing green revolution, and associated developmental activities served to spell doom for Sarus Cranes and several other birds associated with Indian wetlands. Though natural wetlands are considered to be the most crucial habitat requirement for the survival of the Sarus Cranes in its distribution range, the mosaic of wetlands in the agricultural landscape appears to be the changed but most essential component for the present distribution pattern and survival of Sarus Crane. Sarus Crane appears to have adapted to a somewhat different life cycle in the semi-arid tract in its distributional range as compared to the water rich zones in the central and eastern Gangetic plains. The present Ph.D. study was undertaken during the year 2000-2002 to i) to determine the habitat use, breeding biology and behavioural ecology of the Sarus Crane in the semi-arid tract of Kota, and Bharatpur in Rajasthan, and ii) to determine the changes in land-use and its impact on Sarus Crane in the semi-arid landscape and to suggest the conservation strategies for the long-term survival of Sarus Crane. An examination of the former and present distribution range have been made to obtain an insight into the factors that may have helped the Sarus Cranes to survive in some characteristic type of geomorphological, climatological and vegetation zone in its present strong hold from its historical distribution range.

2. The study was conducted in the semi arid tract of Kota, and Bharatpur districts of Rajasthan. District Kota, the first intensive site falls under arid Zone V (the humid south-eastern humid plain zone,) where the development of canal irrigation has made this area rich in agricultural production. The population of Sarus Crane in Kota are dependent mainly on the canal system induced and other natural wetlands. In Keoladeo Ghana National Park in Bharatpur district, the second control study site in the arid Zone IIIB, (the Flood Prone Eastern Plains), a natural depression wetland that has supported a natural population of resident and migratory waterfowl including Sarus Cranes. In this protected study area, the Sarus population has been well distributed but in recent years have been declining, perhaps owing to the increasing aridity of the wetland and drastic changes in the agriculture practices.

3. Data on distribution and habitat utilization of Sarus Crane in Kota and in Keoladeo Ghana National Park were carried out. The home range of breeding pairs with banded juveniles was carried out and they have been monitored from their natal grounds in monsoon and winter to the congregating wetland sites during peak summer during the study period at both the field sites. The Sarus Cranes use habitat resources available to them in protected and unprotected environment. During this present study, the nesting patterns, reproductive success of Sarus Crane in the semi-arid landscape of Kota and Bharatpur districts were studied in natural wetlands and man induced wetlands. Besides this, the differential level of threats to nesting Sarus Cranes in the two wetland landscapes during the two nesting periods were studied. The detailed compendium of behaviour containing defined and described behavioural

activities were also prepared. Scan animal sampling was carried out on pairs and pairs with juveniles to document their diurnal activity budgets. Ethogram was prepared by pooling all the behavioural activities recorded during the sampling of pair and family units and incubating Sarus Crane. Land use changes pattern was studied, by mapping the land cover in the study area relevant to Sarus Crane and compared with past years to evaluate the degree of change with respect to the critical terrestrial habitat requirements of Sarus Cranes so that appropriate conservation measures could be directed more efficiently to the critical habitats. The study areas were mapped and various land-cover/land-use types described and compared to detect changes in the Sarus Crane preferred habitat and its effect on Sarus Cranes populations.

4. The habitat use pattern of Sarus Crane in semi-arid landscape where water bodies (wetlands) are a limiting factor was studied in detail. In the present study, home ranges of breeding pairs with banded juveniles were carried out. The study also deals with the way the Sarus Cranes use habitat resources available to them in Protected and unprotected environment. The finding is based on the small home range observed in Protected Keoladeo Ghana National Park and marsh/wetland habitats, where as home ranges of breeding pairs with banded juveniles were observed to be larger in Kota, depending on the condition, size and duration of availability of water and forage resources in this semi-arid tract. That in semi arid situation the home range will tend to be larger for Sarus Crane appears to be true based on the present study.

5. The abundance and availability of food resources and nest sites were the key ecological factors determining the size of the home range and the extent of local

and seasonal movement of the families of Sarus Cranes. The availability of food and wetland mosaic are widely scattered in semi-arid landscape. In Kota, as the man-induced wetlands and water resources are managed and maintained for human usage, the water level in these wetlands fluctuates very often affecting the activity and movement of Sarus Cranes. The presence of marshes interspersed with agriculture fields along the water bodies was observed to be important for the Cranes as this combination provided an ideal set up for nesting, feeding and escaping from predators among several activities including roosting.

6. Sarus appears to have adapted to a dual nesting pattern, synchronizing with the man-induced flooding of landscape through canal induced waters in semi-arid tract. Sarus Crane in the study area showed a distinct dual nesting pattern, one in (February-May) and the other in (July–Oct), during our study duration in Kota. In Bharatpur only one nest was observed during 2000 dry season nesting, whereas the dry season nests in Kota were ten. While nesting initiation synchronizes with the onset of monsoon in general, Wetlands created through seepage from the Right Main canal (RMC) of Kota barrage offered suitable condition for Sarus Cranes breeding during dry and wet season, but the canal is functional mainly during October to March after that the canal is opened after every 15 days to fill the ponds of NTPC Antha. During monsoon when the entire landscape remains inundated with water for four to five months, it creates a suitable nesting ground and ensure easy food for the Cranes and their chicks which is the major nesting period.

7. The low fledging success in the wet season was triggered by high level of predation related mortality for Sarus Crane in semi-arid tract. This makes the pairs to be physiologically ready for a second nest and the man induced wetlands in dry season provide a sub optimal breeding habitat for the second clutch. The occurrence of second nesting in dry season in the semi-arid tract is hypothesized to be an adaptation. During dry season nesting all the resources become limited and there are no insect and tuber available during that period. The pairs have to invest more time in search of food and the only easy available food is post harvesting left over grains. The second clutch requires larger parental investment for chick rearing. All these factors lead to low or non survival of chicks during dry season nesting. Most of the Sarus nest in Kota and Bharatpur were recorded in man-induced and/or natural wetlands and very few nests were recorded in agricultural field. The results show that nest success and failure does not have any association with nesting characteristic. The water availability and disturbances were the key factor to contribute towards nest success or failure.

8. The breeding success of the Sarus Crane was primarily hampered at all stages by human-related causes in the semi-arid landscape. Direct persecution was most apparent in the egg stage and in both the study sites, natural wetlands were observed to be crucial for the survival of Sarus Cranes. The egg mortality in Kota was mostly seen to have occurred when children removed the eggs to play and intended egg stealing by local farm labourers and migrant for food and medicinal use for curing diseases. Predators recorded for Sarus Crane chicks included jackals and house crows, dogs and marsh harrier.

9. In the semi-arid landscape of north-western India the Sarus Crane spend greater amount of the time foraging and maximizing opportunity of food availability in a wider range home range. The study also examined and found Sarus pairs to spend more time in foraging and searching for food in a water deficient area, the parental investment on chick protection to be less and chick survival to be low. Sarus Crane appeared to spend greater amount of time foraging, standing and searching for food and after feeding, the dominant activity was observed to be loafing. In the semi arid tract, male and female spend more time in feeding and foraging in both summer and winter seasons in the semi arid tract. In the semi-arid landscape Sarus Crane maximizes the opportunity for food availability in a wider home range and from the results it is very clear that in present study Sarus Crane spend more time in feeding in both the summer and winter seasons. Male and female Sarus Crane spends more time in feeding and for searching of food in water deficient areas, which also increases their vulnerability to threats.

10. The ranges of behavioiral pattern exhibited by Sarus are low in the semi-arid and arid tract and great time was diverted to specific activity. A total of forty two major behaviour patterns were recorded during the sampling, different behaviour pattern were recorded. Human related activities were clearly the most important cause of disturbance for Sarus Cranes during the study period in Kota and Bharatpur. In Kota, the farmers working in agricultural fields and the vehicles that continues to pass whole day along the canal road cause disturbances to pairs and families of Sarus Crane. In Bharatpur, the grass cutters were the major disturbing factors and they disturbed the birds at all the level right from nest preparation till the chicks weaning out. Many a time observation were made when tourist entered the blocks for photographing the Sarus Crane.

11. The changes in land use and its possible impact on Sarus Crane life history parameters were also studied. Sarus Cranes used habitat such as natural marshes with reeds, shallow water bodies, ponds and agriculture fields. These marshes are endangered due to increasing agricultural development. The agricultural areas used by these Cranes have the particular characteristic of being located next to bodies of water. The natural marshes along the wetlands with agriculture fields on the margins appear to be the most preferred habitat for the Sarus Crane but the encroachment of these marshes to convert them into agriculture fields is diminishing their survival chance. Sarus Crane was seen to prefer paddy and wheat fields compared to other crops.

12. The wetland condition of Keoladeo Ghana National Park depends largely upon the amount of water received from the Ajan Bund (about 1 Km from the Park) and on direct precipitation. As soon as enough water accumulates in the Ajan bund, water is released into the park filling impoundments to a depth of 20-30cm. During the past few years, reduced availability of water, prolonged dry periods and several management decisions, accelerated the process of terrestrialization and conversion of several wetland areas into dry scrubland. The total count of Sarus Crane inside the park has been regularly done every year since 1983 and a total of 657 Sarus Crane were counted during the 1984, and during the study period only 61 Sarus Crane were counted in 2000, 8 Sarus Crane in 2001 and 14 Sarus Crane in year 2002. The year to year variability in the total amount of rainfall and its distribution during the year affect the depth, duration and timing of water in different blocks of the park. The quantum of water received is the most important factor in the survival of the wetland, and to

some extent that of the Sarus crane both within and outside the Keoladeo Ghana National Park in Bharatpur.

13. The suggested strategies for enabling the long-term survival of Sarus Crane in semi-arid landscape. It is necessary to maintain the periodicity of water, particularly in such wetlands in Kota and Keoladeo Ghana National Park and other semi-arid areas where the post-monsoon provisioning of water to wetlands support the wetland avifauna and the Sarus. If the wetland have an anthropogenic source of water that should be ensured, for seasonality of water to remain for a longer time period, and even those wetland where second nesting is recorded a same strategies be adopted. All the identified wetlands and the surrounding landscape that support large density of breeding Sarus Crane needs to be identified and such mosaic of habitat to be made disturbance free.

14. Additional research based information are also required to enhance Sarus Crane conservation protection and management activities in Kota and Bharatpur. Detailed research on local and seasonal movements of Sarus Cranes in both wet and dry season nesting period. The information on what kinds of threats are prevalent for chick survival is required in detail in the semi-arid landscape where the situation may be different in different semi-arid condition. For the dry season nesting Sarus Cranes to be properly protected in Kota, (which is the only district where second nesting from February to May is recorded), removal of encroachments from wetlands and restoration of the marshes along the wetlands are required by declaring them as "Conservation or Community Reserves" to avoid further encroachments.

15. The protection of the marshes created from the seepage and escapes of the wetland and canals along the agriculture fields are important to be maintained. Maintaining a minimum water level in the larger man-made wetlands or large reservoirs is important too. Destruction of Sarus Crane nests, stealing of eggs, occasional hunting, has been the direct threats to Sarus in Rajasthan. Annual counts of the Sarus Crane population at Keoladeo National Park have been carried out by an NGO since 1983 and has provided the much needed information on what is happening to the Sarus population. Inventorization of important wetlands and the surrounding landscape that support Sarus Crane population and annual Sarus counts can be conducted by local NGO's by creating such network, that will have community involvement.

16. Involving the local communities around the breeding sites of Sarus Cranes through education and awareness campaigns on a prolonged basis conducted by government agencies and Ngo's to protect and monitor the breeding sites, nests and chicks from predation has helped increase the number of the Cranes during the present study.

CHAPTER 1

The Indian Sarus Crane amongst the Cranes of the World

Cranes are large to very large birds with long necks and legs, streamlined bodies and long rounded wings. Crane are among the world's tallest birds, ranging in length from 90cm to more than 150cm. The shortest is the Demoiselle Cranes(*Anthropoides virgo*), while the Sarus Crane (*Grus antigone antigone*) is the tallest. The Red crowned Crane(*Grus japonensis*) is the heaviest Crane, weighing up to 12 kg when fat deposits peak in the autumn. Male and female Cranes of all species are identical in their external features, except that the male is slightly larger than the female (Johnsgard 1983, Meine & Archibald 1996).

1.1 Evolution and Phylogentics of the Cranes in the World

The Crane family (Gruidae) is divided into two sub-families, the Crowned Cranes (Balearicinae) and the Typical Cranes (Gruinae). A total of eleven species of Crowned Cranes are known to have existed in Europe and North America over the last 50 million years. The two species of Crowned Cranes that survive today are found exclusively in Africa (Urban 1987). Modern Crowned Cranes cannot withstand extreme cold, and it is conjectured that as the earth cooled these Cranes died out on the northern continents and held on only in Africa, where tropical conditions persisted through the Pleistocene. The typical Cranes, by contrast, are more cold hardy. They first appear in the fossil record in the Miocene, 5-24 million years ago. It was during this period that the thirteen surviving species of Gruinae evolved. Seven other species of Gruinae Cranes are known to have gone extinct during this period (Brodkorb 1967).

The typical Cranes are divided into three genera: Anthropoides, Bugeranus, and Grus. The Demoiselle Crane (*Anthropoides virgo*) and Blue Crane (*Anthropoides paradisea*) have bustard-like short toes and bills, and like the bustards live in grasslands. Although the morphological features of the Anthropoides genus and the larger Wattled Crane (*Bugeranus carunculatus*) are dramatically different. Studies of their behavior and DNA indicate a close relationship between them (Archibald 1976a, 1976b, Krajewski 1989, Krajewski and Fetzner 1994). The Wattled Crane is a much more aquatic species, and undoubtedly its large size is an evolutionarily convergent feature that it shares with the Grus species that are primarily aquatic. The species in the genus Grus are placed in four groups (Archibald 1976a, 1976b; Krajewski 1989). The Sandhill Crane (*Grus canadensis*) stands alone, as does the Siberian Crane (*Grus leucogeranus*). The "Group of Three" includes the Sarus Crane (*Grus antigone*), the Brolga (*Grus rubicundus*), and the White-naped Crane (*Grus vipio*). The "Group of Five" consists of the Eurasian Crane (*Grus grus*), Whooping Crane (*Grus americana*), Hooded Crane (*Grus monachus*), Black-necked Crane (*Grus nigricollis*), and Red-crowned Crane (*Grus japonensis*).

Within the order Gruiformes, Cranes are closely related to the limpkins (which have similar flight patterns and loud calls), the trumpeters (which resemble Crowned Cranes in their dances and plumage), and the bustards (which are also large, long-legged, long-necked birds found in open lands). Recent studies of morphology, ethology, and DNA have shown similar patterns in the systematic relationships within this order of birds (Archibald 1976a, 1976b; Wood 1979; Krajewski 1989; Krajewski and Fetzner 1994).

1.2 Species And Sub-species Account of the Sarus Crane

Of the 15 species of Cranes found in the world today, six species namely Sarus Crane (*Grus antigone*), Siberian Crane *(Grus leucogeranus)*, Common Crane (*Grus grus*), Demoiselle Crane (*Anthropoides virgo*), Black-necked Crane (*Grus nigricollis*) and Whitenaped Crane (*Grus vipio*) are found in India and the Sarus Crane (*Grus antigone*) is the only resident species. Over their entire distribution range Sarus Cranes utilize wetlands, both natural and manmade, and are well known for their ability to live in association with habitation (Gole 1989, Gole 1996 Archibald & Meine 1996, Birdlife International 2001). In India, people have attributed religious and cultural values to them, and protect Sarus and other Cranes. The Cranes have been documented right from historical times to pair for life (Ali 1927) and this feature has made them a symbol of fertility in large parts of north India. There are three extant subspecies of Sarus Cranes in the world. All three subspecies are discernible on field by morphological features and have different distributional ranges and habitat requirements as described below (Johnsgard 1983, Meine & Archibald 1996).

The Eastern Sarus Crane (Grus a. sharpii): The subspecies is little known and studies on them are minimal. Eastern Sarus Cranes have been seen to be less tolerant of people as compared to the other two subspecies and are thought to be almost completely dependent on natural wetlands in both the dry and wet season. It is suspected that they may be present as two disjunct populations - one estimated at 500–1500 individuals, in the lower Mekong basin (Meine & Archibald 1996) in Cambodia, Laos, and Vietnam, and possibly an isolated population in eastern India, Myanmar, and Yunnan. The subspecies has suffered due to increase in human population and associated developmental projects. Activities like hunting, egg stealing and chick capturing have served to decimate the population and restrict the distribution of the subspecies (Meine & Archibald 1996, Archibald *et al.* 2003).

The Australian Sarus Crane (G. a. gilli): *G. a. gilli* occurs entirely in northeast Australia and are thought to number <5000. They are differentiated based on "smaller size, larger and darker ear patches, and more extensively feathered throat". The Australian Sarus Cranes use open wetlands during the wet period and feed in agricultural fields and grasslands during the rest of the year (Meine & Archibald 1996, Archibald *et al.* 2003).

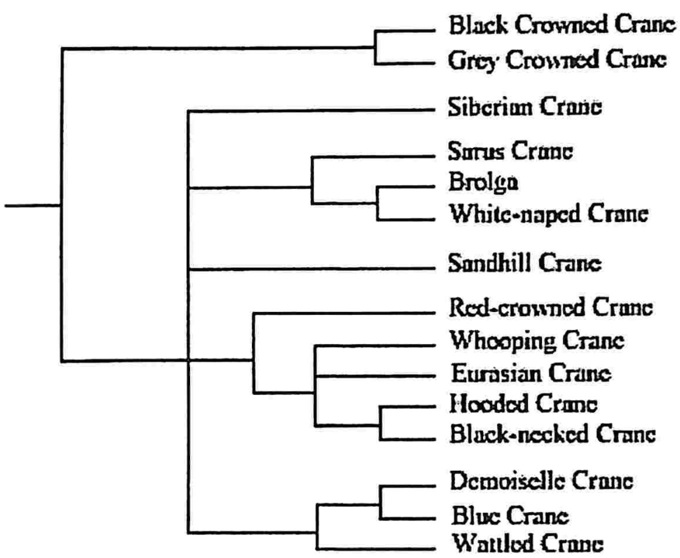
The Indian Sarus Crane (G. a. antigone): is the largest and most abundant of the three subspecies. They prefer open cultivation in well-watered country, marshes, jheels, lakes and large rivers. There has been a recorded reduction in distribution range for the subspecies in India and the population numbers throughout are suspected to be on the decline (Sundar *et al.* 2000a). On the basis of the qualitative evidence accumulated over the past 150 years, it seems entirely plausible to suggest that the global population of the Sarus Crane has diminished to be at best 10% and very probably 5% or even 2.5% of its numbers in 1850. The most up-to-date populations estimates of *G.a. antigone* is estimated to be around 8,000-10,000 individuals and are declining (Sundar *et al.* 2000b, Birdlife International 2001)

The Sarus Cranes that occurred in the Philippines are hypothesised to have belonged to a distinct subspecies, *Grus a. luzonica*, although no taxonomic studies have been undertaken to confirm this (Meine & Archibald 1996).

Apart from the Sarus Crane, the Siberian Crane (*Grus leucogeranus*), Common/ Eurasian Crane (*Grus grus*), Demoiselle Crane (*Anthropoides virgo*), and the Blacknecked Crane (*Grus nigricollis*) are winter visitors to India. Of these, only the Blacknecked Crane breeds within the country. The Whitenaped Crane (*Grus vipio*) was a vagrant in the country in the 19th century (Grimmett *et al.* 1998).

Finding of this study concerns to the nominate subspecies *G. a. antigone* and is henceforth referred to as the 'Sarus Crane'.

DNA Phylogeny of Cranes



Source: http://www.npwrc.usgs.gov/resource/birds/cranes/evol.htm

1.3 Description of Sarus Crane

The Sarus Crane is easily identified as a large, mostly steel-grey Crane with pink to reddish legs standing up to 175 cm (Meine & Archibald 1996). The adults have a naked scarlet head and upper neck, save for an ashy-grey crown. The bill is characteristically large and greenish-grey in colour. In flight, the black primary feathers are distinct against the grey contour feathers. Immatures (juveniles) have a rusty-buff colouring on the head and neck, and the upper parts are marked with brown. Older immatures (subadults) have a dull red head and upper neck and are brownish-grey all over. Sexes cannot be easily differentiated, though some workers have attempted to find characteristics exclusive to the sexes such as in male the lower border of the dark red band round the neck is oblique, where in female the lower border of the red band in horizontal. The bald cap on the head is larger in male than in the female (Gole 1989) & (Desai (1989). The Sarus weighs between 6.8 to 8 kgs (Ali & Ripley 1980, Johnsgard 1983).

1.4 Historical Account

A bird as large as the Sarus Crane has elicited interest right from historical times in India. The beginning of the chapter 2 of the first book of the famous Indian epic Ramayana begins with the author Valmiki's observations of a hunter killing one of a pair of "*kraunca*" (Sarus Crane) and its mate giving a "heart-rendering distress call" (Leslie 1998). For a long time, the identity of the bird was in doubt and different opinions of the identity of the bird ranging from curlews to herons to Cranes have been given in literature. Recent investigations have proven without doubt that the "*kraunca*" was indeed the Sarus Crane (Leslie 1998).

The Emperor Jehangir has recorded some extremely useful and interesting notes concerning the breeding habits of the Sarus, from pairing onwards, to the time the young were hatched. Ali (1927) quotes in detail the methodical documentation by the Emperor on observations of pair-bond maintenance, courting display, mating, nesting and nidification in a couple of Sarus pairs. While the reference in the Ramayana was more romantic and poetic in its being, Jehangir's writings were natural history and behavioural ecology. Subsequently, Buddhist scriptures talk about an incident of a Sarus Crane hunting observed by Gautam Buddha in Lumbini. Sarus have been accurately represented in a painting in the National Museum at Amsterdam (Blaauw 1897). Sarus have been represented in a series of 121 bird paintings by lady Elizabeth Gwillim (1763-1807) housed at McGill University, Canada (Subramanya 1994).

1.5 Distribution of Sarus in India

The Sarus Crane has been recorded to be found all over the northern and central region of the Indian sub-continent historically, including the present day Bangladesh (Gole 1989, Archibald & Meine 1996, Birdlife International 2001). Historical records indicate that their distribution used to extend from the eastern part of the Indus river in Pakistan to the western limits of the state of Assam through West Bengal, and from the Kashmir valley in the north to the west of the Godavari delta in the southern part of the sub-continent (Jerdon 1864, Murray 1890, Ward 1907, Ali & Ripley 1980, Johnsgard 1983, Robert 1991). The Sarus Crane has been seen as high as 3,500 ft. in the Kashmir valley, and in the Dhauladhar range of the lesser Himalayas in Dharmsala (Ward 1907, Hingston 1920). The species was thought to have become extinct as a breeding bird in Pakistan (Roberts 1991) until a nesting pair was recorded in 1997 in Sind district (Claire Mirinde *in litt.*). Few pairs have been repeatedly sighted close to the Indian border in Nagarparker, at the western fringe of the Thar Desert (Ali 1993, Ahmad 1995) and of 7-14 birds from the Rann of Kutch region (Khurshid and Munaf 1994). Sarus is thought to be a casual visitor in the Sindh along the Indo-Pakistan border (A.Khan in litt., 2003).

Outside of India, Nepal is the only other country with.>100 individuals of Sarus Cranes where studies have been conducted on this subspecies. They are present in small numbers, very localized, restricted to five locations, and largely concentrated in the districts of Rupandehi and Kapilvastu with a total population of <150 individuals (Suwal and Shreshtha 1992, Shreshtha 1996).

According to Gole (1996), the fringe areas (areas beyond which the Sarus does not occur) include "Bhandara and Chandrapur district of Maharashtra; Rewa, Chhatarpur and Gwalior in MP; regions east of Allahbhad in UP; Hissar and Panipat in Haryana; Jodhpur in Rajasthan and Surat and Valsad in Gujarat". The subspecies was recorded in the Dibru-Saikhowa Wildlife Sanctuary, Assam recently (Choudhury 1998) and this sighting constituted a range extension for the subspecies by nearly 500 km to the east. Gole (1989) conducted the last countrywide survey to determine the distribution and to assess habitat requirements of Sarus Cranes in parts of north and central India.

These studies, coupled with discussions and observations by other workers (Asad Rahmani *pers. comm.*, Subramaniam *in litt.*, Dave Ferguson *in litt.*) have indicated that the numbers of Sarus has declined sharply and the distribution range of the Sarus has shrunk considerably over the years (Fig 1). Numbers of the Sarus have been monitored in Keoladeo Ghana National Park (KGNP) since 1983 and the trend is one of steady decline from group as large as 258 Sarus Crane to groups numbering only 14 in 2002.

From the distribution range of the Sarus Crane as projected after the 1998-99 countrywide survey by Wildlife Institute of India, it can be seen that major populations are now restricted to a belt comprising of eastern and central Gujarat, southeastern Rajasthan and central and southwestern Uttar Pradesh. The fringe areas (or areas beyond which the Sarus Crane does not occur) can be defined as follows from the survey report of Wildlife Institute of India.

i. Khatua district in Jammu & Kashmir (32°29' N) forms the northern most region where Sarus Cranes are recorded in the country. This is weakly continuous with populations in districts of Himachal Pradesh, such as Kangra.

ii. Sarus Cranes are well distributed in the *terais* of Uttar Pradesh and their northern most limits in the state was recorded to be at Meerut (29°15' N). The eastern most record in Uttar Pradesh was in Mau (83°20' E). Another population, partly discontinuous, to the north comprises the districts of Hisar, Gurgaon, Rohtak and Panipat in Haryana.

iii. Sarus populations were seen in Kutch district of Gujarat (69°34' N). This forms the western most region of Sarus Crane distribution in the country. The western border extends across Rajasthan state covering Jalor, Pali and Jodhpur districts.

iv. Maharashtra is the southernmost state with Sarus Cranes, Chandrapur district (20°12' N) is the southernmost point of Sarus Crane occurrence. This extends to the northeast into Raipur district of Chattisgarh.

v. The eastern most record of Sarus Cranes was from Koochbihar district in West Bengal (89°44' E). This is, however, Choudhury's (1998) record of Sarus Cranes in Assam (95°35' E) which would still form the eastern most occurrence of Sarus Cranes in the country. These sightings are not continuous with the rest of the distribution range as no Sarus Cranes have been sighted in Bihar in recent years.

The range of the Sarus Crane appears to have extended significantly to the north and marginally to the west since Archibald & Meine (1996) (Fig 1). No extensions however, have been recorded in the south. From the 1998-89 survey of Wildlife Institute of India (Sundar *et.al* 1999), no significant difference in distribution was observable except for the few Cranes from West Bengal (Fig. 2). There were, however, significant differences in numbers of Sarus Cranes sighted between the summer and winter seasons (Sundar *et.al.* 2000b). Sarus Cranes are reported to be mostly resident and their distribution range to remain nearly the same throughout the year (Mukherjee 1999, Sundar *et al.* 2000a,b). However In recent surveys conducted in India, both countrywide and local, seasonal migration of Sarus into wet areas from dry areas have been recorded (Choudhury *et al.* 1999, Sundar *et al.* 2000a, Kaur *et al.*2002a).

Fig 1 Shrinkage distribution map of Sarus Crane in India.

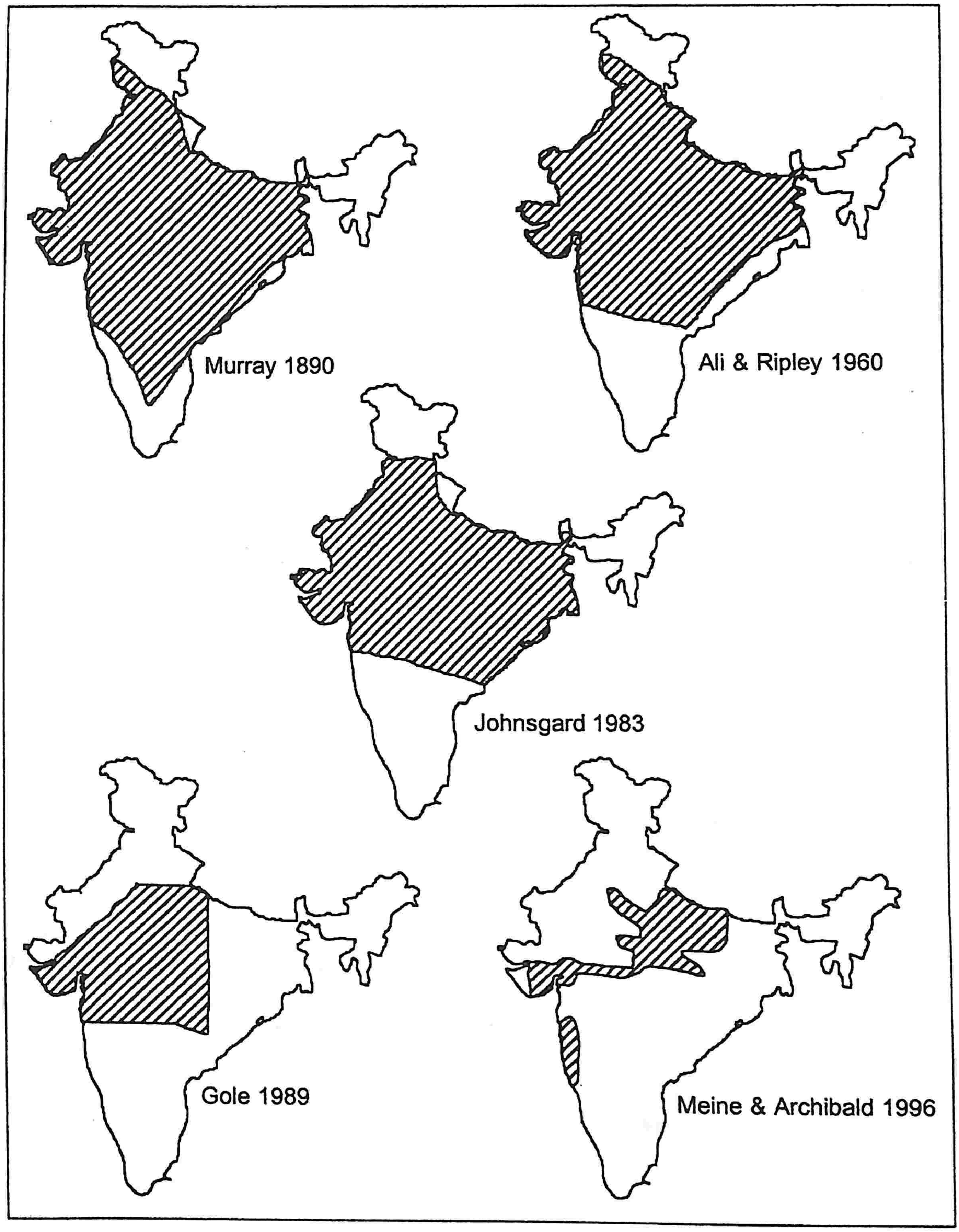
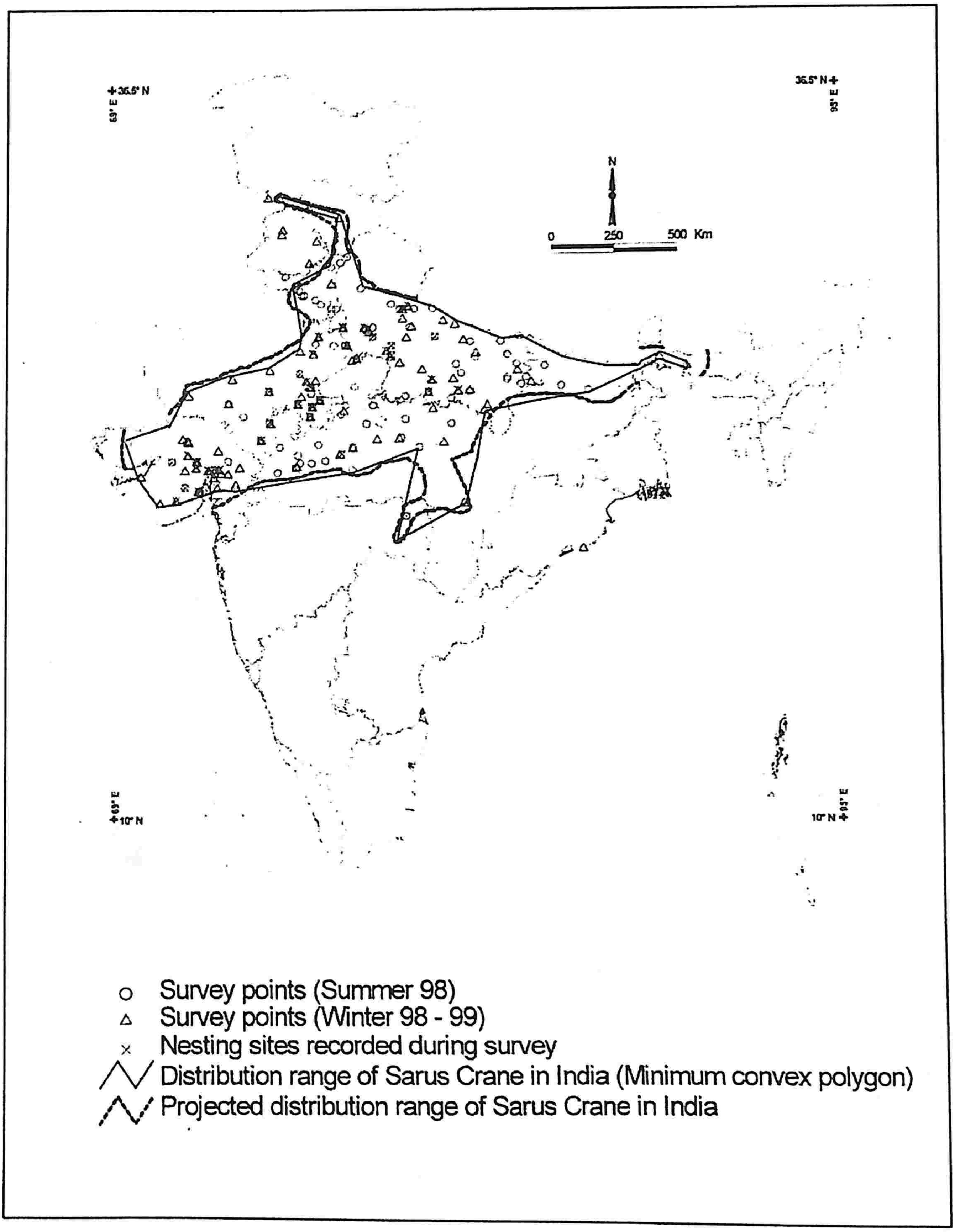


Fig. 2 Map showing distribution range of Sarus Crane (*Grus antigone*) in India.



Source: Sundar *et.al* 1999

1.6 Habitat Description

The Sarus Crane is known to use a wide variety of habitats depending on breeding status, season, food availability and landuse and cropping patterns. They prefer a mosaic of natural wetlands comprising of marshes and ponds even when interspersed with agriculture fields (Gole 1989). They also occasionally use riverbanks and canals for feeding purposes. Breeding pairs typically use larger wetlands wherever available but have been seen to use nearly every type of wetland, natural and manmade (Parashyra *et al.* 1989, Kulshrestha & Vyas 1989, Mukherjee *et al.* 2000, Board *et al.* 2002, Mukherjee *et al.* 2002). Developmental alterations in the landscape in India, however, seem to have led the Sarus to use more agricultural fields than natural wetlands. The Indian agriculture scene has witnessed a rapid change in the cropping patterns over the past 30 years and intensification of the agriculture process has led to a decrease in the number of natural wetlands (Choudhury & Rao 1996). Gole (1989) first noticed this as being significant to Sarus Crane ecology during his survey. From the data collected, it appeared as if the Sarus was partial to paddy fields than to natural marshlands, especially in Uttar Pradesh. This was felt to be an artifact of landscape change rather than a conscious choice on part of the Crane. In Uttar Pradesh, the number of wetlands had declined to give way to paddy fields (Choudhury & Rao 1996, Sundar *et al.* 2000b) and the Sarus has probably remained linked to such altered sub-optimal habitats. They were observed to prefer paddy and wheat fields to other kinds of crop fields. The majority of Sarus Crane sightings during the 1998-1999 all India surveys by the Wildlife Institute of India were made in agricultural fields, particularly rice and wheat, and Cranes tending to avoid soyabean and sugarcane, revealing the importance of man-made habitats (Sundar *et al.* 2000b). In areas with large wetland tracts, Sarus preferred to use more wetlands (Vyas 1999a, Latt 2002), and in areas where agriculture dominated, they used more crops fields. Information on seasonal changes in habitat use is available from Kheda in Gujarat and shows that habitat use varied with season (Mukherjee 1999). There have been no studies on habitat preference of Sarus to date and the present study have focused attention to determine if habitat changes in the landscape has changed the habits of the Sarus, which was previously though to be a wetland specialist.

1.7 Ecology

There have been few studies carried out on the Sarus Crane and little is known about its ecology (Mosse1910, Ali1958, Ali & Ripley1980) provided the first descriptive notes on their distribution and select aspects of their ecology as natural history. In the past couple of decades, there has been a significant increase in interest towards the Sarus and several aspects of their ecology, particularly local abundance patterns and breeding have been documented. The Sarus seems to breed almost throughout the year in places with perennial, freshwater wetlands but seem to show differing periods of nesting at places with dry spells in the year (Gole 1989, Kulshreshta & Vyas 1989, Ladkedkar *et al.* 1989, Parasharya *et al.* 1989, Singh & Khan 1989, Ramachandran & Vijayan 1994, Vyas 1999a, Mukherjee 1999). In areas with dual breeding periods, most of the nesting, and maximum survival of broods, seem to be in the main wet season spreading from July to October when there is enough water and food available. During the breeding season, families maintain well-defined territories ranging from 1 ha in small wetlands to 27 ha in open expanses of suitable habitats (Gole 1989, Ramachandran & Vijayan 1994).

1.8 Protection Status and Threats

The Sarus Crane has suffered a rapid population decline, which is projected to continue, as a result of widespread reductions in the extent and quality of its wetland habitat, exploitation and the effects of pollutants. It therefore qualifies to be a Vulnerable species (Birdlife International 2001).

The Birdlife International Red Data Book, has proposed the Sarus Crane to be placed in the 'Vulnerable' category, (when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future). The Sarus Crane is placed under criteria A1c,d,e; A2c,d,e. by Birdlife International (2001) and the criteria can be defined as follows:

A. *Population reduction in the form of either of the following*

1. An observed, estimated, inferred or suspected reduction of at least 20% over the last 10 years or three generations, whichever is the longer, based on (and specifying) any of the following:

   a. direct observation

   b. an index of abundance appropriate for the taxon

   c decline in area of occupancy, extent of occurrence and/or quality of habitat

   d. actual or potential levels of exploitation \

   e. the effects of introduced taxa, hybridisation, pathogens, pollutants, competitors or parasites.

2. A reduction of at least 20%, projected or suspected to be met within the next ten years or three generations, Whichever is the longer, based on (and specifying) any of (b), (c), (d) or (e) above.

Various International conservation organization and convention such as the IUCN placed Sarus Crane under VUA1Cde+2cde, Cites in Appendix II, and CMS in appendix II. It is protected by the Indian Wildlife (Protection) Act 1972, having been placed under the Schedule IV. While changes in land use and loss of natural wetlands are regarded as the most serious threats to the Sarus, other threats include capture of adult birds for the pet trade and disturbance by farmers in the fields during the nesting period and indiscriminate use of pesticides (Gole 1989, Muralidharan 1992, Meine & Archibald 1996, Parasharya 1989, Thapa & Parihar 1998, Sundar *et.al* 2000a, Mukherjee *et al.* 2000, Birdlife International 2001), mortality due to collision with high-tension electric cables (Sundar & Choudhury 2001), hunting and egg stealing (Kaur & Choudhury 2003b), are reported to recent addition to the range of threats.

1.9 Review of Literature

Most of the studies conducted in India on the Sarus Crane are either status surveys or site specific short ecological studies. The first reference to deterioration of wetland habitat and how this may affect the Sarus and other wetland birds in India occurred in the late nineteenth century (Reid 1881). His words, which describe the drought of 1877-78 in the Lucknow division in Uttar Pradesh, are worth quoting here: "There are still, fortunately, many of these natural reservoirs where birds are plentiful in the (winter) season, but if the cultivation of the singhara nut (water chestnut) becomes as general as it is now in certain localities, a diminution in the number and variety of their aquatic tenants will assuredly follow". After a century, the first thesis on the Sarus Crane in India was produced which was based on observations of a single captive bird (Desai 1980).

Conservation-oriented Crane studies began in earnest after the global review of Cranes (Archibald *et al.* 1981). Very little sustained research was carried out on Sarus Cranes until the 1980's. Parasharya *et al.* (1986) conducted the first field investigation using ecological methods and explored the extent of damage Sarus Cranes caused in paddy crops in Gujarat, and estimation of damage to paddy crop by Sarus Cranes show that they can be responsible for losses of 0.2-13.6% of the produce in fields due to trampling and eating of ripened grain, and up to 26% of grain can be eaten by Cranes (Board *et al.* 2001b) in a season.

Singh & Khan (1989) worked on the status of Sarus Cranes in Lakhimpur-Kheri districts of Uttar Pradesh and according to the authors; it is predominantly a bird of the wetlands in Terai, where availability of food safety plays an important role in its distribution, which varies seasonally. Saxena (1990) reported that in Madhav National Park in Central India Plataeu, cattle grazing is one of the major destructive factors to their breeding grounds. Kulshrestha and Vyas (1989) studied the status and biology of the Sarus Crane along irrigation canals and lakes of Kota district in the arid landscape of Rajasthan and observed two distinct breeding season's i.e., February–April and July-October and found that the Sarus cranes preferred to stay close to agricultural fields and marshy land for roosting and feeding. Parashyra *et al.* (1989) found that the good canal irrigation, large reservoirs and extensive paddy fields are the major factor responsible for the higher concentration of Sarus Crane in Kheda district in Gujarat state. He also surmised that Sarus Crane breed throughout the years (except in May and June, with a peak in July-September), moving locally and utilizing a wide variety of habitat types depending upon food availability, cropping patterns and other seasonal factors. Gole (1989) recorded that the breeding pairs use larger wetlands where available, but are typically scattered across the landscape nesting in fields, along canals and irrigation ditches, besides village ponds and in shallow marshes, rice paddies, jheels and reed beds. Ladkhedkar *et al.* (1989) surveyed Cranes in Vidarbha region of Maharashtra and reported up to 35 Sarus Cranes to inhabit the area around Navegaon bandh lake in 1977 which decreased to five birds in 1989. Iqubal (1992) studied breeding biology of a pair of Sarus Crane in the Aligarh Muslim University Campus.

Ramachandran and Vijayan (1994) publication on the distribution and general ecology of Sarus Cranes in Keoladeo National Park, report that the Sarus population remained constant inside the park during their study period of 1984-85, except spring and summer, where population went up to 250. They attribute this increase to the adjacent water bodies drying up, and Cranes from these places moving into the park. They also observed a main breeding season, from August to October, and a sub-season from February to March. Considering all anecdotal accounts, bimodal nesting in Sarus Crane was widely prevalent even before the 1940s, with records of nesting during the minor season Mahikantha in Gujarat (O'Brein 1909), from Sagar district Madhya Pradesh (King 1911), as well. Previous authors have suggested that the nests in the smaller post-winter season are by pairs with egg/chick loss during the regular breeding season.

Vyas (1999a) studied the Sarus Crane in Rajasthan mainly to determine their status in south, south-east and eastern districts of the state and to obtain information on the habitat and breeding areas. Vyas (1999b) determined the breeding success and chick mortality in Sarus Crane and the study showed that the period of his study at Kota, nesting success had declined drastically particularly in 1992 as compared to 1988-92. Increased human, population, movement and loss of suitable breeding grounds are the main causes for the breeding failure.

Singh & Tatu (2000) conducted a study on Indian Sarus Crane (*Grus antigone*) in Gujarat state, and they estimated a total of 1729 individuals of Indian Sarus Crane in the state. Of these 1456 (84%) Cranes were recorded in about 409 villages of 16 talukas of just two districts, namely Kheda and Ahmedabad. Remaining 273 Sarus were reported from other districts. According to them the nesting is traditionally known to start by July, noticeable numbers of nests were found only in late August in Ahmedabad district and good numbers of nest were found only in September in Kheda district. The species is facing the risks like habitat destruction, degradation due to spreading of residential/ commercial complexes in originally agricultural areas and pollution by the industrial units. The first major thesis on Sarus Cranes included multiple aspects of the Sarus biology with intensive field observation in Gujarat in India (Mukherjee 1999).

Concerned at the recent reduction in the population and distribution range of the Indian Sarus Crane (*Grus antigone*), the Wildlife Institute of India (WII) initiated a research project in March 1998, to look at the "Impact of land use changes on the habitat and ecology of the Indian Sarus Crane (*Grus antigone*) in the Indo-Gangetic flood plains, in India," the major objective of the project was to determine the ecological requirements of the Sarus Crane. The project have a completed national survey and determine the present range of distribution, the demographic characteristics of the Sarus population, district-level abundance and encounter rates in various districts in 11 states of India. The results of the survey have been compiled into a report and published as a scientific paper (Sundar *et al.*1999, Sundar *et al.* 2000a). Preliminary field observations of this project have been communicated in popular science articles (Sundar 2001, 2002a,b, Kaur and Choudhury 2002). Another key feature of the project was the first coordinated all-India Sarus Crane Count, which helped to bring interested people together on a common platform that paved the way for a long-term monitoring programme (Choudhury *et al.* 1999, Sundar *et al.* 2000a, Kaur *et al.* 2002).

Pre-nesting mating behaviour has been described by Mukherjee (2002). For nesting, Sarus Crane use the material immediately around the nest site piling vegetation into a roughly round heap of vegetation surrounded by a narrow moat (Lowther 1944, Breeden and Breeden 1982, Gole 1987, Ramachandran and Vijayan 1994, Mukherjee 1999). In a mosaic landscape, the Sarus prefer natural wetlands as nesting habitats, though they are known to use flooded paddy fields extensively for nesting (Mukherjee *et al.* 2000, Board *et al.* 2001a). Sarus built nests at an average of 410m away from houses in Nepal Terai (Suwal 1999). Sundar and Choudhury (2003) recorded that Sarus Cranes are known to keep their nests clean of fecal matter during incubation, and of egg shells post-hatching. There is growing amount of literature on breeding biology in general, but few that relate landscape quality to breeding density and success. Very little published information is available on chick mortality. A possible case of cannibalism is reported, but the author was uncertain if it was an adult scavenging on a dead chick (Xavier 1995). Chick mortality was the most during the pre-fledged stage (Vyas 1999b). Predation is considered to be largely on eggs by crows as documented by (Ramachandran and Vijayan (1994) and possibly by jackals (Mukherjee *et al.*2002). Stealing of eggs for various purposes were observed during the present study in Kota district of Rajasthan (Kaur & Choudhury 2003b). An instance of a young chick taken by marsh herriers is also known (Kaur & Choudhury 2005).

Movement and social structure of Sarus Crane were studied by various authors and regular daily movements to and from wetland roost sites recorded (Walkinshaw 1973, Ramachandran &Vijayan 1994). During surveys, Sarus are characteristically seen as pairs or families, and few flocks (Gole 1991a,b, Vyas 1999a,b, Sundar *et al.* 2000b). Seasonally Cranes seem to flock away from nesting territories in wet and moist reservoirs (Mukherjee 1999). The biggest flocks occur during the dry years or months in Rajasthan and Gujarat (Breeden and Breeden 1982, Banerjee and Gopakumar 1986, Mukherjee 1999), while some areas in Uttar Pradesh are known to have more regular flocks (Sundar 2003) suggesting stable water conditions.

The information on territoriality was studied in Keoladeo Park, Rajasthan and has provided information on observing unmarked birds, and their estimates of territory size vary from 0.68-1km^2 within park and 1.5-2.7km^2 in areas outside protected areas in Nepal and India (Suwal 1999, Gole 1989, Gole 1990, Ramachandran and Vijayan 1994). The present study obtained information using marked birds in area.

Field observations suggest that the Sarus is omnivorous (Hume and Marshal 1879, Walkinshaw 1973, Ghorpade 1975, Johnsgard 1983, Birdlife Inernational 2001). The uplands food including paddy (Parasharya *et al.* 1986, Board *et al.* 2001b, potatoes, peas, a variety of gram, and insects (Mukherjee 1999). Sarus Crane occasionally take eggs of birds including water birds (Mukherjee 1999, Sundar 2000, Roland 2002), and though Sarus Cranes take fish in captivity (Law 1930), it is also observed in wild (J, Kaur personal observation).

An initial effort at educating and awarding farmers who protected Sarus Cranes nests has also been carried successfully in Kota district of Rajasthan (Kaur & Choudhury 2003a & Kaur *et al.* 2005).

1.10 Objectives

1. To determine extent of changes in land-use pattern in the two study areas over the past 20 years using satellite imageries (with five-year intervals).

2. To obtain data and compare habitat use by Sarus Cranes in the study sites.

3. To study the breeding biology of Sarus Crane by investigating the bi-annual nesting peaks in natural wetlands and man-induced wetlands (over flow of canals).

4. To determine the changes in behavioural ecology of the Sarus Crane between the two areas.

5. To suggest strategies for enabling long-term survival of Sarus Crane in the study area.

1.11 Organization of the thesis

The present thesis is organized into eight chapters that include the first three introductory sections followed by five main chapters:

Chapter 1, as being read, introduces the distribution of Sarus Crane in India and past and present distribution range of Sarus Crane. Presents a brief account of the past studies on Sarus Cranes. Chapter 2. contains an examination of the former and present distribution range have been made to obtain an insight into the factors that may have helped the Sarus Cranes to survive in some characteristic type of geomorphological, climatological and vegetation zone in its present strong hold from its historical distribution range.

Chapter 3 contains a concise description of the physiography of the arid zone and the Indo-Gangetic Plain in India and Sarus distribution and abundance. The study area, with notes on geography, climate. Sarus Crane in Rajasthan with relation to study sites and detailed description of both study sites in Kota and Bharatpur. In Chapter 4, I investigated the habitat use pattern of Sarus Crane in semi-arid landscape and home range of breeding pairs with juveniles was carried out. This chapter also deals with the way the Sarus cranes use habitat resources available to them. Chapter 5 examines the_dual nesting pattern of Sarus Crane in study area, synchronizing with the man-induced flooding of landscape through canal induced waters in semi-arid zones. Besides this, the differential level of threats to nesting Sarus Cranes. Chapter 6 contains the ethogram and activity budget of Sarus Crane in the semi-arid landscape. Chapter 7 examines the land use changes, by mapping the land cover in the study area relevant to Sarus Crane and compared with past years to evaluate the degree of change. Chapter 8 deals with the conservation strategies for the long-term survival of Sarus Crane in semi-arid landscape.

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CHAPTER 2

Factors that govern the former and present distribution and abundance of Sarus Crane in India with special reference to the semi-arid regions

2.1 Introduction

The distribution of Sarus, the tallest–terrestrial bird, both historical and present is not linked to the forested habitat but into the plains. An examination of its former distribution and abundance clearly shows that though the Sarus is the tallest flying terrestrial bird, it has not found the canopy covered forested landscape an ideal habitat. The habitat mosaics of grassland and low height agricultural croplands, interspersed with natural wetlands are the present habitat of the Sarus (Gole 1989, Birdlife International 2001). Its, present distribution range extending from Jammu in the north, through Nepal, to Chandrapur in Maharashtra in the south, from Gujarat in the west to Assam in the east (Sundar *et al.* 2000ab, Birdlife International 2001) is also largely grassland, cropland dominated plains. Its well being, distribution and abundance are largely, therefore, appears to have been governed by the extent and availability of suitable plain habitats at any given point of time. The only other requirement in such plains appears to be wetlands with some enough water for certain period of the year. Variation in precipitation in any given geographic area, and thus, availability of water in wetlands in such areas is also known to trigger local migration of Sarus into relatively water rich areas (Parasharya *et al.*1989, Mukherjee 1999). Anthropogenic means of creating temporary water rich areas also seems to have favoured Sarus; however "sub optimal" such "created" habitats may be. An example of this is in the Kheda district of Gujarat where anthropogenic means of water availability has favoured Sarus (Mukherjee 1999). In human altered water regimes, particularly in the arid and semi-arid zone, the species appears to have adapted to a dual nesting season synchronizing the second breeding season to availability of water, while this may be an adaptation for a "better Survival strategy", large scale conversion of land use and changing agricultural cropping patterns and availability of "optimal habitat" for Sarus is considered to be a major factor for the gradual decline of Sarus cranes in India.

The present distributions of Sarus crane are influenced by the changing agricultural patterns and hydrological intervention which affects its biology and therefore its distribution. The conversion of wetland to agricultural use, a factor which reduces the number and extents of sites suitable for feeding and breeding and now their distribution is restricted to portion of northwestern India and the terai lowlands of Nepal (Johnsgard 1983). The north-western India region being a semi-arid region it is important to examine how Sarus Crane had adapted to this region, where the species has a synchronized life cycle in water-rich Gangetic plains.

In this chapter an examination of the former and present distribution range have been made to obtain an insight into the factors that may have helped the Sarus Cranes to survive in some characteristic type of geomorphological, climatological and vegetation zone in its present strong hold from its historical distribution range.

2.2 Methodology

To this end, the former distribution range maps of Sarus Crane from the year 1890 to 1990 have been superimposed on forest and vegetation biogeographic zone, and agro-climatic zone and agricultural cropping pattern maps of India. Based on such overlapping as well as examining the current stronghold and abundance maps of Sarus Crane, at different times an attempt has been made to find out the factors that has governed the former and present distribution and abundance of Sarus and how the factors that may have helped Sarus distribution in the semi-arid zones of India which is the focus of the present study.

2.3 Forest and Vegetation type and distribution of Sarus Crane

Champion and Seth (1968) classified the natural vegetation of India into sixteen forest types (Table1) and by overlapping the distribution map of Sarus Crane generated by (Murray 1890, Fig 1, Ali and Ripley 1960, Fig 2 and Sundar *et al.* 1999, Fig3) reveal that though Sarus were largely distributed over much of India, from Assam and Manipur in the east, through the Gangetic plains into the arid and the semi-arid regions of the Deccan plateau in central India and perhaps as far south as Andhra Pradesh, much of its occurrence are from the valley, flood plain and lowland areas. The former wide distribution of Sarus Crane appears to have been influenced by the climatic factors (Precipitation and Temperature zones) combined with the natural vegetation (*i.e* lowland forest and grassland types).

The Sarus Crane has been recorded in non forested regions as high as 3,500ft, in the Kashmir valley, and in the Dhauladhar range of the lesser Himalayas in Dharmsala (Ward 1907, Hingston 1920). Though Sarus is a cold hardy species, the distribution of Sarus Crane is not reported from the high altitude regions due to the climatic factors which are not suitable for the species. The present distribution of the species is largely in areas where a pronounced precipitation followed by mild to briefly severe winter exists. In peninsular India, the distribution of Sarus Crane is not well established due to non-availability of water for the twelve months where wetlands are largely dependent on the natural precipitation .The factor that dominates both directly and indirectly the entire ecology of the Peninsular India is, however, also is the massive disappearance of the all natural habitats brought about by alteration of natural vegetation by man (Mani 1974), which may also have influenced the former distribution of Sarus to its present distribution.

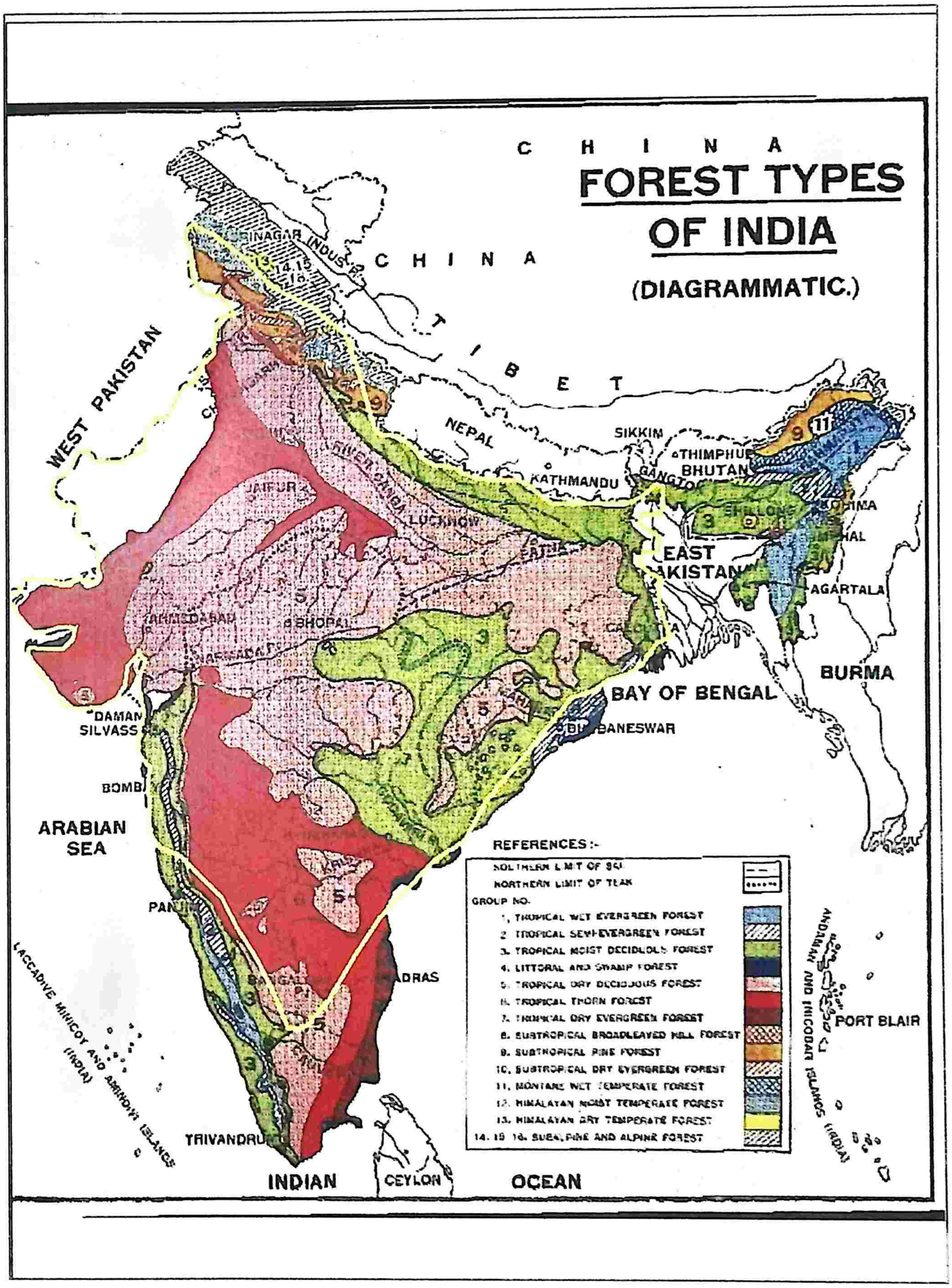
An examination of the former and present distribution and abundance of Sarus Crane on forest and natural vegetation exhibits its affinity largely with tropical dry deciduous and tropical thorn scrub vegetation to valley grassland systems supporting regions. Much of our present day riverine flood plains and/or lowland mountains valleys supported either of these two types of vegetation before being converted into intense agricultural areas. The natural scrub-thorn vegetation and grasslands were always considered as low productive areas and were the targets for conversion. The present day occurrence of Sarus Crane in last remains of scrub-thorn vegetation, and natural grassland areas of Gujarat (Singh 2000) and Rajasthan (Vyas 1999a.) and the ravines of Central India (Sundar *et al.* 2000a) is clearly indicative of the preference of Sarus in to such non-canopy forest and natural grassland where seeds, tubers and occasional insects are plentiful to feed on.

The absence of Sarus in the very moist regions of Western Ghat, North-eastern hills and Alpine cold high altitude regions show that Sarus is a species that does not necessary prefers areas where it is cold and wet. Table 1 and Fig 1, 2 & 3 supports the above mentioned explanation of Sarus distribution and natural vegetation types.

Table 1 **Champion and Seth classification (1968) and distribution of Sarus Crane in India.**

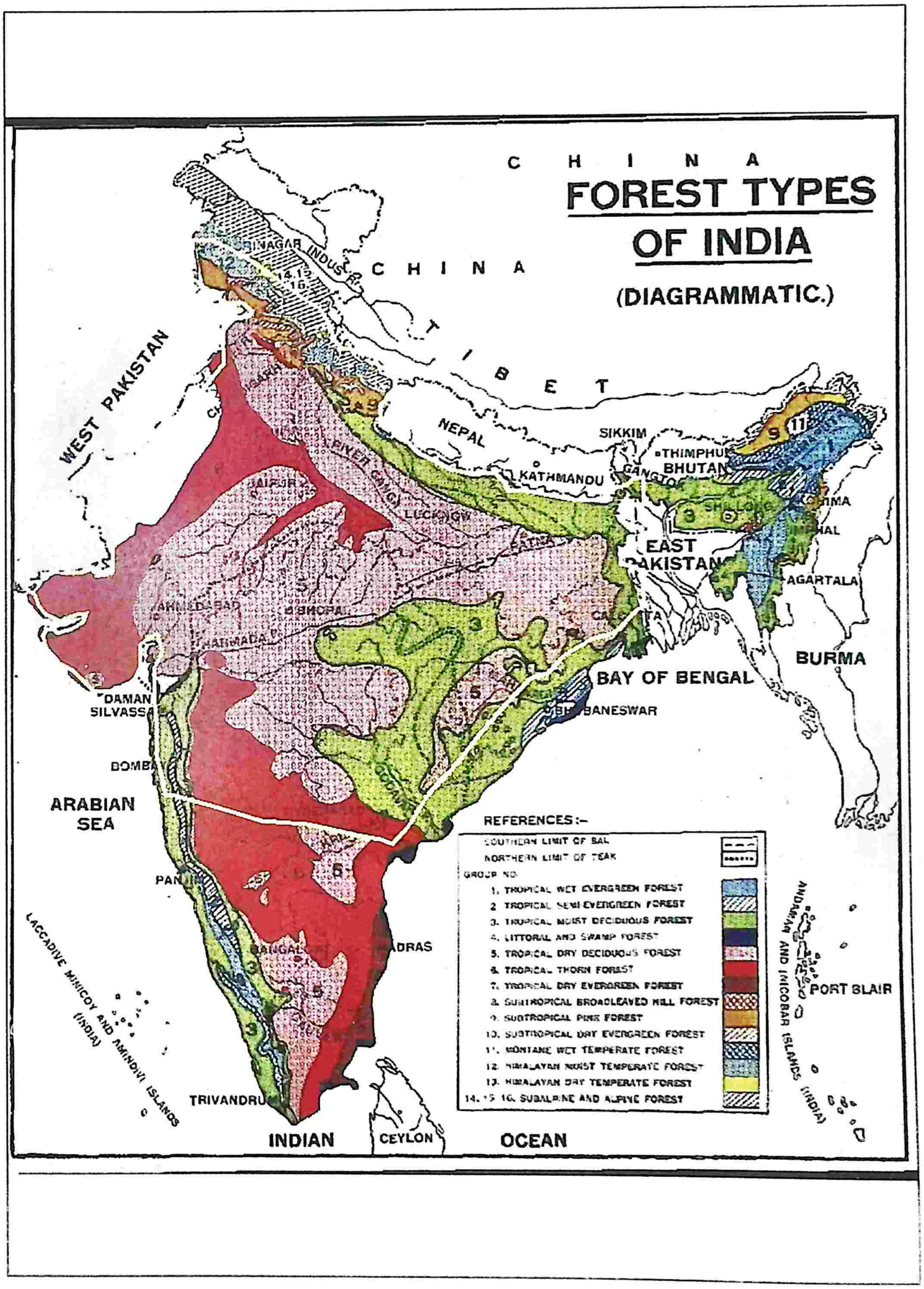
Forest Types of India	Sarus Distribution
1. Tropical Wet Evergreen Forest	Rare
2. Tropical Semi-Evergreen Forest	Rare
3. Tropical Moist Deciduous Forest	Rare
4. Littoral and Swamp Forest	Not Present
5. Tropical Dry Deciduous Forest	Abundant
6. Tropical Thorn Forest	Common
7. Tropical Dry Evergreen Forest	Not Present
8. Subtropical Broadleaved Hill Forest	Not Present
9. Subtropical Pine Forest	Not Present
10. Subtropical Dry evergreen Forest	Not Present
11. Montane Wet Temperate Forest	Not Present
12. Himalayan Moist Temperate Forest	Rare
13. Himalayan Dry Temperate Forest	Not Present
14. Sub-alpine and Alpine Forest	Rare
15. Sub-alpine and Alpine Forest	Rare
16. Sub-alpine and Alpine Forest	Rare

Fig 1 Map showing the forest types and Sarus Crane distribution in India



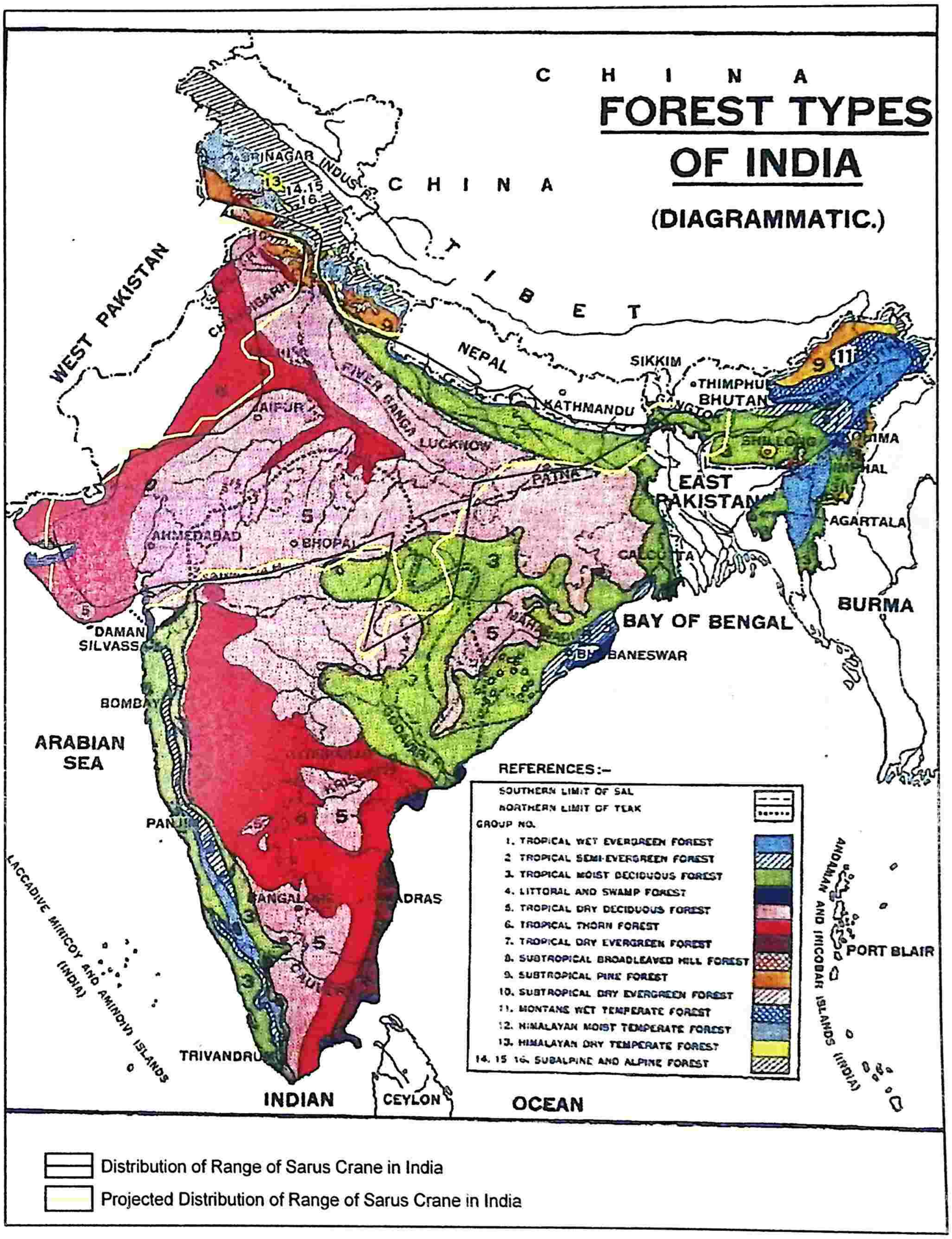
Source: Champion &Seth 1968 and Sarus Crane distribution range : by Murray 1890.

Fig 2 Map showing the forest types and distribution of Sarus Crane in India.



Source: Champion and Seth 1968 and distribution range of Sarus: (Ali and Ripley 1960).

Fig 3 Map showing the forest types and distribution of Sarus Crane in India.



Source: Sundar *et al.* 1999

2.4 Biogeographic Classification of India and Sarus Distribution:

Rodgers & Panwar (1988) has divided India into 10 biogeographic zones and further 26 provinces. The biogeographic zones are large distinctive units of similar ecology, biome representation, community and species e.g. the Himalaya, the Western Ghats. The biotic province are secondary units within a zone, giving weight to particular communities separated by dispersal barriers or gradual change in environmental factors e.g. North West and West Himalaya on either side of the Sutlej River. The examination of the historical and current distribution range of Sarus with the biogeographic map of India reveals that the Sarus occurres largely in the non hilly valleys, open plains and riverine flood plains of India and restricted to the biogeographic zone of the Gangetic plain, the semi arid zone, the Indian desert and the foot hills of the Himalayas.

The distribution of Sarus Cranes according to the biogeographic zone of India show that Sarus is mainly restricted to the Palaeotropical, African and Palaeotropical, Indo-Malayan zone. In the desert zone there are distinctive but xerophytic plant associations and communities and the presence of Sarus Crane is a rare occurrence in such region except in the Kutch Peninsula. The great Rann and the little Rann of Kutch forms a distinctive biogeographic province 3A, where the Sarus is not reported significantly. The Thar Desert is the more typical sand dune system of western Rajasthan and the earlier reports shows the presence of Sarus Crane was rare in western fringe of the Thar Desert (Ali 1993, Ahmad 1995).

The Semi-arid Zone has two provinces of Punjab and Gujarat Rajwara. The Punjab plains include Punjab, Haryana, Delhi, fringe of J&K, H.P., part of Bharatpur and western edge of Uttar Pradesh and this area is originally an arid area, where intensive irrigation has lead to settlement and cultivation and perhaps irrigation water supporting Sarus Crane. The Gujarart-Rajwara province includes East Rajasthan, East Gujarat and North-west Madhya Pradesh and they have fairly good wetlands, mainly man made reservoirs, marshes and rivers. The occurrence of Sarus Crane is common in this Zone.

The Gangetic Plains are one of the most fertile areas in the world and supports a dense and still growing human population. Most original vegetation in this zone has been converted into cropland, which once supported rich grassland/wetland complexes remnants of which are seen in the Terai region that supported a good population of Sarus till recently (Sundar *et al.* 1999).

The Gangetic plains and the semi arid zone of India are the regions with large river valleys and encompass the great flood plains of Ganges basin and part of the Indus basin (See Fig 1, in Chapter 3). Natural grassland and wetland complexes in this region had supported the Sarus in historical time and evidences of this are available in literature and writings of Mughal rulers. Interestingly, much of the India's early irrigation network development was also in this zone. The semi arid tract of Punjab, Haryana, Eastern Gujarat and Rajasthan along with the Gangetic plains is the grannery food bowl of India. Availability of forage and water has made these two zones favourable for the Sarus. The foothills of Himalayas with abundant water and the Eastern Brahmaputra floodplains also historically reported to support the Sarus, when conversion of natural wetlands have been responsible for decline of Sarus. The Table 2&3 and Fig 4 explain the historical and current distribution pattern of the Sarus in the Bio-geographic zones and provinces of India.

Table 2 Sarus Distribution in different Biogeographic Zone of India

Biogreographic Zone and Provinces	Historical Occurrence of Sarus	Current Occurrence of Sarus	Remarks*
1. Trans-Himalaya with 2 Provinces	Not Present	Rare	In Jammu & Kashmir Sarus is present close to the Indo-Pakistan Border (Sunder *et al.* 2000ab)
2. The Himalaya with 4 provinces	Rare	Rare	Sarus have been seen regularly at Pong Dam near Dharamsala, lower Himalayas and areas of Himachal Pradesh (Hingston 1920, Singh 2003)
3. The Indian Desert with 2 provinces	Rare	Rare	Present in western fringe of the Thar desert (Ali 1993, Ahmad 1995), Rann of Kutch (Khurshid and Munaf 1994)
4. The Semi-Arid Zone with 2 provinces	Common	Common	In Rajasthan Sarus is rare in drier western portions of the state, but locally common in eastern part. Largely confined to northern region of the Gujarat State.
5. The Western Ghats with 2 provinces	Not Present	Not Present	No records of Sarus Crane in this Zone.
6. The Deccan Peninsula with 5 provinces	Rare	Rare	Symons (1909) recorded Sarus from Bombay Area, near Bandra. Record in Maharashtra are from the eastern district of Chandrapur. Sarus never occurred so far in South (Andhra Pradesh) (Whistler & Kinnear 1931-37). Orissa only record from Sambalpur, North of Mahandi (Ball 1878)
7. The Gangetic Plain with 2 provinces	Abundant	Abundant	Most Sarus are concentrated in the western fringe of the Gangetic flood plains continuing westwards into Rajasthan and Gujarat.
8. The Coast with 3 provinces	Not Present	Not Present	No record of Sarus Crane from this Zone.
9. North East India with 2 provinces	Rare	Rare	Sarus crane is a rare and occasional visitor to Assam (Baker 1899, Choudhury 1998, 2002). Manipur thought to hold populations previously, but recent survey and counts indicate uncertain reports (Sunder *et al.* 2000b).
10. The Islands with 2 provinces	Not Present	Not Present	No record of Saurs Crane from this region.

- Rare = Few individuals, Common = >1000, Abundant = >3000
- Sarus is abundant only in the Gangetic plains, common in the semi-arid tracts of north-western, western, north and central Indian province and Rare in the Himalayan, Deccan and is not found in the cost, island, Western Ghat and the upper Himalayas.

* Text taken from Birdlife International 2001

Table 3 Distribution of Sarus Crane in Biotic Province in India

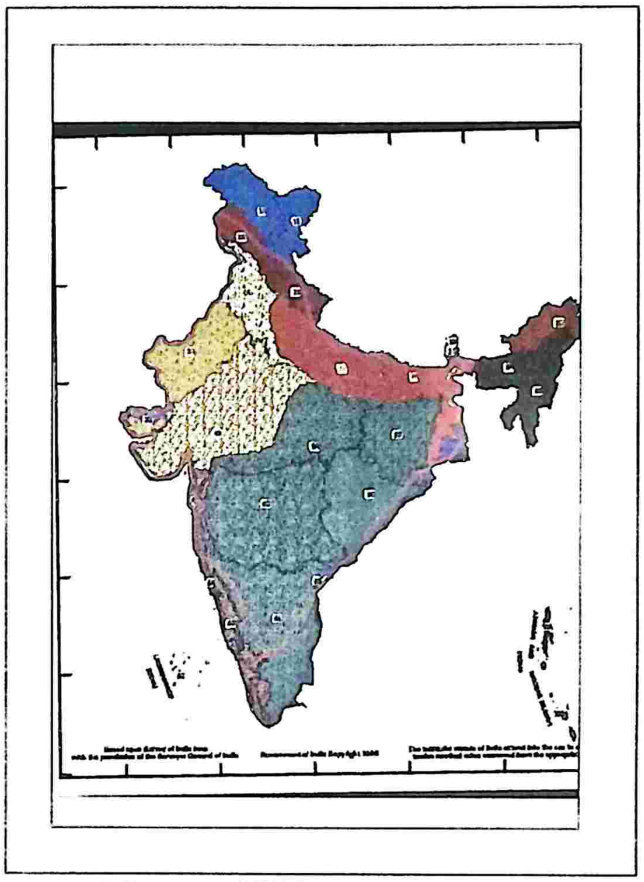
Biogeographic Zone	Biotic Province	Sarus Crane Distribution
A. Palaeoarctic		
1. Trans-Himalayan (Tibetan)	a. Ladakh 1A	Not present
2. Himalayan	a. N.W. Himalaya 2A	Rare
	b. W. Himalaya 2B	Not Present
	c. Central Himalaya 2C	Not present
	d. East Himalaya 2 D	Not Present
B. Palaeotropical: African		
3. Desert	a. Kutch 3A	Rarely present in Rann of Kutch (Khurshid and Munaf 1994)
	b. Thar 3B	Rarely present in western fringe of the Thar desert (Ali 1993, Ahmad 1995)
4. Semi Arid	a. Punjab 4 A	Common
	b. Gujarat Rajwara 4B	Common
C. Palaeotropical: Indo-Malayan		
5. Western Ghats	a. Malabar Coast 5A	Not Present
	b. Western Ghat Mountain 5B	Not Present
6. Deccan Peninsula	a. Deccan Plateau South 6A	Not Present
	b. Central Plateau 6B	Symons (1909) recorded Sarus from Bombay area, near Bandra. Records in Maharashtra are from the eastern district of Chandrapur. Sarus never occurred so far in South (Andhra Pradesh) (Whistler & Kinnear 1931-37) Rare
	c. Eastern Plateau 6C	Rare Orissa only record from Sambalpur (north of Mahandi) (Ball 1978)
	d. Chhota Nagpur 6D	Rare

	e. Central Highlands 6E	Rare
7. Gangetic Plain	a. Upper Gangetic Plain 7A	Abundant
	b. Lower Gangetic Plain 7B	Abundant
8. North-East India	a. Brahmaputra Valley 8A	Sarus Crane is a rare and occasional visitor to Assam (Baker 1899, Choudhury 1998, 2002)
	b. Assam Hills 8B	Manipur thought to hold populations previously, but recent survey and counts indicate uncertain reports (Sunder *etal.* 2000b).
9. Islands	a. Andaman Islands 9A	No record of Sarus Crane from this Zone
	b. Nicobar Islands 9B	No record of Sarus Crane from this Zone
	c. Lakshadweep 9C	No record of Sarus Crane from this Zone
10. Coasts	a. West Coast 10A	No record of Sarus Crane from this Zone
	b. East Coast 10B	No record of Sarus Crane are from this Zone

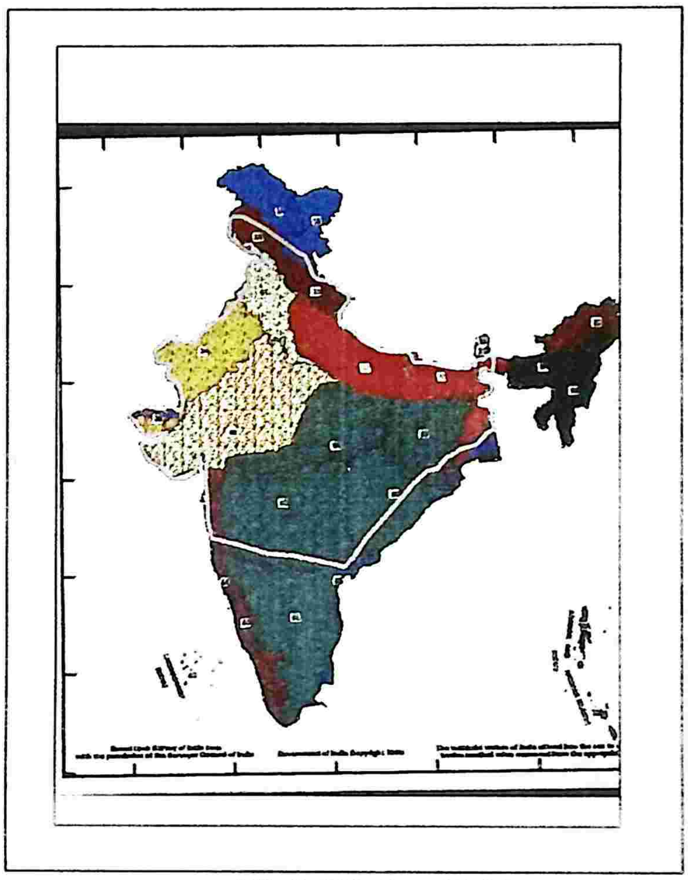
Rare = Few individuals, Common = >1000; Abundant = >3000

Out of the 26 provinces, Sarus is abundant only in 2 provinces, common in 2 provinces and rarely seen in seven provinces and absent in 15 provinces of India.

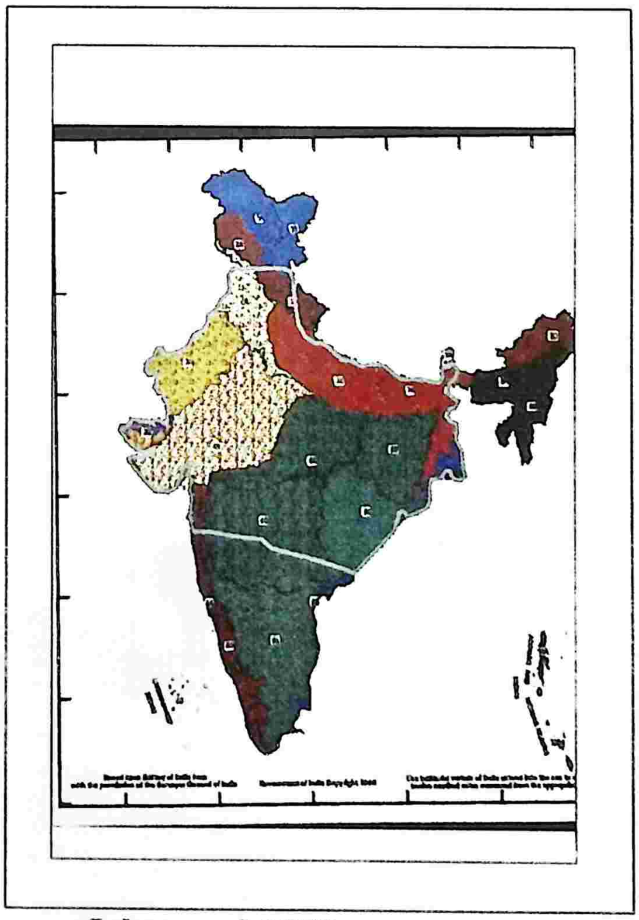
Fig 4 Historical and present distribution of Sarus Crane in the various biogeographic zones of India.



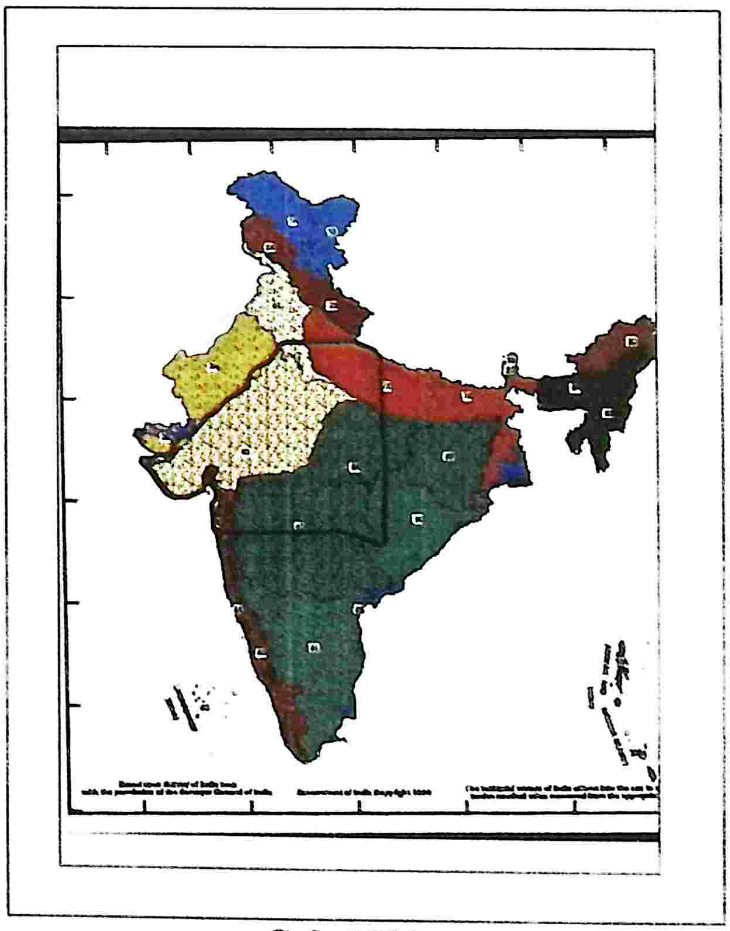
Murray 1890



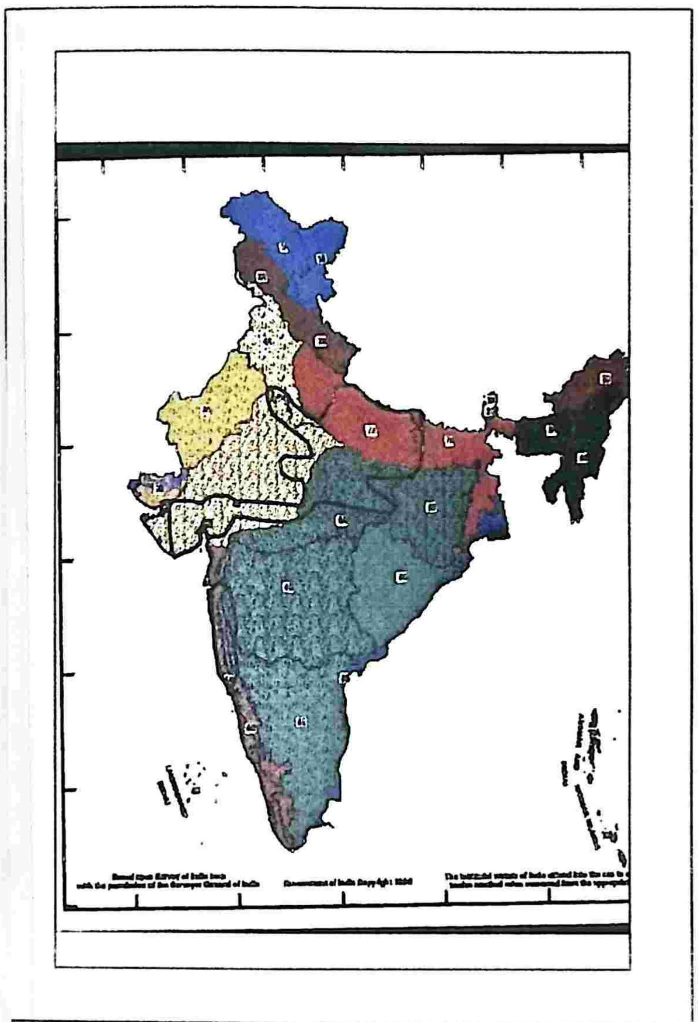
Ali & Ripley 1960



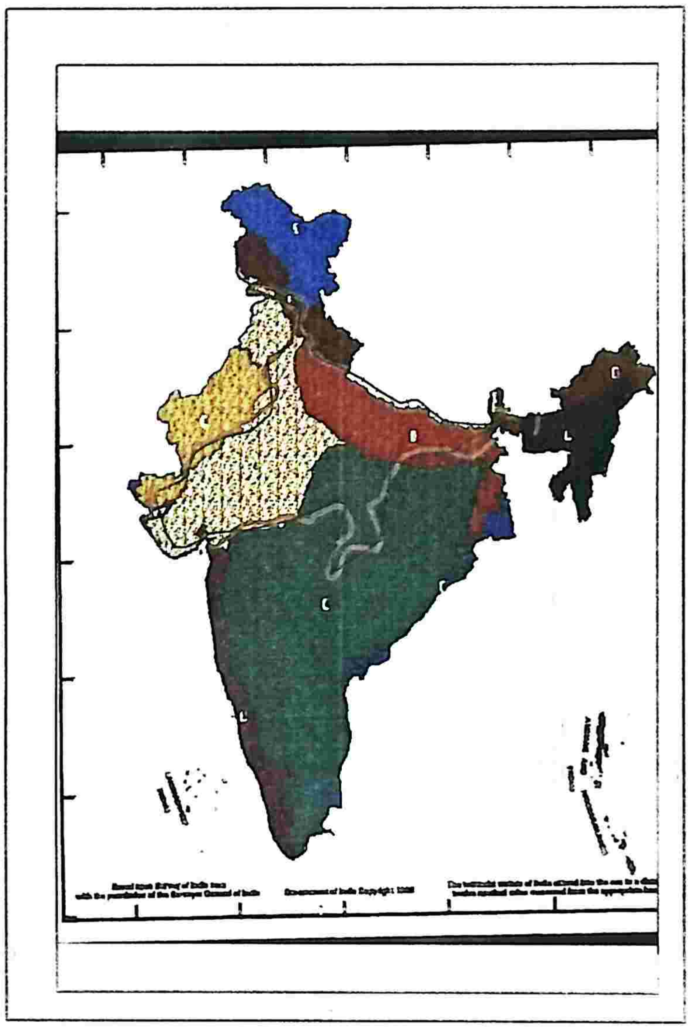
Johnsgard 1983



Gole 1989



Meine & Archibald 1996



Sundar *et al.* 1999

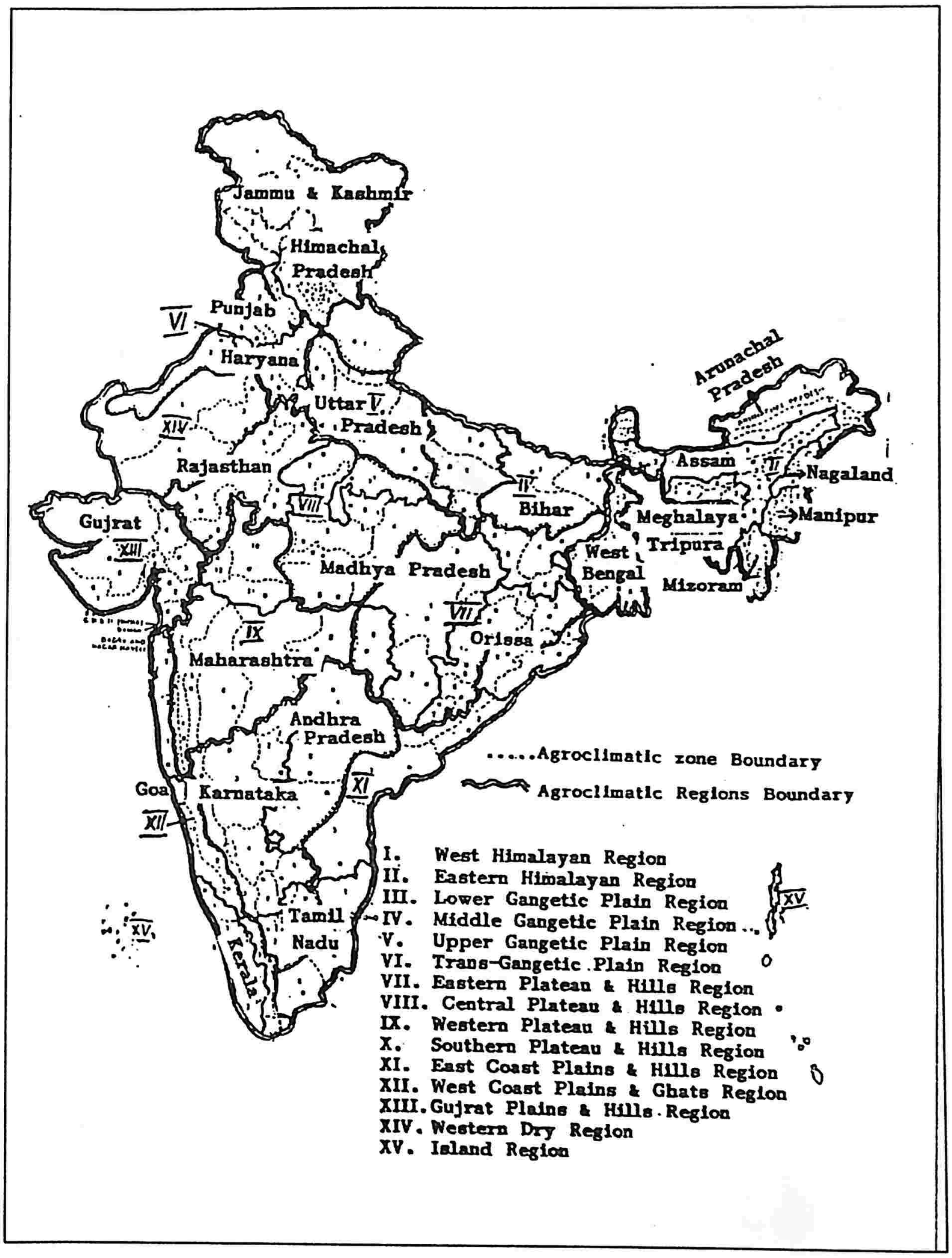
2.5 Agro-Climatic and Agro-ecological Zones and distribution of Sarus Crane in India

The Food & Agriculture Organization (FAO) has recognized 14 major climatic and agro climatic zones. The land units are defined in terms of major climate and growing period, and their suitability for certain range of crops and cultivars. The Planning Commission of India in 1989 has identified 15 resource development regions in the country, 14 of which are in the mainland and the remaining one in the islands of Bay of Bengal and the Arabian Sea (Ghosh 1991) (Fig 5). The National Bureau of Soil Survey and Land Use Planning, of the ICAR, has also attempted to delineate agro-ecological zones in India with the concept that an agro-ecological zone is super imposed on physiography and the kinds of soil and soil conditions that act as modifiers of climate and length of growing period. The country is thus divided in to 21 agro-ecological zones according to the criteria of delineation of regions where growing period as an integrated criteria of effective rainfall, soil groups, delineated boundaries adjust to district boundaries and number of regions as minimal as possible (Fig 6&7).

A rapid examination of the Sarus occurrence and distribution in relation to the Agro-ecological zones of Indian Sub-Continent reveals that the Sarus is largely confined to semi-arid and sub-humid zones with occasional forays into the arid zone but have not radiated into the humid zones, with large canopy cover (Table 4&5).

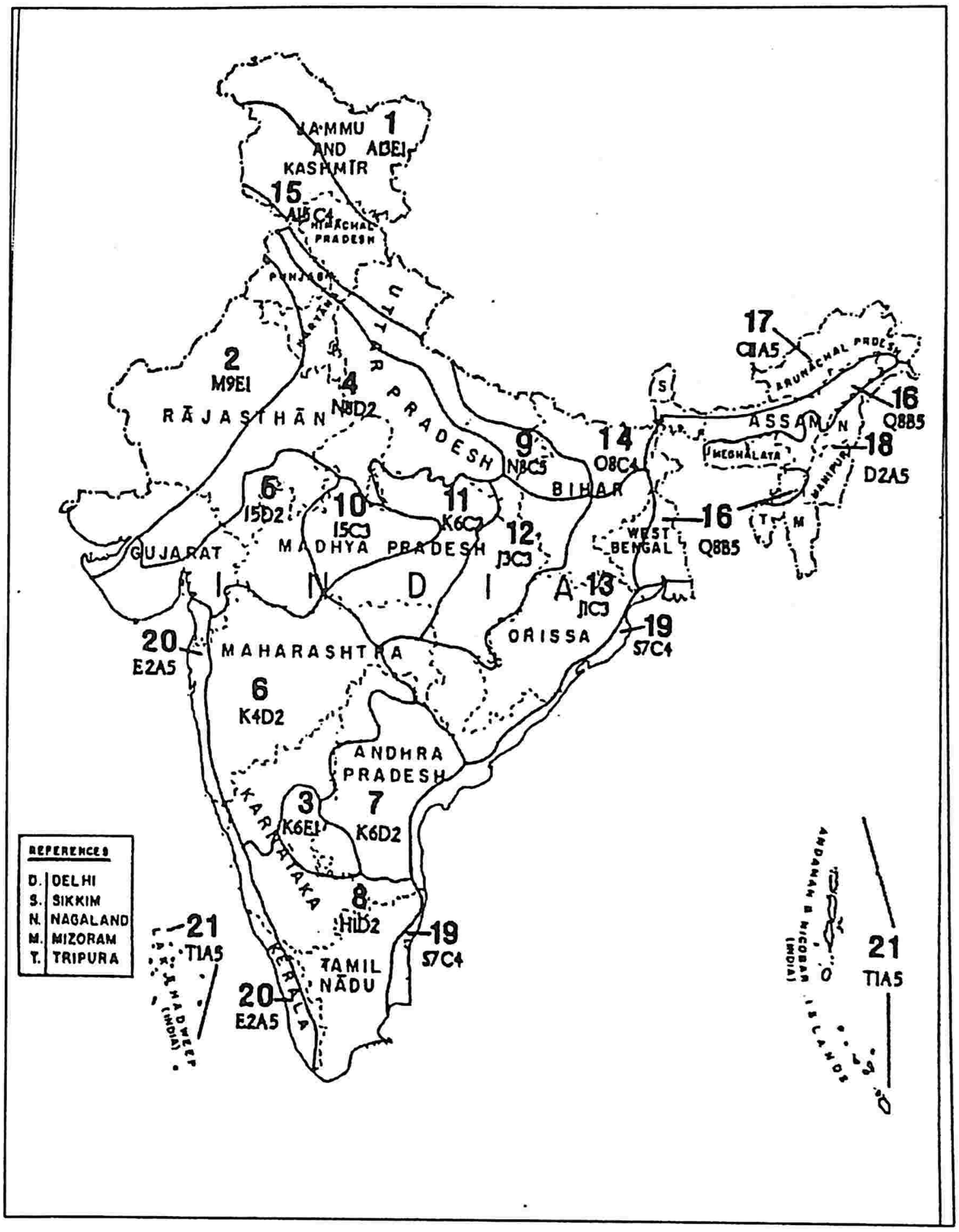
The Upper Gangetic Plain, Gujarat Plains, the Central Plateau and hill region support the Sarus best with the lower Gangetic Plains, middle Gangetic plains, Western Plateau and Western Dry regions providing the second best option for the Sarus, where the climate is above 20°C for most part of the year(Table 4&5).

Fig 5 State wise Agro-climatic zones shown under various agro-climatic regions in India (Planning Commission of India)



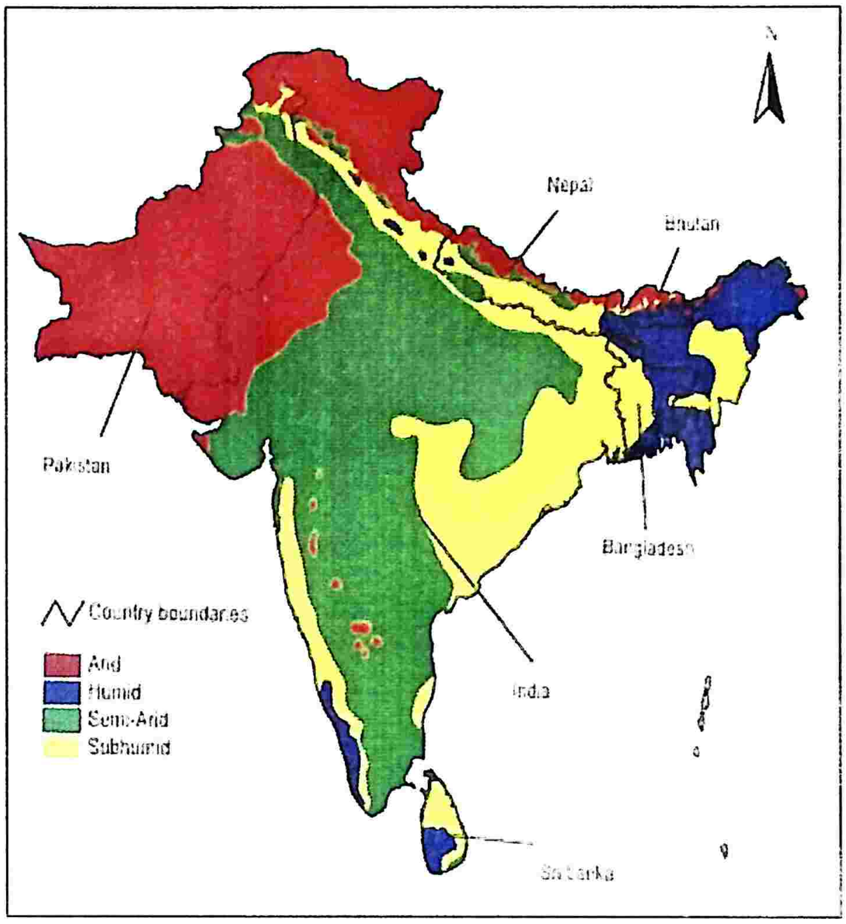
Source : Ghosh 1991

Fig 6 Twenty One Agro-Ecological regions of India.



Source: Ghosh 1991

Fig 7 Map showing the Agro-ecological Zones of Indian sub-continent



Source:
http://www.ilri.org/InfoServ/Webpub/Fulldocs/SoutAsia/2Characterisation.htm

Table 4 **Occurrence and distribution of Sarus Crane in different agro climatic zones of India**

Agroclimatic Zones	**Distribution of Sarus Crane**
1. West Himalayan region	Rare
2. Eastern Himalayan region	Rare
3. Lower Gangetic Plain region	Rare
4. Middle Gangetic Plain region	Rare
5. Upper Gangetic Plain region	Abundant
6. Trans Gangetic Plain	Rare
7. Eastern Plateau and Hills region	Rare
8. Central Plateau and Hill region	Common
9. Western Plateau and hill region	Rare
10. South Plateau and Hill Region	Not Present
11. East Coast Plains and Hills region	Rare
12. West Coast Plains and Ghat region	Not Present
13. Gujarat Plains and Hills region	Common
14. Western Dry region	Rare
15. Island region	Not Present

Table 5 Agro ecological region and distribution of Sarus Crane in India

Agro-Ecological Regions	Distribution of Sarus Crane
1. Western Himalayas, cold arid eco-region	Not very commonly seen in Jammu Kashmir and Himachal Pradesh
2. Western Plain and Kutch Peninsula, hot arid region and eco-region with desert and saline soil	Sarus Crane occurs rarely in western part of Rajasthan and Gujarat
3. Deccan Plateau, hot arid eco-region	Not present in this ecological region
4. Northern Plain and Central Highlands, hot semi-arid region	Commonly seen
5. Central (Malwa) Highland and Kathiawar Peninsula, hot semi-arid eco-region	Commonly seen
6. Deccan Plateau, hot semi-arid eco-region	Rarely seen in this ecological region
7. Deccan Plateau and Eastern Ghats, hot semi-arid eco-region	Not present in this ecological region
8. Eastern Ghats and Deccan Plateau, hot semi-arid eco-region	Not present in this ecological region
9. Northern Plain, hot sub-humid eco-region	Commonly seen in this ecological region
10. Central highlands, hot sub humid eco-region	Rarely seen in this ecological region
11. Deccan Plateau and central highlands, hot sub-humid ecoregion	Rarely seen in this ecological region
12. Eastern Plateau (Chattisgarh), hot sub-humid eco-region	Rarely seen in this ecological region
13. Eastern (Chhota Nagpur) Plateau and Eastern Ghat, hot sub-humid eco-region	Rarely seen in this ecological region
14. Eastern Plain, hot sub-humid eco-region	Rarely seen in this ecological region
15. Western Himalayas, warm sub-humid eco-region	Rarely seen in this ecological region
16. Assam and Bengal Plains, hot sub-humid region	Rarely seen in this ecological region
17. Eastern Himalayas, warm per-humid eco-region	Rarely seen in this ecological region
18. North-Eastern Hills, warm per-humid eco-region	Rarely seen in this ecological region
19. Easter coastal Plains, hot sub-humid eco-region	Not present in this ecological region
20. Western Ghats and Coastal Plains, hot sub-humid per-humid eco-region	Not present in this ecological region
21. Islands of Andaman-Nicobar and Lakshadweep, hot per humid eco-region	Not present in this ecological region

2.6 Agricultural Cropping Patterns and Their Influence on Distribution of Sarus Crane in India

The cropping pattern of major crops growing in India and distribution of Sarus Crane were examined in following maps. The cropping pattern maps were taken from http:www.mapsofindia.com/indiaagriculture/oil-seeds/soyabean-growing-states.html.The Sarus distribution overlaps largely with the millets, wheat and rice growing areas of India (Fig 10). Revisiting WII's 1998 "All India Sarus Crane" survey results shows that much of the Sarus observations were in wheat, rice and other millet growing areas. However, some observations were also in the soyabean crop fields. The observation of Sarus in sugarcane fields are almost nil. It is felt that the full sugarcane field do not provide any food availability opportunity as well as cover value and nesting prospect as they do not hold water and they are grown in too close proximity between plants. From the all India survey of Sarus Crane, the distribution range of Sarus in 1998-99 (Fig 10) revealed that there was marked increase in use of wetlands after the rains and the pooled data over all the states and both seasons, 50.49% of cranes were using agriculture fields, 42.59% were seen in artificial wetlands, such as bunded tanks, ponds and canals. In states, where very low numbers of Sarus Cranes were seen, information on differential habitat use by the species was not available and they have been seen in one habitat type only (Fig 8).

In J&K and Himachal Pradesh, they were seen in agriculture fields, and in Haryana and Maharashtra, they were seen in natural wetlands. In Uttar Pradesh, 76.65% of cranes were seen in agriculture fields. This could be a result of rapid conversion of natural wetlands into agriculture fields in the state. On the contrary, in Rajasthan and Gujarat, Sarus were found more in natural wetlands and in both states, there was a marked increase in the use of wetlands during winter.

Among the crop fields, paddy and wheat fields were seen to be used more in summer and winter respectively (Fig 9) followed by inundated fields and soyabean fields. This is expected since Sarus Cranes eat wheat and paddy, indeed are even regarded as pests in places (Parasharya *et al.* 1986), and find little to feed on in other crop fields.

Most pairs were seen foraging in soyabean fields in Madhya Pradesh which had the highest amount of soyabean grown and was introduced in India in 1977 and mainly in Madhya Pradesh, Maharashtra, Rajasthan and Andhra Pradesh. In India, Madhya Pradesh tops the list of soyabean producing states. Nearly 88% of soyabean is produced in the state. During 1997-98 total soyabean production in the state was 49.19 metric tones which was about 84.2% of total produce but since then the production has gone up because of the more agriculture area coverage. http://www.ruchihealth.com/soya/soyinfo.htm. The total production is around 62% in Madhya Pradesh, while Maharashtra contributes around 27% and 8% comes from Rajasthan. It is also grown in small acreage in Himachal Pradesh, Punjab and Delhi. India produces 5-7 million tons of beans, 1 million ton of oil and 3-5 million tons of soya meal in a normal year. Madhya Pradesh (3.5-4.5 million tons), Maharashtra, Rajasthan are the major producers of soyabean in India. In Uttar Pradesh, the soyabean cultivation has started gearing up in the recent years. It is a kharif crop, sown in June-July and harvested by September-October. Peak arrivals are from October-November. www.ikisan.com/links/ap_soyaHistory.shtml. If previously used field of wheat and rice have been converted to soyabean fields that too during July to October does not support Sarus at all.

Sarus cranes were seen to prefer paddy and wheat fields to other kinds of crop fields. Rice and winter wheat, which were the erstwhile largest cash crops all over the country (Fig 10) are being replaced in several areas by sugarcane and soyabean. The area under sugarcane has nearly doubled and that under soyabean has tripled in the past decade. These fields are not ideal crane habitat since sugarcane forms a thick, impenetrable barrier to the movement of the cranes and soyabean fields are pumped with pesticides which kills the fauna leaving spare little for cranes to forage on (Fig 11).

India was the first country to extract natural cane juice to make the first crude sugar in 500 BC. Asia is the largest producer of sugar followed by Europe. Uttar Pradesh has the largest area almost 50 per cent of the cane area in the country, followed by Maharashtra, Karnataka, Tamil Nadu, Andhra Pradesh, Gujarat, Bihar, Haryana and Punjab. These nine are most important sugarcane producing states. Sugarcane production is also highest in U.P. followed by Maharasthra (Fig. 12). Productivity wise, Tamilnadu stands first with over 100 tones per hectare followed by Karanataka, Maharashtra, Bihar has the lowest productivity amount the major sugarcane growing states. Uttar Pradesh has the largest acreage under sugarcane, and accounts for about 52 per cent of the area under this crop in whole of India and also accounts for 40 per cent of the total annual production. The total sugarcane area during 1950-51 was 1.7 million hectares which rose to 2.46 million hectares by 1960-61 and to 2.62 million hectares by 1970-71. Over the last 25 years, the area has expanded by 45.8 per cent and the present area is 3.82 million hectares. Sugarcane production also had similar increases. http://www.ikisan.com/links/ap_sugarcaneHistory.shtml.

Fig 8 State-wise habitat use by Sarus Crane (*Grus antigone*)

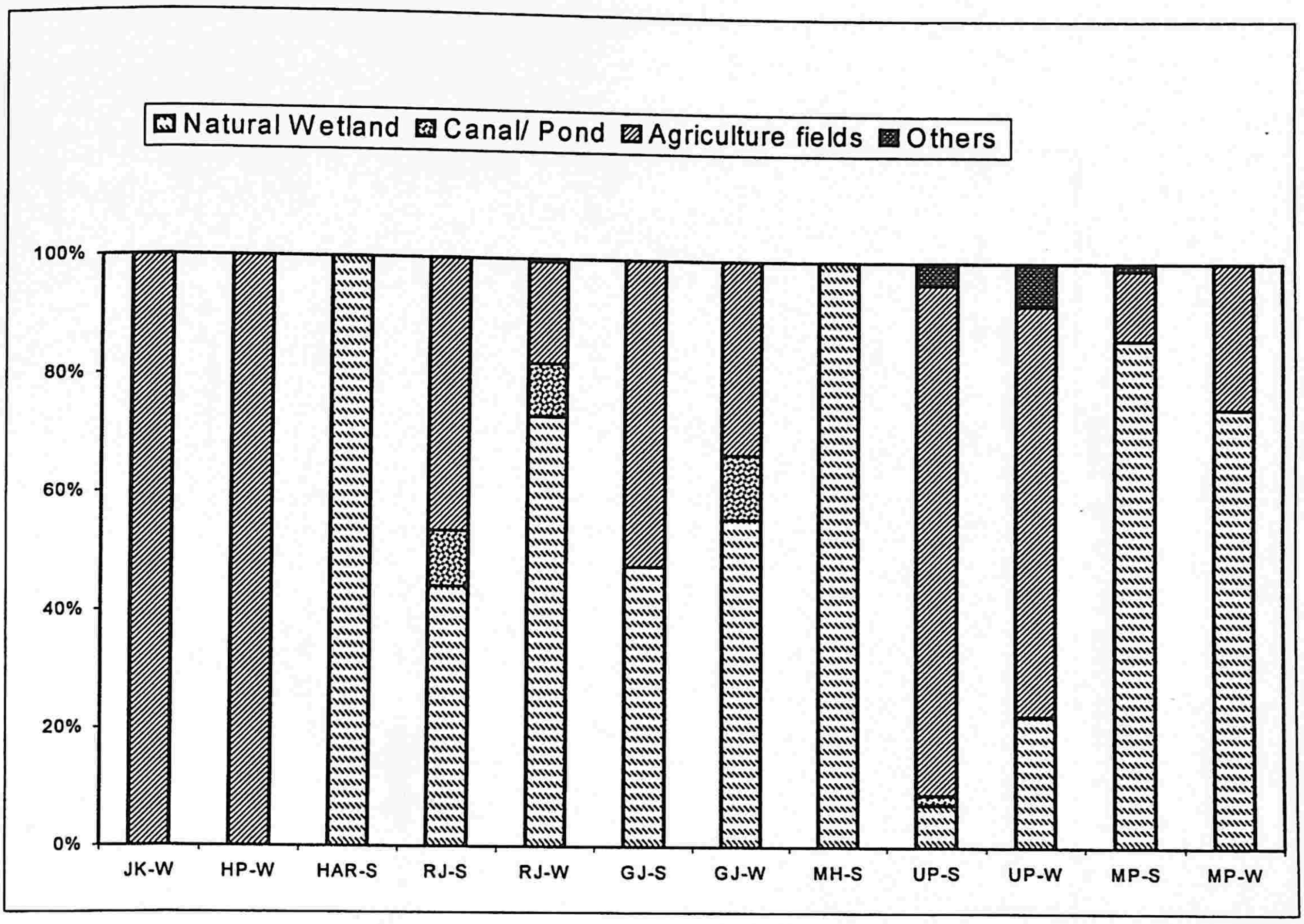
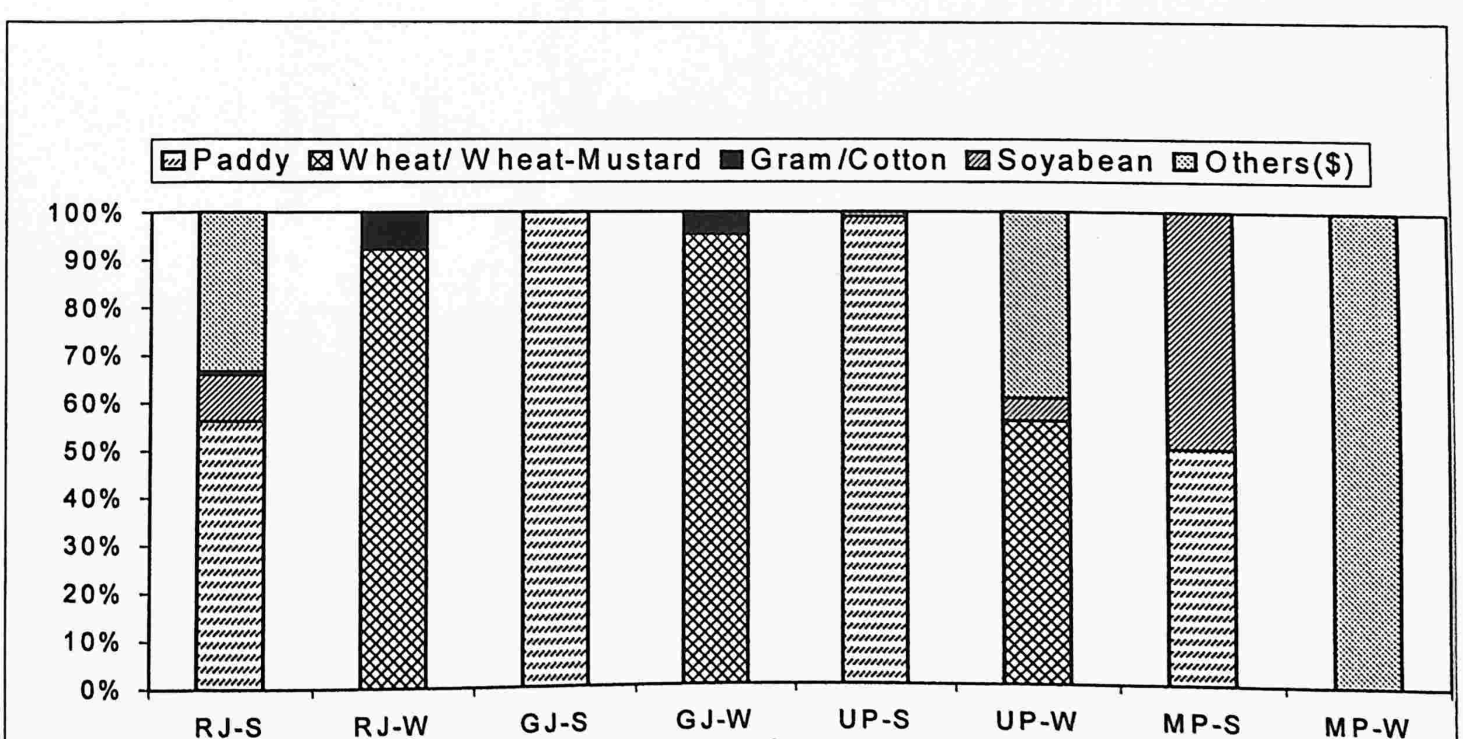
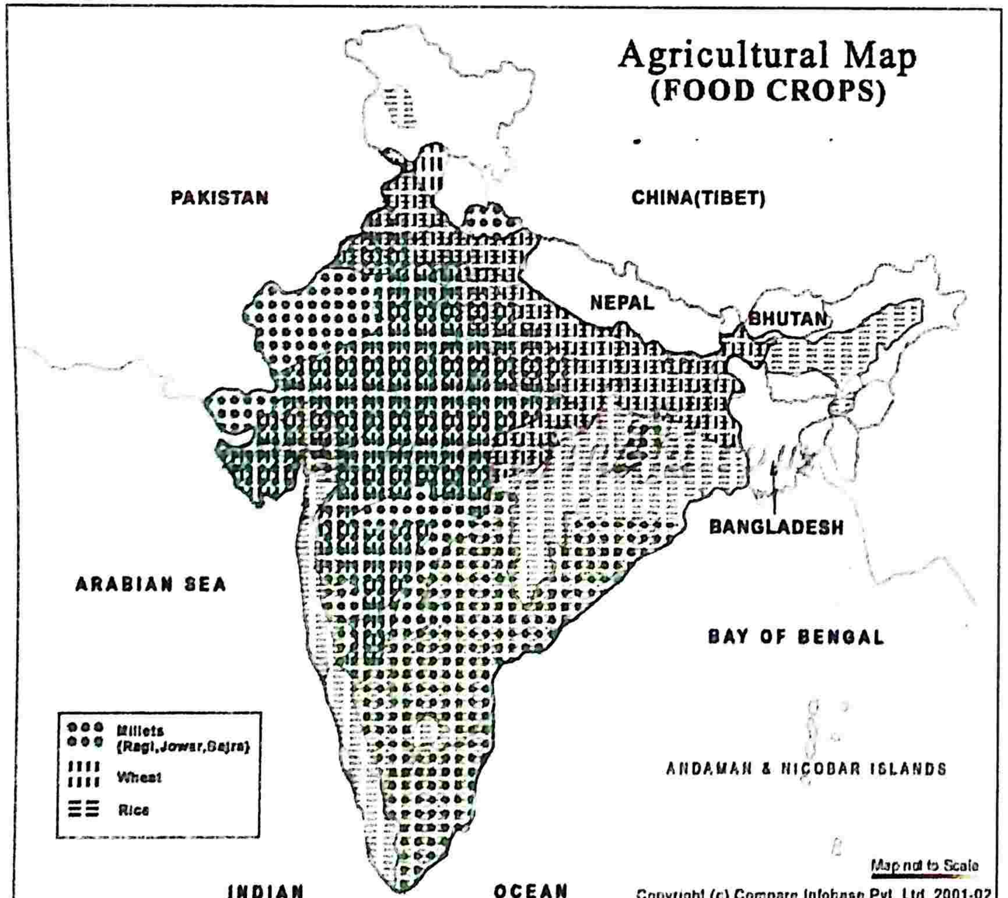


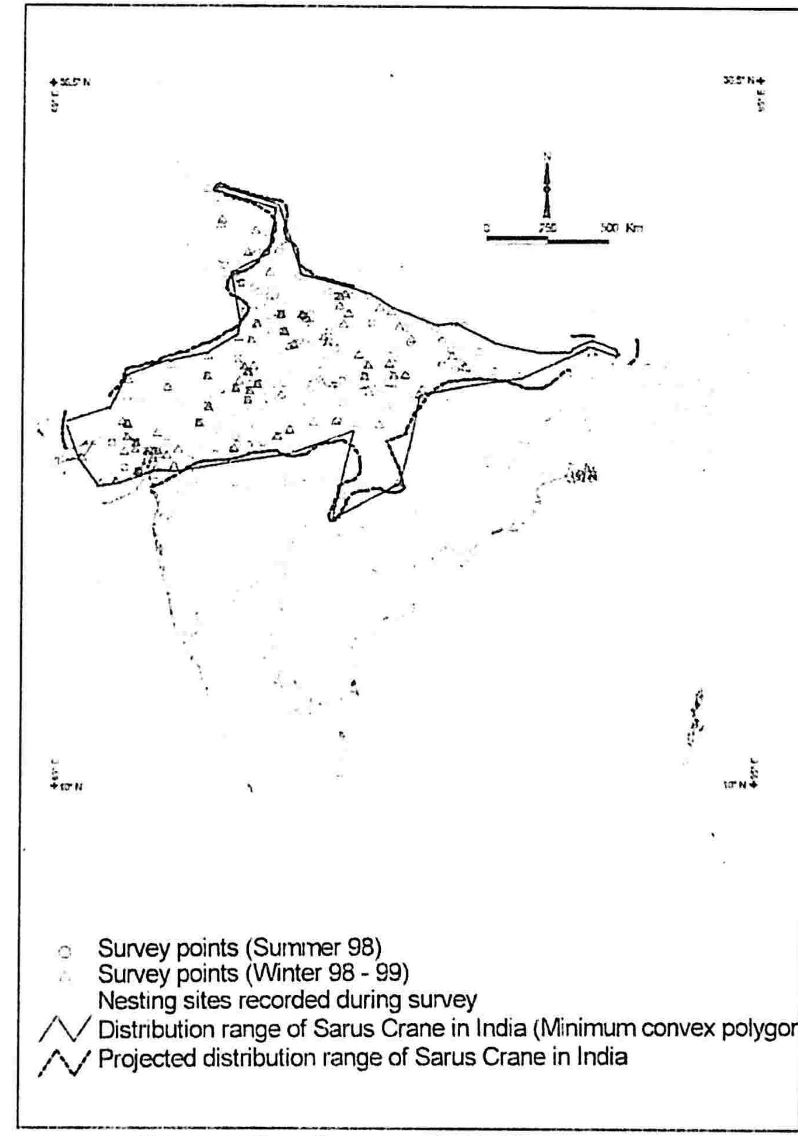
Fig 9 Different crop-land use by Sarus Crane (*Grus antigone*)*



* - Sarus Cranes in other districts used only wetlands.
$ - Includes inundated, groundnut and vegetable fields

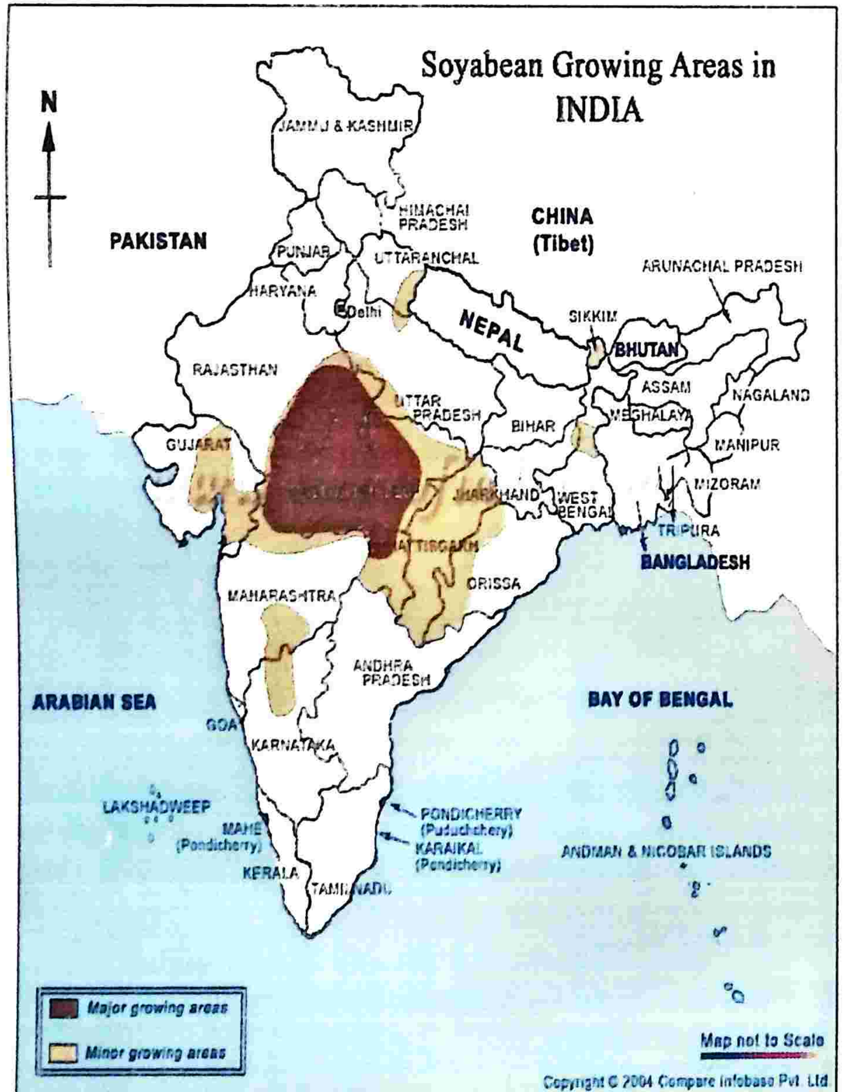


Source: Maps of India

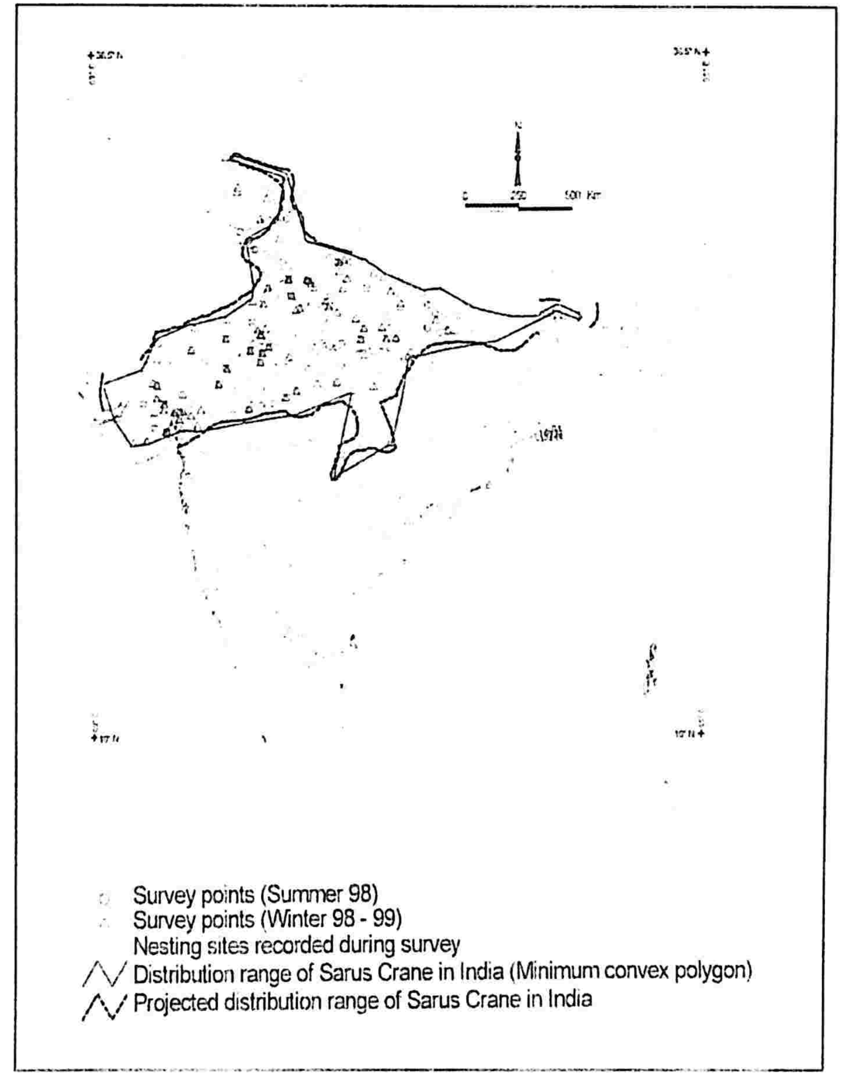


Source Sundar *et al.* 1999

Fig 11 Map showing the Soyabean growing areas and Sarus Crane distribution in India.

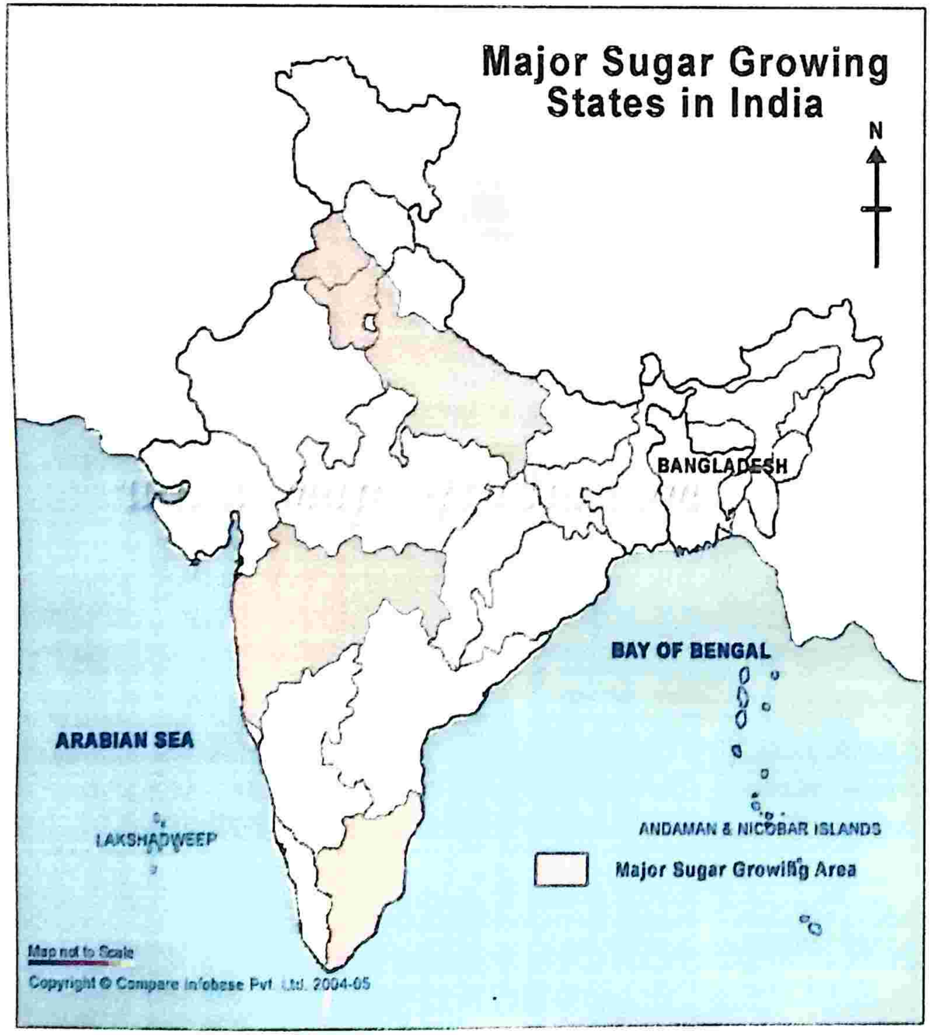


Source: Maps of India

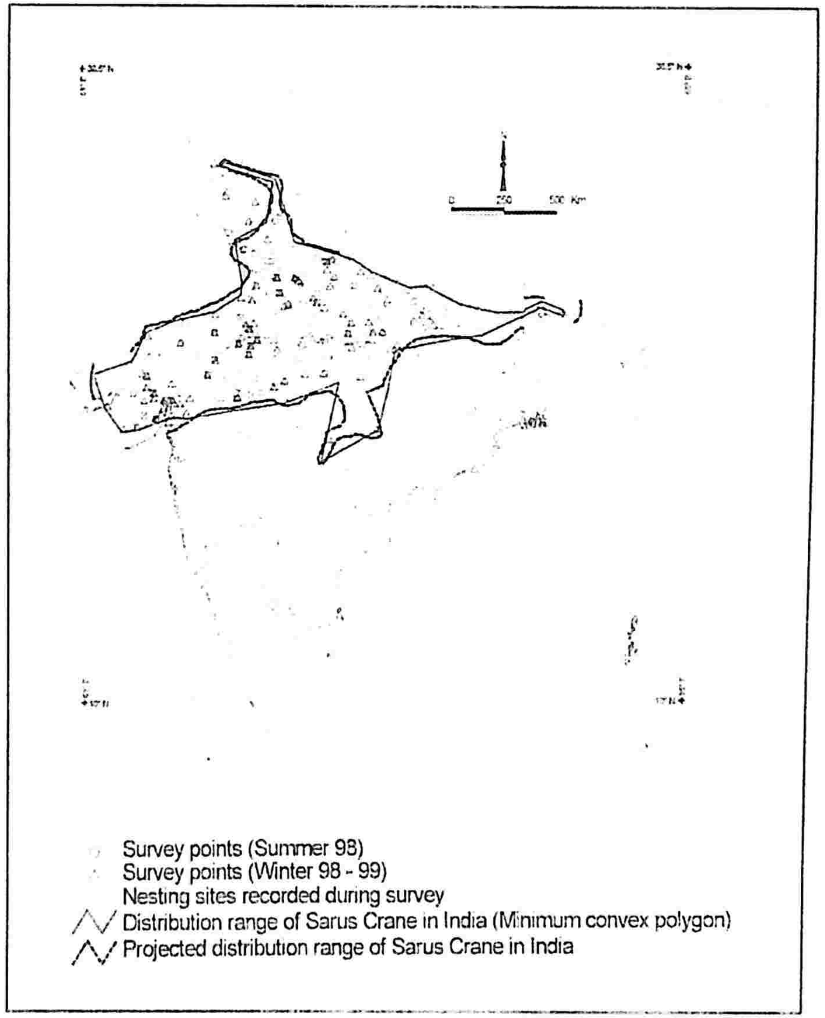


Source Sundar *et al.* 1999

Fig 12 Map Showing the Sugarcane areas and Sarus Crane distribution in India.



Source: Maps of India



Source:Sundar *et al.* *1999*

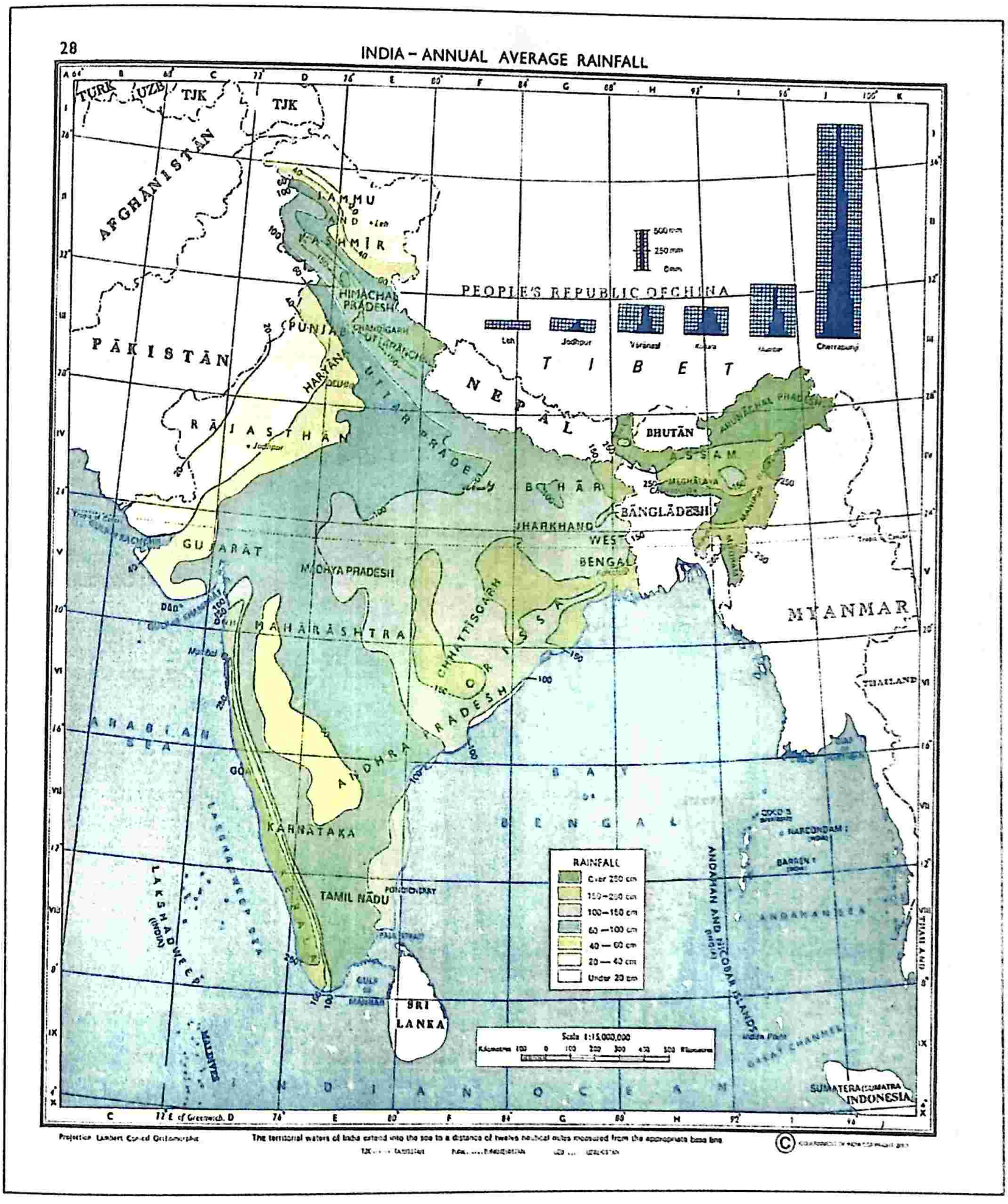
More crane species actively select natural wetlands for breeding, but all species, with the exception of the Siberian Crane (*Grus leucogeranus*), use dry lands as well for foraging (Johnsgard 1983). Species such as the Blue Crane (*Anthropoides paradiseus*) and Demoiselle Crane (*A. virgo*) use dryland habitats throughout the year (Johnsgard 1983, Allan 1995). From available studies and the survey, it appears that Sarus Cranes time their breeding activity such that the young hatch when there is no dearth of water and food. This habit, combined with their partial tolerance to agricultural development, is a good survival strategy for the species. The importance of maintaining natural wetlands, which are undoubtedly superior Sarus Crane habitats, cannot be overemphasized. However, given the fact that India is primarily an agriculture-based country, the development of the agricultural sector constitutes a very important agenda for the government. This invariably is done at the cost of natural wetland habitats. For conserving Sarus Cranes, it may not be necessary, however, to develop large tracts of continuous natural wetlands. They seem to thrive quite well in mosaics consisting of suitable crop fields and small natural wetlands, as was recorded in Etawah and Mainpuri districts of Uttar Pradesh. This observation is consistent with that of Gole (1989). Previous studies have documented the importance of agriculture fields, particularly rice fields, as foraging habitats for water birds (Lane & Fujioka 1998).

2.7 Rainfall and Temperature Zones of India and Sarus Distribution

Based on the annual average rainfall and temperature India has been divided in to rainfall regimes and temperature climes. Based on precipitation in the arid zones where rainfall is below 20cm, India also has areas where the rainfall is over 250cm. Much of the north-western India, Deccan highlands and the cold arid zones have a rainfall pattern below 60cm annually. Most part of India and a larger geographic area of India have a rainfall pattern between 60-150cm and only the Western Ghat and the north eastern has rainfall above 150-250cm range (Fig 13).

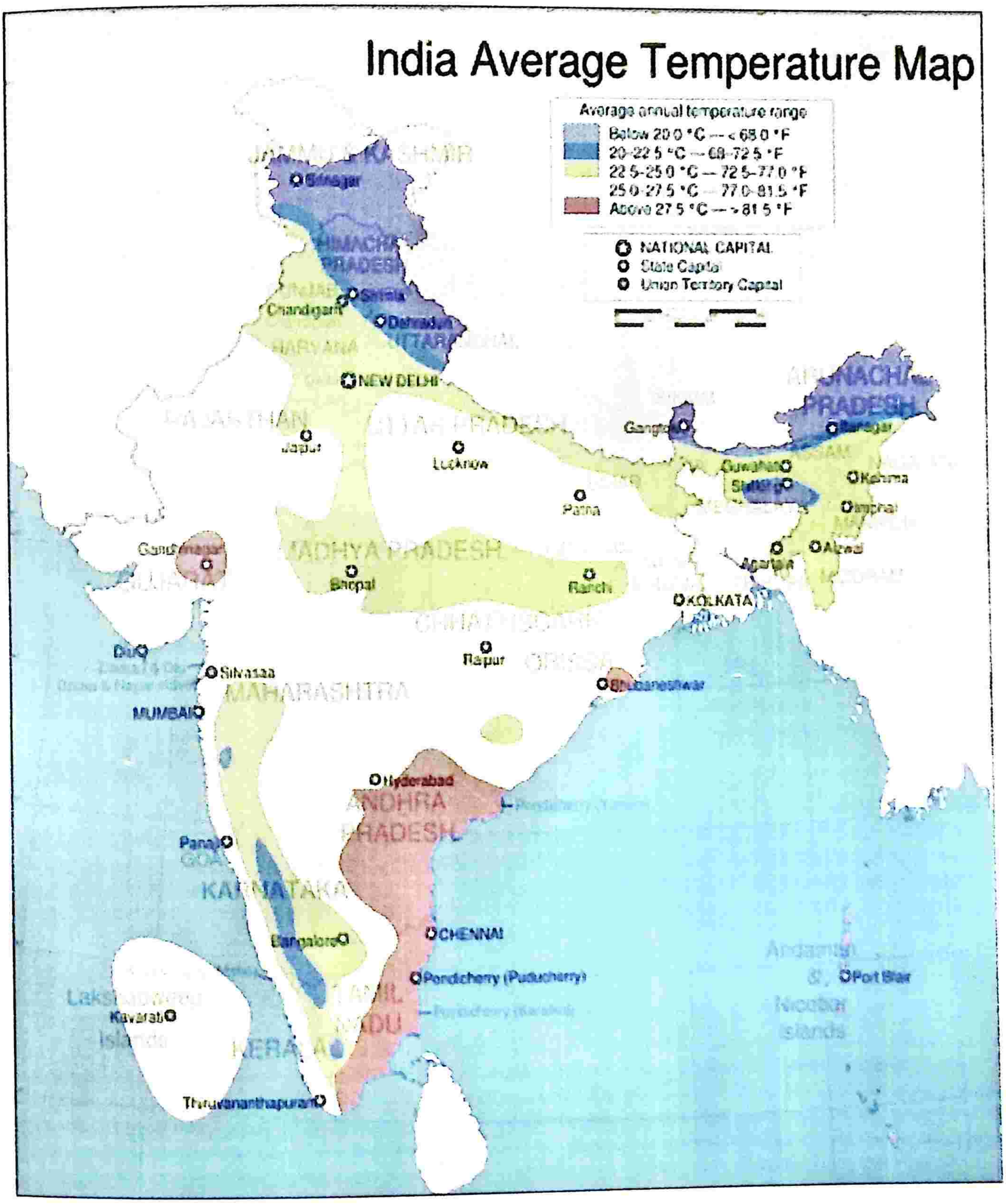
Similarly based on the annual average temperature the country has been dived into 5 temperature climes ranging from below 20°C to above 27.5°C. Much of the Himalayan range and the higher hill ranges of Western Ghat are the regions where the average annual temperature is below 20°C. The low elevation regions such ads lower foothill of Himalayan region, lower elevation of the Western Ghat, the mountain regions of Himalaya, north-east foothills of Himalayas are in the temperature zone of 20-22.5°C. A greater part of the low elevation plain of India are in the range of 22.5 °C to 25.0°C with the hot arid zone of India in the north western region going up to 27.5°C average only a small region of western region in Gujarat and the coastal Andhra Pradesh and Tamil Nadu, the average temperature goes above 27°C (Fig 14).

Fig 13 Map showing the annual average rainfall in India.



Source: Survey of India

Fig 14 Map showing the average Temperature of India.



Source: <u>http://en.wikipedia.org/wiki/Image:India_annual_rainfall_map.syg.file</u>

An examination of Sarus distribution with rainfall and temperature zones of India reveales the Sarus to prefer a temperature zone above 22.5^{0}C with average rainfall ranging from 40 cm to 150 cm. Sarus appears to avoid low temperature and high rainfall and humid areas, where flooding and wetness is prevalent.

However, Sarus, though a cold hardy species tend to adapt to an arid and extreme temperature zones with moderate to low availability of water. Looking at the present distribution pattern of Sarus in the Indio-Gangetic flood plains, it is observed that Sarus is also doing well in the arid and semi-arid dry zone of north, North West and western India.

2.8 Dryland (Arid-Semi Arid – Dry Sub-Humid) Regions of India and Sarus Crane distribution

A quick examination of the dry land region of India, which is as under is necessitated to bring into context the present study on Sarus and its findings.The dry arid and semi-arid region information have been obtained from Sources http://www.ilri.org/InfoServ/Webpub/fulldocs/ soutAsia/2Characterisation.htm and are explained below.

2.8.1 The Arid Region

The arid zone region of India based on temperature, elevation and rainfall have been divided into hot arid and cold regions.

1. Hot Arid Region: These include the hot arid regions that occupy major parts of Rajasthan (Western), Gujarat, southern parts of Punjab and Haryana and a small portion of Deccan Peninsula in the States of Andhra Pradesh, Karnataka, Maharashtra. Roughly, three-fourths of the State of Rajasthan, comprising of 12 western districts falls within the hot arid zone. These are the districts of Barmar, Bikaner, Churu, Sri Ganganagar, Hanumangarh, Jaisalmer, Jalore, Jhunjunu, Jodhpur, Nagaur, Pali and Sikar the hot aird region suffers low and erratic rainfall, frequent droughts, high evaporation, intense heat and high winds. The soils are not conducive to intensive crop production. The Great Indian Desert also known as the 'Thar' Desert, lies in Western Rajasthan and comprises of an area of 196,150 sq.km, and is one of the hot and arid region of the world.

Cold Arid Region:

In addition, area of about 15.2 mha of cold desert are located in Jammu and Kashmir and the Lahul-Spiti region in Himachal Pradesh. Much of these areas are located on the high altitudinal range of above3000m elevation.

2. Semi-Arid region:

About 123.4 mha (37.6%) of the country's geographical area consists of the semi-arid region. The semiarid tropical areas (SAT) can be further classified into dry and wet. In the SAT, the crops and cropping systems are quite diverse depending on the soil type and the length of growing season. Sorghum, cotton, soyabean, groundnut and pulses are the major crops grown in this zone.

3. Dry Sub Humid:

About 54.1 mha (16.5%) of country's geographical area falls within the dry sub-humid region. The dry sub-humid region receives fairly high rainfall providing ample opportunities for water harvesting. This can be effectively integrated with the safe disposal of excess runoff to overcome water congestion of soils for crops (other than rice). Rain-fed rice is the predominant crop followed by pulses, oilseeds and to some extent, vegetables. Fruit crops particularly in Orissa are also an important component of the production system. The Sarus Crane abundance is largely in the dry-sub humid region in much of the middle Gangetic plains where the rainfall is abundant and also wetlands in the floodplains. The Sarus also appears to have a preference to the warmer and drier western Gangetic flood plains and the semi-arid tracts rather than the warmer but wet humid regions of the lower Gangetic plains, where Sarus have been recorded historically. It is perhaps the present distribution range of the Sarus that requires an explanation, why and how Sarus has adapted to the semi-arid and hotter regions which is the focus of this study.

2.9 Land use Pattern & Sarus Distribution:

The pattern of land use of a country at any particular time is determined by the physical, economic and institutional framework taken together. In other words, the existing land use pattern in different regions in India has been evolved as a result of the action and interaction of various factors, such as the physical characteristics of land, the institutional framework, the structure of other resources (capital, labour etc.) available.

From the available literature the area under agricultural uses in states of Haryana, Punjab, West Bengal, Maharashtra, Uttar Pradesh, Kerala, Karnataka, Gujarat, Bihar, Pondicherry, Delhi and Union Territories of Lakshadweep, and Andaman and Nicobar cultivate more than 45 per cent of their reporting area. In some of the states like Haryana and Punjab, which lie in the fertile Indo-Gangetic plains of India, the net area shown is between 60 and 70 per cent of the corresponding reporting area. Maharashtra has the highest net area sown in the country. The states of Maharashtra, Madhya Pradesh, Karnataka, Gujarat and Bihar account for more than three-fourths of the country's net area sown. http://www.krishiworld.com/html/land_utilization1.html

The land under non-agricultural uses it includes all lands occupied by buildings, roads and railways, or under water, e.g. rivers and canals, and other lands put to uses other than agricultural. During recent years, there has been an increase in the area put to non-agricultural uses, as expected, as a result of increase in the developmental activities, more and more land is being used for industrial sites, housing, transport systems, recreational purposes, irrigation systems etc. The states where the proportion of land under non-agricultural uses is higher than the all-India average are Haryana, Jammu & Kashmir, Kerala, Orissa, Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Bihar, Assam, Goa, Delhi, Pondicherry and the Union Territory of Daman and Diu. The states which account for more than two-thirds of the land under non-agricultural uses are Andhra Pradesh, Madhya Pradesh, Uttar Pradesh, Bihar, Tamil Nadu, Rajasthan, Orissa and Karnataka.

The other types of areas, which are covered under barren and uncultivable lands, are generally unsuitable for agricultural use either because of the topography or because of their inaccessibility. Instances are the desert areas in Rajasthan, the saline lands in parts of the Rann of Kutch in Gujarat, the weed infected and ravine lands in Madhya Pradesh and alkaline lands in Uttar Pradesh. The proportions of barren and uncultivated lands to the reporting areas are higher in the states of Rajasthan, West Bengal, Assam, Gujarat, Manipur, Nagaland, Meghalaya, Arunachal Pradesh and Mizoram. The states of Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Meghalaya, Assam and Maharashtra together account for more than 67 per cent of the land under this category in the country.

The land use pattern of the country is constantly changing. As irrigation facility reaches to drier and rain deficient areas, cropping patterns are changing. Urban growth is changing the landscape. The scrub thorn forest, fallow land, grassland in undulating landscape and river valleys with rich water sources are the region which are changing the most. These are the habitat where Sarus was most abundance historically. The rapid change in the land use over the last 50 years have brought in major problem for Sarus. The land use pattern changes are now expanding even to traditionally drier and arid and semi-arid zones of India. The present study is an examination of how the Sarus has adapted into the semi-arid landscape where aridity is supplemented with man induced water at the same time the cropping patterns are changing from dry land low height crops to more water hungry crops.

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CHAPTER 3

STUDY AREA IN THE NORTH WESTERN INDO-GANGETIC PLAINS

3.1 The physiography of the semi-arid zone and the Indo-Gangetic Plain in India and Sarus distribution and abundance

The Indo-Gangetic Plain, located in south of the Himalayas where the Sarus Crane is best distributed, is formed by the basin of the three major rivers - the Indus, Ganges and Brahmaputra. The Indus flows west, draining into the Arabian Sea; the Ganges flows east, emptying into the Bay of Bengal; and the Brahmaputra flows through Bangladesh, joining the Ganges. The entire Gangetic plain has almost been completely cleared for farming and is one of the most fertile areas on earth as well as one of the most densely populated regions (Mani 1974).

3.1.1 Drainage in the Indo-Gangetic Plain semi-arid Zone

The Indo-Gangetic Plain of north India, about 250-450 Km wide, extends from end to end more than 3000Km, from the Arabian Sea to the Bay of Bengal. This great plain is remarkable for the dead flatness, the gentle slope seaward and the immense thickness of the alluvium, which the present- day rivers Indus, Ganga and Brahmaputra could not certainly have laid down, at the speed of the present day deposition (Mani 1974).

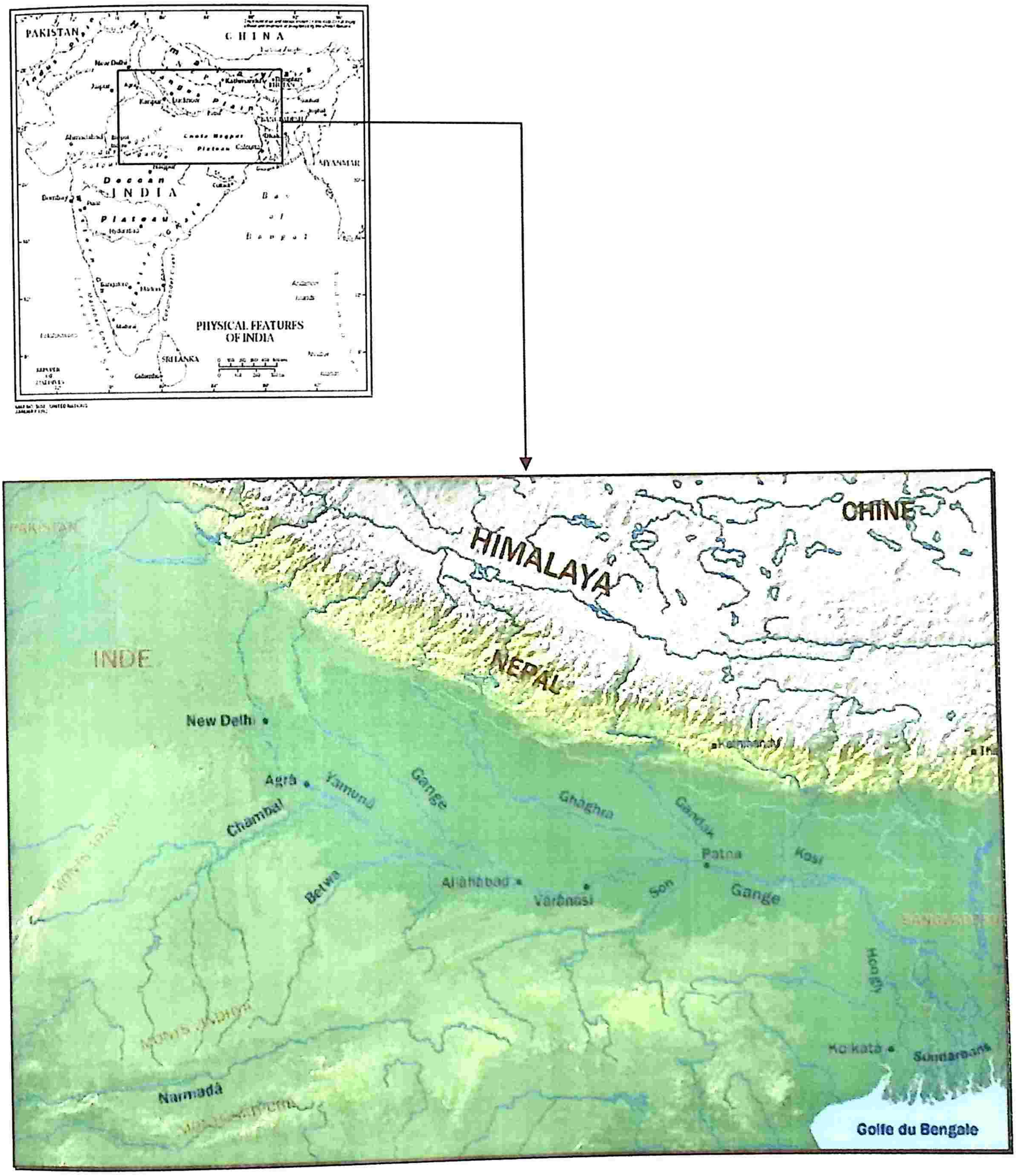
The plain is topographically homogeneous for hundreds of Kilometers, the only noticeable relief being that of the flood plain bluffs and belts of ravines and badlands, formed by gully erosion along some of the larger streams like the lower course of the River Chambal. Along the outer slope of the Siwaliks, there is commonly steep gravel called the *bhabar*, in which all but the larger streams lose themselves, but seep out lower down in marshy and jungly terai. The older or the Pleistocene alluvium, called *bhangar* occupies generally higher ground than the recent *khadar* that grades into the most recent delta silts. The alluvium is on the whole fairly stiff clay, with some sand (Mani 1974). Two narrow terrain belts, collectively known as the Terai, constitute the northern boundary of the Indo-Gangetic Plain. Groundwater from these areas flows on the surface where the plains begin and converts large areas along the rivers into swamps. The southern boundary of the plain begins along the edge of the Great Indian Desert in the state of Rajasthan and continues east along the base of the hills of the Central Highlands to the Bay of Bengal. The hills, varying in elevation from 300 to 1,200 meters, lie on a general east-west axis. The Central Highlands are divided into northern and southern parts. The northern part is centered on the Aravalli Range of eastern Rajasthan. In the northern part of the state of Madhya Pradesh, the Malwa Plateau comprises the southern part of the Central Highlands and merges with the Vindhya Range to the south. The main rivers that flow through the southern part of the plain the Narmada, the Tapti, and the Mahanadi--delineate North India from South (Mani 1974).

Some geographers subdivide the Indo-Gangetic Plain into three parts: the Indus Valley (mostly in Pakistan), the Punjab (divided between India and Pakistan) and Haryana plains, and the middle and lower Ganga. These regional distinctions are based primarily on the availability of water. By another definition, the Indo-Gangetic Plain is divided into two drainage basins by the Delhi Ridge; the western part consists of the Punjab Plain and the Haryana Plain, and the eastern part consists of the Ganga-Brahmaputra drainage systems. This divide is only 300 meters above sea level, contributing to the perception that the Indo-Gangetic Plain appears to be continuous between the two drainage basins. The Punjab Plain is centered in the land between five rivers: the Jhelum, the Chenab, the Ravi, the Beas, and the Sutlej.

Both the Punjab and Haryana plains are irrigated with water from the Ravi, Beas, and Sutlej rivers. The irrigation projects emanating from these rivers have led to a decrease in the flow of water reaching the lower drainage areas in the state of Punjab in India and the Indus Valley in Pakistan. The benefits that increased irrigation has brought to farmers in the state of Haryana are controversial in light of the effects that irrigation has had on agricultural life in the Punjab areas of both India and Pakistan (Mani 1974).

The middle Ganga extends from the Yamuna River in the west to the state of West Bengal in the east. The lower Ganga and the Assam Valley are more lush and verdant than the middle Ganga. The lower Ganga is centered in West Bengal from which it flows into Bangladesh and, after joining the Jamuna (as the lower reaches of the Brahmaputra are known in Bangladesh), forms the delta of the Ganga. The Brahmaputra (meaning son of Brahma) rises in Tibet (China's Xizang Autonomous Region) as the Yarlung Zangbo River, flows through Arunachal Pradesh and Assam, and then crosses into Bangladesh. Average annual rainfall increases moving west to east from approximately 600 millimeters in the Punjab Plain to 1,500 millimeters around the lower Ganga and Brahmaputra. Following map shows the Indo-Gangetic flood plain in India (Fig 1).

Fig 1 Map showing Indo-Gangetic Flood Plain in India



Source: **www.un.org/Depts/cartographic/map/profile/india.pdf**

http://en.wikipedia.org/wiki/Image:River_Ganges_and_tributaries.png

3.1.2 Two river basin Indus and Ganges

The Indus river basin consists of the main river Indus and its major tributaries. The Indus, 2880 km long, arises at an elevation of 5182m above mean sea level in the springs of the Singge Khambab northeast of Mt. Kailsh and 85km from Parkha in Tibet. It is this river that has given the name India to the country. It flows first northwest around the lake Mansarovar, takes turn southwards in the Haramosh Mountain. Opposite Attock (in Pakistan) it is joined by the river Kabul. It then flows parallel to the Sulaiman range and receives the accumulated waters of the five rivers of the Punjab, the eastern tributaries, at 805km up from its mouth. It empties into the Arabian Sea by many mouths near Karachi.

The Indus river is distributed in 5 Indian states-Jammu and Kashmir (60%), Himachal Pradesh (16%), Punjab (16%), Haryana (3%) and Rajasthan (5%) respectively.

The river Ganga has for several generations been confused with the R.sutlej and thus across the myth that the Ganga arose from the lake Mansarovar and the Mt.Kailas. The source streams of the River Ganga are five, viz. the Bhagirathi, Mandakini, Alaknanda, Dhauli-Ganga and the Pindar. The combined water of the rivers Alaknanda, Dhauli-Ganga, Pindar and the Mandakini join the R.Bhagirathi at Devprayag, to form the Ganga, which then emerges finally from the Himalayan mountains into the north Indian plains at Hardwar. The Ganga then flows through the Indo-Gangetic Plains of North India to empty into the Bay of Bengal, near Sagar Island. Of the tributaries of the River Ganga, the Yamuna, Ghagra, Sarda, Rapti and Gandak arise on the Himalaya and except the Yamuna, are all on the left bank of the Ganga. Though rising on the Himalaya, Yamuna is a right-bank tributary of the Ganaga. The other right-bank tributaries like the river Son, arise on the Peninsular tableland. Rivers Chambal, Banas, Sindh, Betwa, Ken and Son flow northwards from the central ranges to form important right bank tributaries to river Ganga.The Ganga basin is joined by the river Yamuna from the west at Allahabad, then the rivers Ramganga, Gomti and Tons from the north and the Chambal, Betwa, Sindh, Ken and Son from the south. In India, the Ganges basin covers 8 states: Uttar Pradesh (34.2%), Himachal Pradesh (0.5%), Haryana (4%), Rajasthan (13%), Madhya Pradesh (23.1%), Bihar (16.7%), West Bengal (8.3%) and Delhi (0.2%).

3.2 The semi-arid Zone in the Indo-Gangetic Plain

The arid zone in India forms a part of the Thar Desert and covers about 12 per cent of the of the north-western area of the country. It occupies about 3.2 million km² of the hot desert located in the states of Rajasthan (62 per cent), Gujarat (20 per cent), and Punjab and Haryana (9 per cent), besides small pockets (9 per cent) in the states of Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu. The semi-arid area occupies about 9.6 million km² in peninsular India. In addition to these, the cold desert of Ladakh in Jammu and Kashmir occupies an area of 0.7 million km² and presents an entirely different set of agro-climatic conditions. The Thar Desert the aridest region of India and there is a very rapid and marked decrease in rainfall west of the Aravalli range, making western Rajasthan the most arid part. The average annual rainfall in this part ranges from less than 10cm, lies southwest of the Indo-Gangetic Plain, from the southern edge of the Punjab through northwestern Rajasthan. Average annual rainfall in the Indian arid zone varies between 150 and 500 mm. The climate is characterized by high temperatures, with a mean diurnal variation of 14°C, the mean maximum being 32.7°C and the mean minimum 18.8°C. The mean relative humidity is 41 per cent (Mann 1979). The surface water availability in this region except for snow fed perennial rivers is only for 3-4 months in July to October in a calendar year, if however, the rainfall based precipitation is low or minimal the region goes through drought. This kind of drought is cyclic in nature and naturally occurring flora and fauna have co-existed and adapted in this region to microclimatic regime. The Sarus Crane, though a cold-hardy species have also adapted, itself to have survived so well in this hot, cold and dry climate, particularly in the state of Rajasthan and Gujarat.

Rajasthan lies between 23° 30' and 30° 11' north latitudes and 69° 29' and 78° 17' east longitudes and occupies an area of about 3,42,239 sq km, representing 11% of the total geographical area of India. The Aravallis, one of the oldest mountain systems, divide the state into two unequal parts: the northwest consisting of desert and semi-desert, and the southeast consisting of the Gangetic plain fertile land. The Aravalli defines the eastern limit of the Thar Desert and cover over 30% of the state. The western dry land stretch of the state is covered by the Thar Desert and takes up 12% of the state. In spite of the aridity, Rajasthan continues to support the third largest population of Sarus Cranes in India next to Uttar Pradesh and Gujarat.

3.2.1 Sarus Crane in the Semi Arid Region of the Indo Gangetic Plains

In India, the present extent of distribution of Sarus Crane is from Jammu in the north, through Nepal, to Chandrapur in Maharashtra in the south, and from Gujarat in the west to Assam in the east (Choudhury 1990, Choudhury 1998, Choudhury 2002, Choudhury *et al.* 1999, Sundar *et al.* 2000ab, Kaur *et al.* 2002). Information from Crane counts indicate that the distribution is contiguous for most of the distribution range, the only exceptions being the Cranes in Maharashtra and Assam, which seems isolated (Choudhury *et al.* 1999, Sundar *et al.* 2000a, Kaur *et al.* 2002).

Though natural wetlands are considered to be the most crucial requirement for the survival of the Sarus Cranes in its distribution range, the mosaic of wetlands in agricultural landscape appears to be the changed but most essential component for the present distribution pattern of Sarus Crane. Sarus Crane appears to have adapted to a somewhat different life cycle in the Semi-arid tract in its distributional range as compared to the water rich zones in the central and eastern Gangetic plains.

3.3 The Rajasthan, and its Agro climatic Zones with relation to the study sites

The state of Rajasthan where the study was conducted is divided in to nine Agro-Climatic Zones on the basis of climatic conditions and agriculture produce (Fig 2).

1. Arid Western Zone: Districts falls under these zones are Jaisalmer, Barmer, Jodhpur and Bikner.
2. Irrigated N.W. Plain Zone: Sriganganagar districts come under this zone.
3. Transitional Plain of inland Drainage Zone: Sikar, Jhunjhunu, Churu, Nagaur and Ajmer districts falls under this zone
4. Transitional Plain of Luni Basin Zone: Jalor, Pali and Sirohi districts
5. Semi Arid Eastern Plain Zone: Jaipur, Tonk and Alwar districts
6. Flood Prone Eastern Plain Zone: Bharatpur and Dholpur districts
7. Sub Humid Southern Plain Zone: Bhilwara, Udaipur and Chittorgarh
8. Humid Southern Plain Zone: Banswara
9. Humid S.E. Plain Zone: Kota, Budi, Baran and Jhalwar

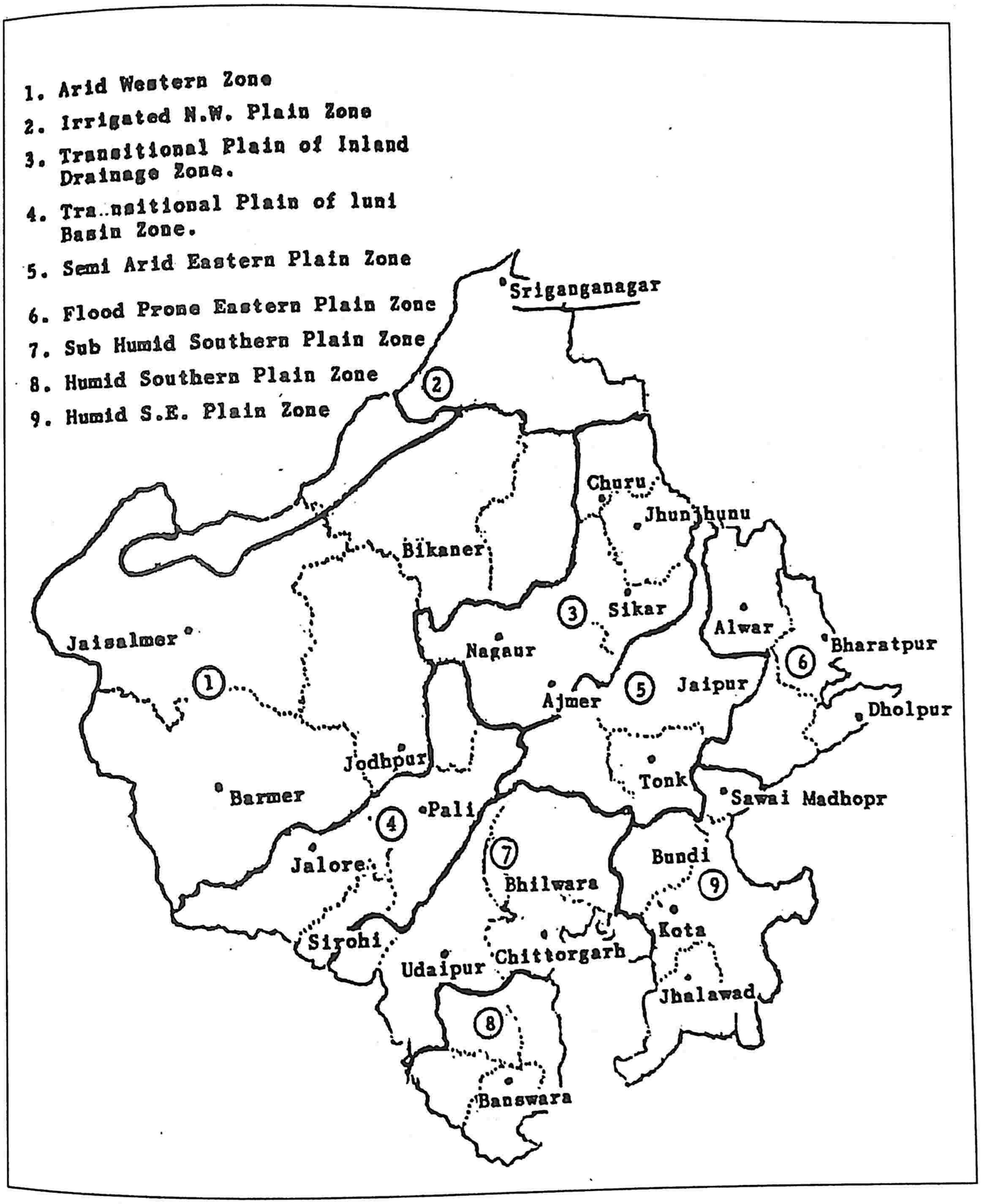
The district Kota , the first intensive sites falls under Zone V the humid south-eastern Humid plain zone and Bharatpur districts the second intensive study site in Zone IIIB the Flood Prone Eastern Plains (Ghosh 1991).

1. The South Eastern Humid Plain Zone: This zone lies in south eastern part of Rajasthan state and covers a geographical area of 26.96 lakh ha and 7.87 per cent area of the state. It includes the districts of Bundi, Kota, Jhalawar districts and two tehsils viz. Sawai Madhopur and Khandar of Sawai Madhopur district. The Chambal is the main river along with its main tributaries like Parvati, Kali sindh, Parwan and Banas. The development of canal irrigation has made this area rich in agricultural production. The region has warm summers but mild winters. Summer temperatures sometimes touch 45°C. The annual rainfall varies from 60 to 85cms (Ghosh 1991, Sharma1994).
2. Flood Prone Eastern Plain Zone (Zone III-B):

Being a flood prone zone the water availability in natural depressions in the Bharatpur district in general is water rich and Keoladeo Ghana National Park is a natural depression wetland that has supported a natural population of resident and migratory waterfowl including Sarus Cranes.

The Zone III-B consists of the districts of Alwar, Bharatpur, Dholpur and Sawai Madhopur and covers a geographical area of 23.68 lakh ha. The entire region is a flood plain of the Banganga and the river Ghambiri. The annual rainfall average being about 75cms. A network of canals drawn from the upper Yamuna Canal and the Panchana Dam irrigate this area.

Fig 2 Map showing the Agro-climatic Zones in Rajasthan



Source: Ghosh 1991.

3.4 Geology and soils of Rajasthan and the two study district

The geological sequence of the state is highly varied and complex, revealing the co-existence of the most ancient rocks of Pre-Cambrian age and the most recent alluvium as well as wind-blown sand. The Aravallis, one of the most ancient mountains in the world, have the oldest granite and gneissic rocks at their base (Sharma1994). The dominant physiographic feature of Rajasthan is the Aravalli Mountain Chain, which traverses it from near Delhi in the northeast to northern Gujarat in the southwest (Mani 1974). Rajasthan is endowed with continuous geological sequences of rocks from the oldest Archaean Metamorphites, represented by Bhilwara super group to subrecent alluvium and wind blown sand. The western and northwestern parts of the state are covered by vast blanket of unconsolidated deposits including the blown sand of the Thar desert (Sharma 1994). The remaining area exposes to a wide variety of hard rocks which include various types of metamorphic schist, quartzites, marbles and gneiss of Pre-Cambrian age with associated acid and basic intrusive rocks. The sedimentaries include the rocks of Aravalli super Group, Delhi Super Group, Upper Precambrian Vindhyan Super Group and of Cambrian to Jurassic, cretaceous and Tertiary periods (Mani 1974, Wadia 1973). The south extremity of the state is occupied by a pile of basic flows of Deccan Traps of Cretaceous period (Bakliwal 1993).The Great Boundary Fault, through which river Chambal has covered its course, passes through southeastern parts of the state. This Fault is visible at Begun in Chittorgarh district and northern parts of Kota. This fault reappears again in Sawimadhpur and Dholpur districts (Sharma1994 & Anon 1996).The soil of Rajasthan are complex, highly variable, reflecting a variety of parent material, physiographic land features range if distribution of rainfall and its effect, etc. However broadly, the soils can be put in five major groups, based on fabric of soils, ie. Soil texture which governs its many other properties. They are 1. Sandy soils or light soils, 2. Sandy loam or light medium soils, 3. Loam or medium soils, 4. Clay-loam to clay or heavy soils and 5. Skeletal soils or shallow rocky and hilly soils (Shetty & Singh 1987, Anon 1996).

a. Soil in Kota

In the Kota district soil are in general black and deep and are well drained. Eastern area and western area of Rajasthan has mixed red and black and the western area red and yellow soils (Pal 1993). The medium black soil group is mostly found in Kota. It may be heavy, medium and yellow and red light.

b. Soil in Bharatpur

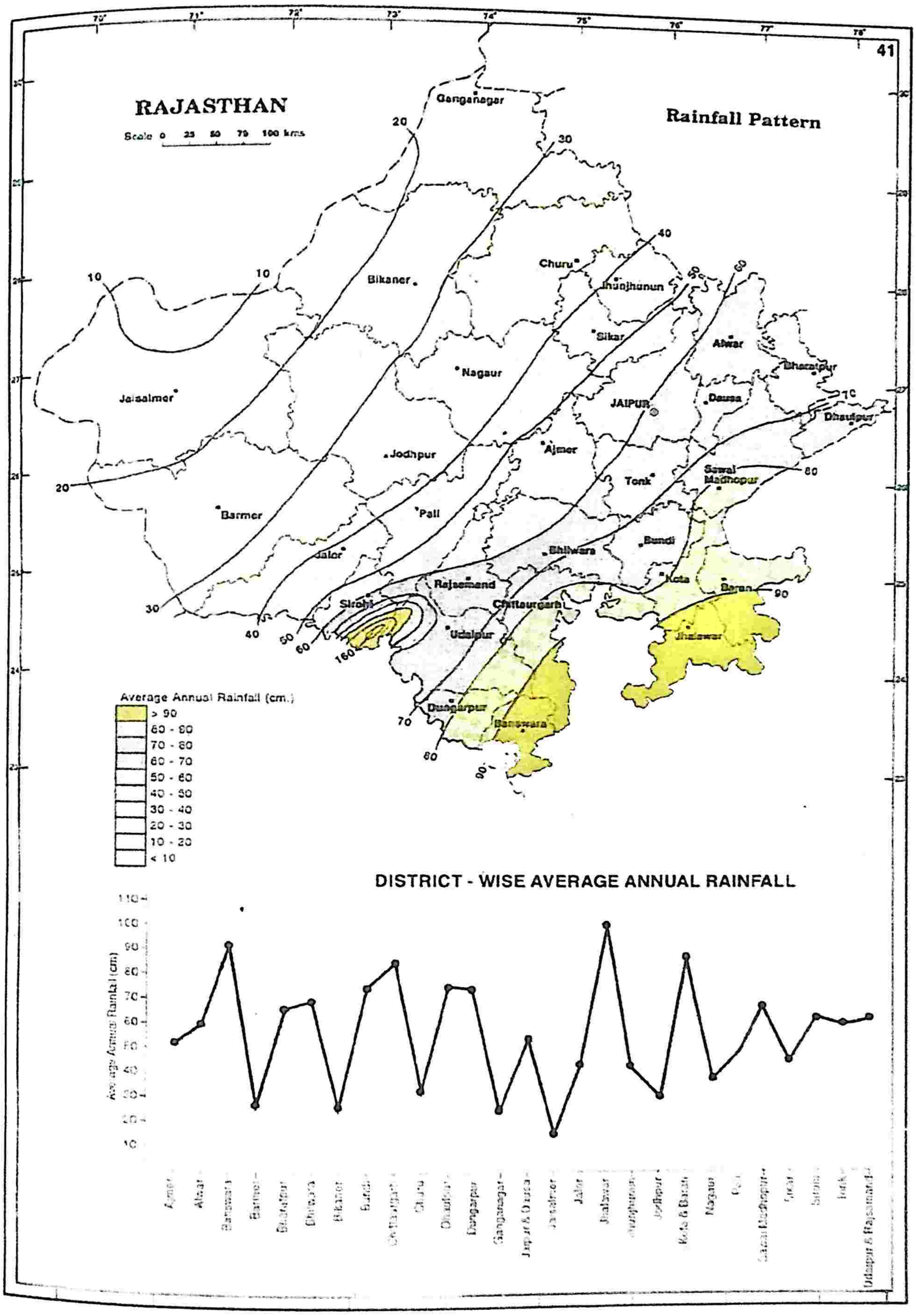
The soil is alluvial and at many places the saline patches can be seen. The soil group found in Bharatpur district is alluvial soil. They are deficient in lime, phosphoric acid and humus. This soil produces a large variety of crops including wheat, rice, cotton and tobacco.

3.5 Climate of Rajasthan and the two study areas

3.5.1 Climate in Kota

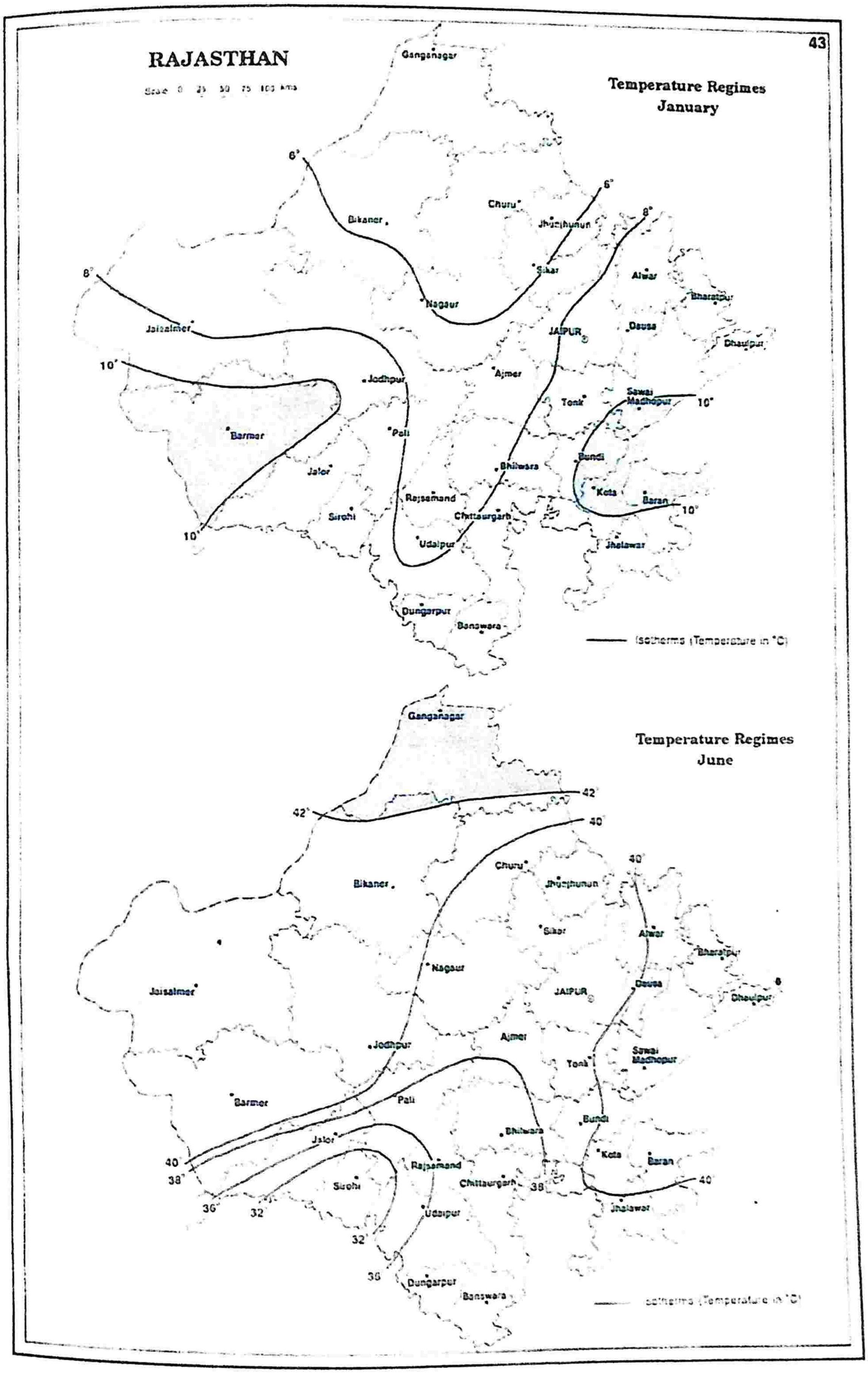
The climate of Rajasthan state varies from arid to sub-humid. To the west of the Aravalli range, the climate is characterized by low rainfall with erratic distribution, extremes of diurnal and annual temperatures (Fig 3 & 4). The climate of the Kota district is sub-humid to semi arid, but has remained mostly semi-arid, and comes under Zone 4B of Biogeographic classification (Rogers *et al.* 2002). It experiences climatic extremes from a hot, dry summer (April to June) to a cold winter (November to January) and Monsoon (July to September) seasons. The temperature ranges from minimum of 11.6° C to 24.5° C in winter to maximum of 42.6° C to 29.7° C in summer and receives annual total rainfall up to 760mm and number of rainy days are 35. The temperature and rainfall pattern in Kota district during 2000-2002 (Fig 5&6).

Fig 3 Rainfall Pattern in the state of Rajasthan.



Source: Sharma 1994

Fig 4 Temperature in the state of Rajasthan



Source: Sharma 1994

Fig 5 Temperature of Kota district during 2000-2002 study period.

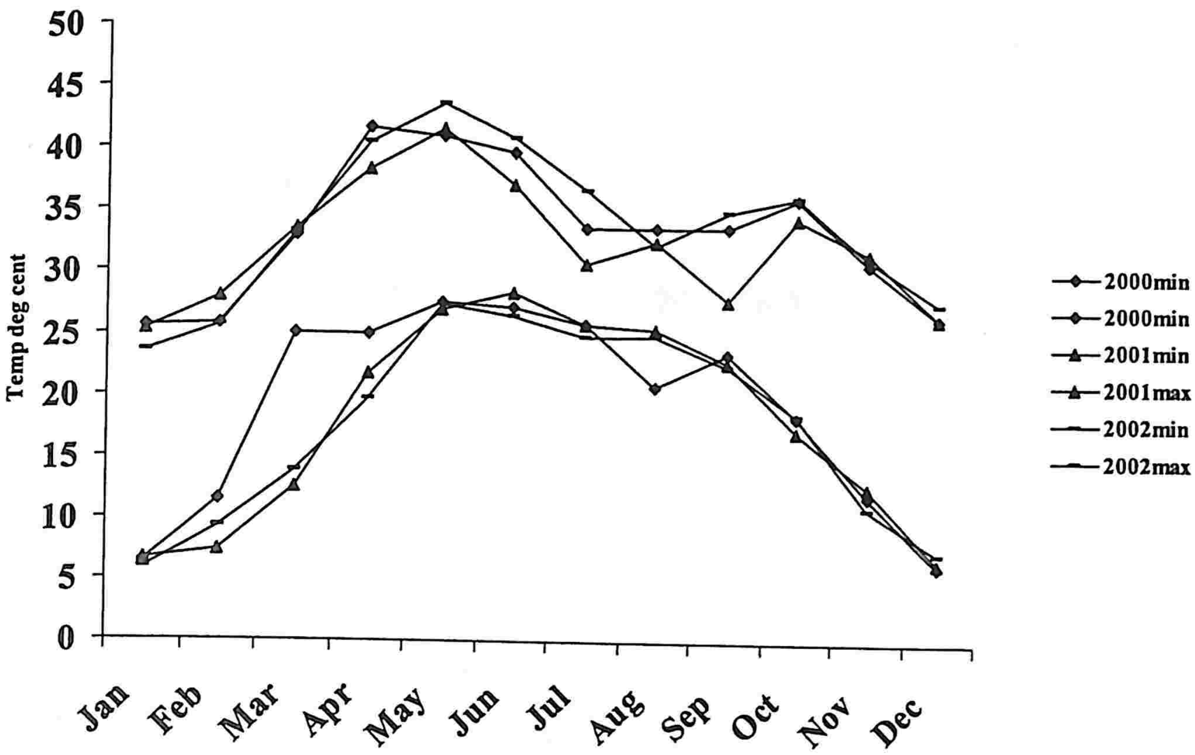
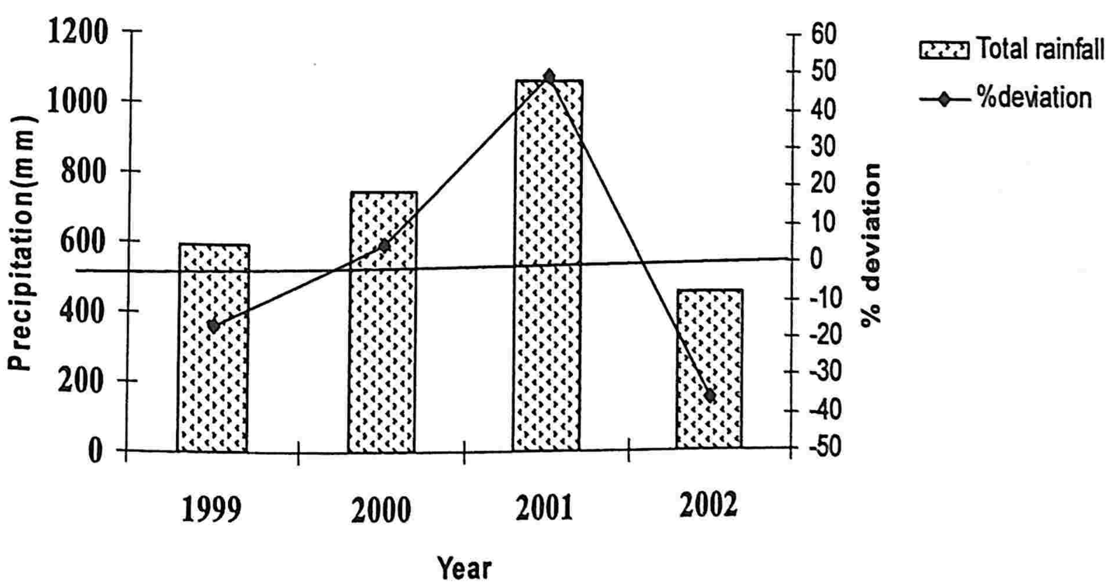


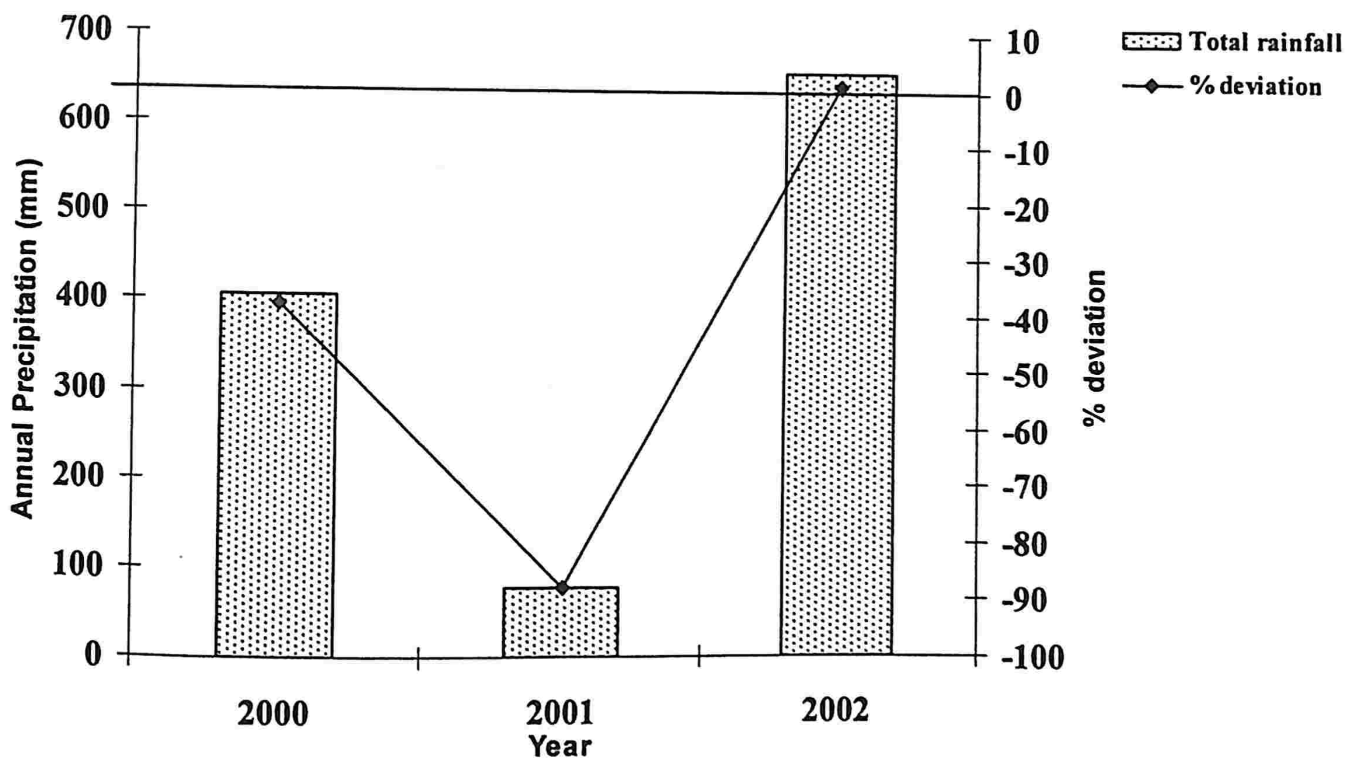
Fig 6 Total Rainfall in the district Kota (1999-2002)



3.5.2 Climate in Bharatpur

The climate of the area is sub-humid to semi arid, but has remained mostly semi-arid during the 1981-91 decade. Bharatpur experiences climatic extremes from a hot, dry summer (April to June) to a cold winter (November to January) and short monsoon (July to September) and post monsoon (September to October) seasons. The temperature ranges from minimum of 0° C to 20 ° C in winter to maximum of 48 ° C to 50 ° C in summer (Vijayan 1991). Fig 7. Showing the rainfall pattern in Bharatpur district.

Fig 7 Total rainfall in Bharatpur district (2000-2002).



3.6 People and Occupation

People of various castes and sub-castes reside in Rajasthan. The Rajputs, who were the rulers of most of the erstwhile princely states of Rajasthan, form a major group of residents of Rajasthan. Rajputs are generally stoutly built people of good height. The Rajputs generally worshipped the Sun, Shiva, and Vishnu. Vedic religion is still followed by the Rajputs. All the auspicious and inauspicious activities are done in accordance to the Vedic traditions. The other castes found in Rajasthan are Brahmins and Vaishya.

The generality of the people of Rajasthan is of the Indo-Aryan type. Their stature is mostly tall, complexion fair, eyes dark, head long and nose narrow and prominent. Over 80 per cent of the people of Rajasthan live in villages. Their chief occupation is agriculture. But about 30 per cent of them are landless labourers including village artisans like blacksmiths, carpenters, potters, shoemakers, leather dressers and petty shopkeepers. The chief components of the economic structure of Rajasthan are agriculture and allied activities like animal husbandry. About 70 per cent of the people earn their livelihood from these sources; only about 3 per cent are engaged in trade and commerce and a little over 6 per cent in cottage industry. The main organised industries are food processing and textile goods. Next to agriculture, animal husbandry occupies an important place in the economy of the state. It is the main occupation of the rural population in the arid and semi-arid zones. The livestock of Rajasthan constitutes about 11 per cent of the all-India total. It has 56 per cent of the camel population of the country and 9 per cent of the sheep population (Sharma 1994).

a. Kota

The major communities of people in the Kota district are Brahmins, Rajputs, Dhakads Gujjars, Muslims, Bhil. Kharif and Rabi are the two main crop seasons in the Kota district. The chief Kharif and Rabi crops are sown in June-July and October-November and harvested in September-October and March-April respectively. Cultivation of Paddy, Soyabeen is done during the monsoon where as wheat is grown in winter. The district was the largest producer of Jowar and linseed. Even in the case of wheat and other Rabi pulses. It occupied the second place in the entire state. The irrigational facilities available in the district are mainly in the form of canals followed by wells and tube-wells, due the perennial river Chambal which flow. The largest number of livestock found is cattle followed by goats, buffaloes, sheep, pigs, camel and horses (Bhatt 1997).

b. Bharatpur

The people surrounding the area are predominantly Jats, Vaishyas, Brahmins, Gujjars, Rajputs and Ahirs. Kharif, Rabi and Zaid Rabi are the principal crops in the district. Under Kharif crop, the main are rice, maize, jowar, bajra, urad, chaula, arhar etc and Rabi crop includes wheat, mustard, cumin seed etc. Zaid Rabi includes water melons, vegetables, fodder crops etc. The largest number of livestock found is cattle followed by buffaloes, sheep, goats, horses.

3.7 Flora and Fauna

The state of Rajasthan is endowed with a wealth of a wide range of vegetation which can be categorized into two distinct groups- one comprising the arid vegetation, falling western part of the state while the other belonging to semi-arid to sub humid one of the eastern and southern Rajasthan. The vegetation of western zone is characterized by sparse vegetation which is largely influenced by climatic edaphic and biotic factors. The vegetation of Rajasthan has been grouped on a broder scale, in the following types (Sharma 1994):

1. Calligonum-Haloxyion type
2. Salvadora Oleoides-Euphorbia canducifolia type
3. Zizypus nummularia-Capparis decidua type
4. Suadea fruticosa-Salsola baryosma type
5. Prosopis-Capparis-Zizyphus type
6. Prosopis-Tecomella type
7. Prosopis cineraria-Accacia nilotica type
8. Salvadora oleoides-Prosopis cineraria-capparis deciduas type
9. Acacia nilotica type
10. Acacia Senegal-Euphorbia caducifolia type.

B. Vegetation of Eastern Zone: It largely constitutes the plains, deeply buried or exposed pediment plains, valleys and the Aravalli range.

1. Acacia leucophloea-Prosopis cineraria- Acacia nilotica type
2. Acacia nilotica type
3. Acacia nilotica- capparis deciduas type
4. Butea monosperma
5. Anogeissus pendula
6. Tectona grandia
7. Mangifera indica

a. Kota

The western part of Deccan plateau extends to the southeast part of Rajasthan over Kota, Bundi and Jhalawar districts with the Vindhyan and Aravalli outliers (Shetty & Singh 1987). The vegetation of the Kota district has been described by (Champion and Seth 1968) a rich forest belt of mixed deciduous type, showing and altitudinal zonation of the vegetation to the extent that *Adina, Aegle, Boswellia, Buchanania,Lanzen, Cassia fistula, dendrocalamus, Diospyros,* Lagerstroemia, Lannea, Sterculia etc. are more abundant in the middle zone, while *Acacia leucophloea, Butea monosperma* etc. are abundant at the foot or outskirts. *Anogeissus pendula* is the dominant species of these forests extending right from the base to the top of the hills. These forests are concentrated mainly in the southwestern and central portions on the Mukundara hills. The main species of flora found in *Anogeissus Pendula* forests are Dhokra (*Anogeissus latifoloias Wall*) mixed with Gurjan *(Lannes coromandelica*), Bhel (*Aegle marmelos*), Tendu (*Diosoyros tomentosa*) etc (Shetty & Singh 1987).

Miscellaneous forests include Kherja (*Acacia leucophlae*), Khair (*Acacia catechu*), Bel (*Aegle marmelos*) etc. The *Anogeissus pendula* is the dominant species of these forests extending right from the base to the top of the hills (Shetty & Singh 1987). The commonly found grasses species Lapla (*Aristid depressa*), Polard (*Apluda mutica*), Ratarda (*Themeda quadrivulvis*), Surwal (*Heteropogan contortus*) and Karar (*Dichanthium annulatum*).

Among faunal species Black buck (*Antelope cervicpra*), Chinkra (Gazalla bentti), Blue bull (*Boselaphus tragocamelus*), Leopard (*Panthera pardus*), Sloth bear (*Melursus ursinus*), Jackal (*Canis aureus*) and Jungle cat (*Felis chaus*) have been reported from the Kota district (Bharat Singh *Pers. comm.*). The Great Indian Bustard is sighted from Sorson grassland Area. Two species of migratory Crane i.e. Common Crane (*Grus grus*) and Demoiselle Crane (*Anthropoides virgo*) are found in and around Right Main Canal of Chambal; the second breeding site of Painted storks after Keoladeo Ghana National Park (Nair 2006).

b. Bharatpur

The Forest is of dry mixed deciduous types. The general habitat of the park can be divided into the eleven major physiognomic types, as Forest, Woodland, Scrub Woodland, dense of continuous thickets, Scattered shrubs, Savannah-woodland to Scattered tree savannah, Shrub savannah, Grass savannah, Low grassland with scattered tree and shrubs, wetlands and Mosaic of several types (Vijayan, 1991). A total of 282 species of plants have been identified in the park, consisting 41 species of trees, 32 of shrubs 156 of herbs, 24 climber and 39 of grass among these grass which is *Paspalum distichum*, a perennial grass, is the most dominant species (Prasad *et al.*1996). The park has about 6 km² of grassland consisting of perennials such as *Cynodon dactylon*, *Vetiveria zizaniodes* and *Desmostachya bipinnata* annual such as *Dicanthium annulatum*, *Paspalidium punctatum*, *Sporobolus helvolus*, *Echinochloa colonum*, *Panicum antidotale*, *Paspalum species*, *Cyperus rotundus* and *Scrrpus tuberous* (Nanjappa 1986). Among faunal species, a total of 50 species of fish, 5 species of amphibians, 8 species of lizards, 13 species of snakes, 7 species of turtle, 375 species of birds and 27 species of mammals have been reported from the park (Vijayan 1991). A total of 35 species belonging to 19 genera of 7 families of butterfly have also been reported from the park.

3.8 Birdlife and Sarus Crane in Rajasthan with special reference to study sites

Rajasthan's birdlife has been well documented and the Sarus Crane in the state has been recorded since a very long time (Whistler 1949), with the first known behavioral observations on the species from the Keoladeo Ghana National Park (Ali 1958). Sarus Crane in the state have received increasing attention in the past couple of decades and several works describing local distribution and breeding ecology have made their way into notice largely by the BNHS in Keoladeo Ghana National Park (Kulshreshta & Vyas 1989, Ramachandran & Vijayan 1994). The other major work on Sarus in the state has been carried out by the Hadoti Naturalist Society based in Kota and most of their work had been in wetlands around Kota districts. Their pioneering work in the state has confirmed eastern Rajasthan in general and the districts of Kota, Bundi, Baran, Jhalawar to be one of the more densely Sarus-populated areas in the state (Vyas 1999a,Vyas 1999b) and these are the only bench mark information available from the state where the present study conducted some of its intensive investigations. During Wildlife Institute of India detailed survey in 1998-99, in twenty one districts of the state, 618 individuals of Sarus Cranes were counted in the state, of which 253 in the summer and 366 in the winter. Few districts in southeast Rajasthan (namely of Bundi, Kota, Bharatpur, Baran, Jhalawar and Dhoulpur) and southern Rajasthan (namely Chittorgarh, Bhilwara, and Banswara) accounted for more than 80% of the species population in the state. The local abundance of Sarus Crane during both seasons showed that Kota and Tonk were the two districts to record higher counts in summer while other districts showed higher Sarus Crane abundance during the winter period of the survey. More breeding pairs were recorded in winter as compared to summer (20.18%) breeding pairs in summer; 29.4% breeding pairs in winter). More families were observed with two juveniles each in winter (n=9) (Sundar *et al.* 1999). Sarus Crane occurrences from the state of Rajasthan are shown in (Table 1 and Fig 8).

Sarus Crane Population in Kota and Bharatpur district of Rajasthan.

The surveys and regular counts of Sarus Crane in Kota and Bharatpur districts were done by many authors during different period of time. In the year 1989 Gole had counted 386 Sarus Cranes from the 15 districts of Rajasthan. He estimated a population 1373 Sarus in Rajasthan. The estimated a population of Sarus Crane in Kota district, were a total of 82 Sarus Cranes (68 Adults, 2 Sub adults, 8 Juveniles and 4 Chicks were recorded during October to February survey (Vyas 1999a). They counted 58 Sarus Cranes in Bharatpur district mainly concentrated in Keoladeo National Park and Ajan. During 1998-99 Wildlife Institute of India survey the district of Kota and Bharatpur were surveyed and counts differed with season and the differential amount of wetlands available was probably the major cause. Kota district showed higher counts in summer and other districts higher abundance was recorded during the winter. During the summer survey a total of 57 Sarus Cranes were counted which include 7 Juveniles and during winter 29 Sarus Cranes (include 7 Juveniles).
In Bharatpur district a total of 21 Sarus recorded during summer (4 Adults, 2 Sub adults in KGNP, Outside KGNP 14 Adults, and 1 Sub adults). During winter count a total of 35 were counted in the Bharatpur district (16 Adults, 4 Juveniles in KGNP, and Outside KGNP 14 Adults and 1 Juvenile).

During Sarus Crane Count from 1999 till 2001 by Wildlife Institute of India, 1999 a total of 28 Sarus (1 Sub adult were counted in Kota and in Bharatpur 28 Sarus Crane 26 Adults, 2Juveniles) were counted inside KGNP and 54 Sarus crane outside KGNP (39 Adult and 15 Sub adults) (Choudhury *et.al* 1999). In the count of 2000 30 Sarus

Cranes were recorded from Kota district which include 2 Sub adults and during 2001 a total of 58 Sarus Cranes were counted which include 1 sub adult (Kaur *et.al* 2001). No counts were done in Bharatpur district during the year 2000 and 2001. Sarus Crane population shows a sharp decline as compared to 21 years from first count of 258 during 1983 to 19 Sarus Crane in 2004 inside the Keoladeo National Park on 22nd Sarus Count. Outside Keoladeo National Park 16 Sarus Crane were counted during 1986 and 22 Sarus Crane during 2004 were counted (Krishna 2004).

Fig 8 Occurrence of Sarus Crane in the districts of Rajasthan

Table 1 **Current Occurrence of Sarus Crane (*Grus antigone*) in the districts of Rajasthan**

S.No	Districts	Sighting of Sarus Crane	Source of Information
1	Ajmer	Reported	Gole 1989, Sundar *et.al* 1999
2	Alwar	Reported	Gole 1989, Sundar *et.al* 1999, Choudhury *et.al* 1999, Kaur *et.al* 2001
3	Banaswara	Reported	Gole 1989, Sundar *et.al* 1999
4	Baran	Reported	Sundar *et.al* 1999
5	Barmer	Reported	Sumit Dookia pers. comm.
6	Bharatpur	Reported	Walkinshaw 1973, Gole 1989, Ramachandran &Vijayan 1994, Sundar *et.al* 1999
7	Bhilwara	Reported	Gole 1989, Sundar *et.al* 1999
8	Bikaner	Not reported	Asad Rahmani pers.comm.
9	Bundi	Reported	Gole 1989, Vyas 1999a, Sundar *et.al* 1999
10	Chittorgarh	Reported	Sundar *et.al* 1999,
11	Churu	Not reported	Harkirat Singh Sangh pers.comm.
12	Dausa	Reported	Sundar *et.al* 1999
13	Dhoulpur	Reported	Gole 1989, Sundar *et.al* 1999
14	Dungarpur	Reported	Kaur *et.al* 2001
15	Ganganagar	Not reported	Harkirat Singh Sangha pers. Comm.
16	Hanumangarh	Not reported	Harkirat Singh Sangha pers.comm.
17	Jaipur	Reported	Sundar *et.al* 1999
18	Jalor	Not reported	Sundar *et.al* 1999
19	Jaisalmer	Not reported	Harkirat Singh Sangha pers. comm.
20	Jhalawar	Reported	Sundar *et.al* 1999

21	Jhunjhunun	Not reported	Harkirat Singh Sangha pers. comm..
22	Jodhpur	Reported	Himmat Singh pawar pers. comm.
23	Karauli	Not reported	Ansar Khan pers. comm..
24	Kota	Reported	Sundar *et.al* 1999, Vyas pers. comm.
25	Nagaur		Sundar *et.al* 1999
26	Pali	Reported	Gole 1989, Sundar *et.al* 1999,.
27	Rajsamand	Reported	Gole 1989
28	Sawai Madhopur	Reported	Gole 1989, Sundar *et.al* 1999
29	Sikar	Not reported	Harkirat Singh Sangha pers.comm.
30	Sirohi	Not reported	Harkirat Singh Sangha pers.comm.
31	Tonk	Reported	Sundar *et.al* 1999
32	Udaipur	Reported	Sundar *et.al* 1999

3.9 The two intensive study sites in semi-arid region in Kota and Bharatpur

Since the rationale and objective of the study was to examine low land use practices particularly from agriculture and cropping pattern in the semi-arid zone and its impact on the Sarus habitats and thereby the biology. The present work was carried out in the semi-arid tracts of Rajasthan state.

The present study was conducted in a semi-arid tract of Kota, and Bharatpur districts of Rajasthan, which is situated (25 °10' N 75° 52'E and 27 °7'6" N 27 12'2" and 77 °33'9') in the southern part of the state in the northwestern part of India.

In study area the Sarus population have been well distributed but in recent years appeared to be declining. If the Sarus Crane have adapted to a semi-arid landscape the study intends to examine these adaptation for the survival and how the changing landscape impacts the adapted biology of the species

3.9.1 Kota Study Area

Kota is on a high sloping table and forming a part of the Malwa Plateau and the Mukandara hills run from southeast to northwest axis of the town, with an altitude of 251.1m. The total area of the district is 5480.6 sq.kms. It is located on the eastern bank of Chambal River and is drained by its tributaries. The population of Sarus Crane in Kota is dependent mainly on canal systems and natural wetlands. Several wetlands and grasslands mosaic where population of resident Sarus Crane occurred, were identified as Intensive Study Population (ISP) in Kota district (Fig 9&10). Kota district is situated along the bank of river Chambal and is relatively well irrigated by the canal network of Kota barrage, resulting in reedy marshes and marginal wetlands supporting a fairly good breeding population of Sarus Cranes (Vyas 1999a, 1999b, Sundar *et al.* 2000b). The following table shows the man-induced wetlands and natural wetlands in Kota districts (Table 2 & Fig 9 & 10) where the study was conducted.

Table 2 **Wetland in Kota districts of Rajasthan study area**

Wetland	Lat, long	Wetland type	No. of Sarus Crane	Seasonality of wetlands
1. Sursagar		Man-induced wetland	2	July till February first week
2. Raipura	25°09,24N, 75°52,97E	Man-induced wetland	2	July till February
3. Ummedganj	25°06,92N 75°5530E	Man-induced wetland	6	July till February
4. Railgaon	25° 08,00N 76° 09,25E	Man-induced wetland	4	July till February
5. Janakpur	25°06'0N 76°09'60E	Man-induced wetland	2	July till February
6. Amalsara	25°16,11N 76°14'18E	Man-induced wetland	2	July till February
7. Arnetha	25°24'15N 75°02'01E	Man-induced wetland	2	July till January
8. Lakhava	25°05' 23N 75° 50'40E	Natural wetland	4	July till January
9. Ranpur	25 02'22N 75 49'39E	Natural wetland	4	July till February
10. Alynia	25°00'19N 75°52'38E	Natural wetland	10	July till May
11. Haripura	25°06'53N 75°55'05E	Natural wetland	2	July till January
12. Boravas	25°01'35N 75°41'34E	Natural wetland	2	July till Februaury
13. Badjillia	25°02'18N 76°06'15E	Natural wetland	2	July till Janauary
14. Kurar	25°10'18N 75°52'47E	Natural wetland	2	July-January
15. Rajpura	25°07'41N 76° 02' 29E	Natural wetland	2	July till February
16. Abheda	25°12'0N 75°47'25E	Natural wetland	2	July till March
17. Dayra	25°10'20N 76°0'58E	Natural wetland	2	July till February
18. Polai	25°10'17N 76°03'15E	Natural wetland	2	July till April
19. Karadia	25°10'06N 76°05'40E	Natural wetland	2	July till Februaury
20. Brijpura	25°05'14N 75°50'43E	Natural wetland	2	July till April
21 Godylahedi	25 08'49 N 75 01' 51E	Natural wetland	2	July till February

Fig 9 Location map of study area in Kota, Rajasthan

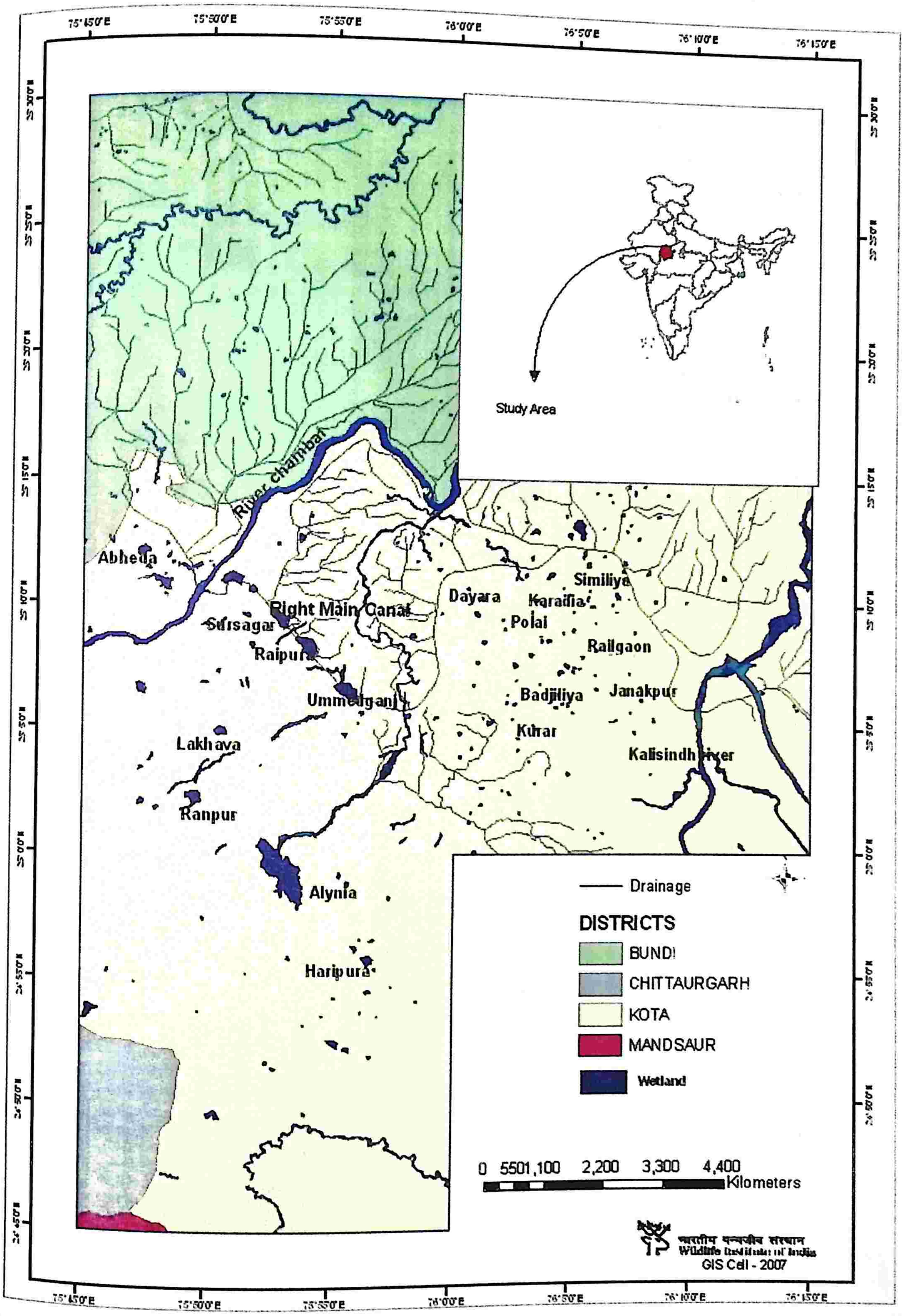
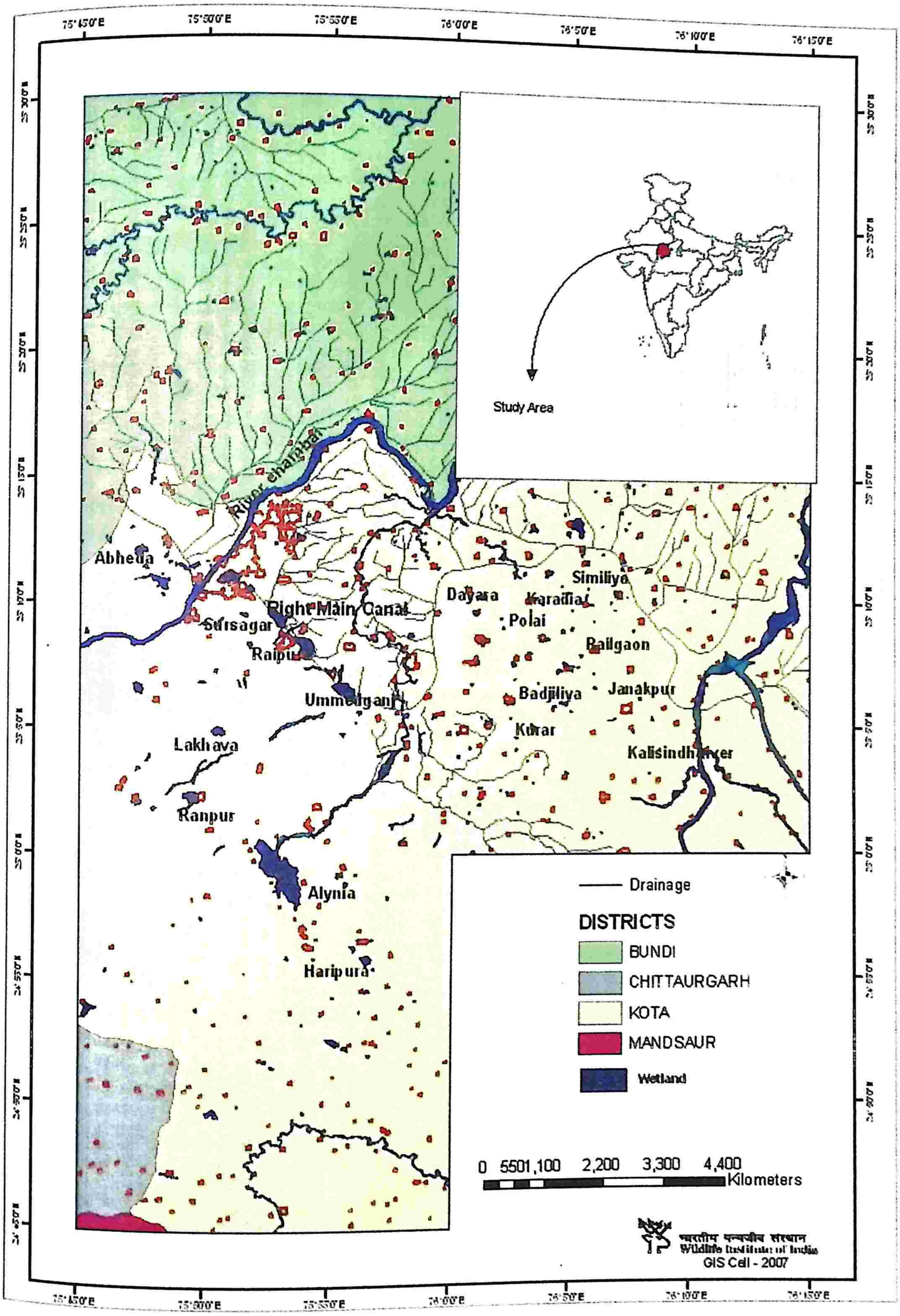


Fig 10 Settlement map of study area in Kota, Rajasthan



3.9.2 Keoladeo Ghana National Park

Bharatpur district is located on the north eastern part of the Rajasthan state in the undulating flat Yamuna river flood plains. The district because of its topography is eroded with many natural depressions holding a large volume of rain water. However being flat in nature, the water does stored overflows into flatters surroundings areas, the sooner the number of rainy days become continues, thus making the district a flood prone area. The natural depression wetlands however are short lived as the water gets evaporated in the extreme hot and arid climate. In a situation of this kind, there are a series of traditional and man-made water storage and harvesting structures created which serve as wetlands supporting resident and migratory avifauna.

Keoladeo Ghana National Park, a natural depression which was one of the intensive study site, lies on the extreme western edge of the Gangetic basin and is the only natural wetland left in the Yamuna flood plains. It is situated between 27° 7.6' to 27 ° 12.2'N and 77 ° 29.5' to 77° 33.9'E, in Bharatpur district of Rajasthan (Fig 11). The terrain is almost flat with elevation varying from 173m to 176m above mean sea level with a gentle slope towards the central depression. The submersible area of about 900 ha is divided into various compartments by eastern dykes where sluice gates are built at strategic locations to regulate the water supply. The mean annual rainfall is 650mm. The wetland compartments are surrounded by terrestrial habitats of about 2000ha except in a small area on the northwest, which is contiguous with the agricultural fields of nearby villages (Ali, 1953). A masonry wall surrounding the border separates 29 km^2 Park from the surrounding agriculture fields. There are 18 villages around the park (Vijayan 1991, Vijayan 1994). The numbers of the Sarus have been monitored in

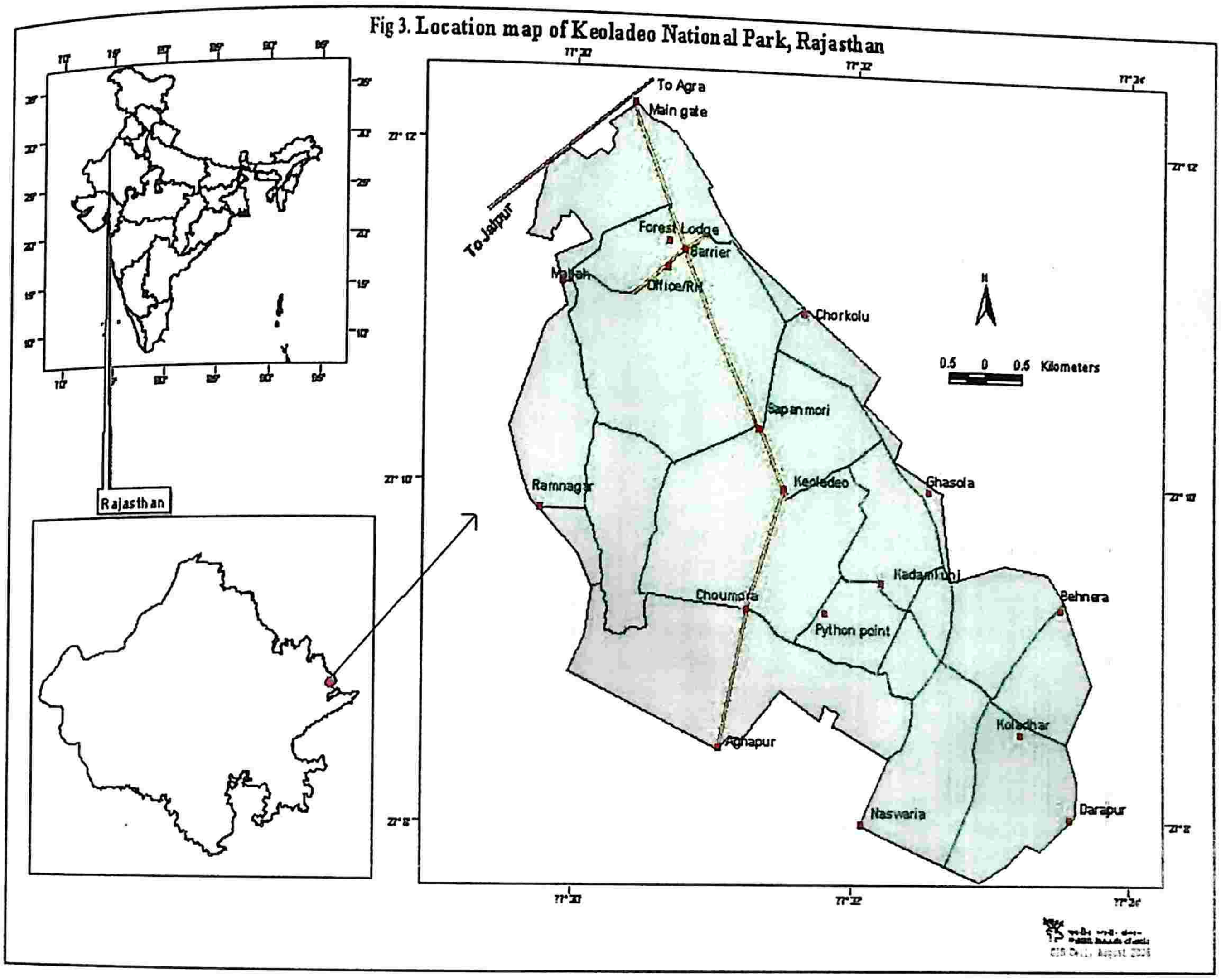
Keoladeo Ghana National Park (KGNP) since 1983 (Table 3). Bharatpur population of Sarus Crane in a wetland habitat, which is also a protected area.

Table 3 Annual Counts of Sarus Cranes in Keoladeo-Ghana National Park, Bharatpur.

Month	Day	Year	Sarus
April	15	1983	258
April	29	1984	657
April	14	1985	326
April	13	1986	299
April	19	1987	19
April	17	1988	59
April	16	1989	102
May	29	1990	1*
May	21	1991	8*
Feb	23	1992	40
March	3	1993	57
April	24	1994	59
April	29	1995	77
Feb	18	1996	34
April	15	1997	55
May	21	1998	59
April	25	1999	55
April	29	2000	61
April	21	2001	8
April	21	2002	14

Source : Krishna Kumar

Fig 11 Location map of Keoladeo Ghana National Park, Bharatpur



3.9.2.1 History of Keoladeo Ghana National Park

The National Park is located at the confluence of the Gambhiri and the Banganga rivers. Water from these reaches Keoladeo National Park through the Ajan Bundh Reservoir, which forms the major source of water to the wetland. The other sources to the park wetlands being direct rainfall and runoff water The Ajan bundh, is a temporary reservoir, situated about a kilometer from the present border of the park, constructed 150 years ago and the subsequent, several earthen bunds and sluice gates were constructed to contain and regulate the water level. Two major canals pass through the park, Chiksana and Ghana canal which are the major source of water in the park. The water is drawn through a canal from the Ajan bund during monsoon. However the water gradually recedes and the park dries up between February and May, leaving only some pools in the deeper areas. During this season the park is supplied water with water pumps, (from tubewells) therefore some resident species are able to survive and use the park for roosting including Sarus Crane and Black-necked Stork.

3.9.2.2 Water management

The quantity, quality and time to supply along with the duration of the dry period determine the biological cycles and the functioning of the wetland system (Vijayan 1991), has been observed in the case of many wetlands and marshes (Weller, 1999). As the water is let only for a short duration either during July-August or during August-September depending on the monsoon, the biological events in the calendar year are influenced by the rainfall and the quantum of water is received in the preceding year as well as the current year.

The rainfall in the area for the last hundred years was 655mm, for the decade of 1981-1991, it was 496mm. Drought was experienced in two consecutive years 1986 and 1987, when the rainfall was 425mm and 423mm respectively (Vijayan, 1991). The optimum amount of water for Keoladeo Ghana National Park has been assessed to be 14.0 million m^3 to be released in first and third weeks of July. Although this area has a history of floods and droughts, the frequency of these has changed over the decades during this century, with a decrease in floods but increase in drought during 1980s (Vijayan, 1991). Supply from Banganga has almost stopped and that from Gambhir is neither steady nor dependable which may be detrimental to wetland system. The water balance has been worked out and water budget for the park has been calculated to be 575.6 million cubic feet an year (Choudhury & Shiva Kumar 2000).

3.9.3 Watershed and Drainage in Rajasthan in the two study area

The area in the west of the Aravalli has inland drainage system with a large number of separate drainage basins like Kanti basin, Sota, Sahobi basin, Barah basin and misfit streams in Luni basin. The water in all these basins sinks into the desert tract. There is no perennial river in this physiographic unit. In the east of Aravalli, the river Chambal, its tributaries and rivulets form a network in the area. The Chambal originates in the Vindhyas and enters Rajasthan near Kaukhera village (Chittorgarh district) up to Kota city, it passes through bare rocks and hilly tract. Near Kota city, it enters the alluvial plains and passes through tectonic plain up to Sawaimadhopur. Ultimately Chambal joins the river Yamuna in Uttar Pradesh passing through Dholpur district (Shetty & Singh 1987). On its way, the river Chambal receives many tributaries like Kali Sindh, Parbati, Banas, Mej, Parvan etc. These tributaries are also fed by a number of riverlets like Kali Sindh by Amjhar, Parvan by Chhapi, Dhar, Ajnar, Ghora Pachhar and Nevas, Parbati by Andheri and Koolu, Mej by Talera and Mangli. The tributary Banas originates in the catchment area lying between Kankroli and Nathdwara and flows towards east up to Mandhalgarh and then towards north-east up to Tonk. Later it flows toward south to join Chambal. Its main feeding riverlets are Khari, Sodra, Mooshi and Morel on the left bank and Berach, Najaenand Galwa on the right. The bottom and beds of the rivers like Mahi and Chambal and most of the tributaries are stony. In the hilly tract they form deep gorges and in tectonic and sandy or alluvial plains form ravines which are very conspicuous in Kota, Sawaimadhopur and Dholpur districts (Anon 1996).

3.9.3.1 Kota and Chambal River Basin

The Chambal river originates from the summit of Janapav hill of the Vindhyan range at an altitude of 854m at 22° 27' N and 75 ° 37' E in Mhow, district Indore, Madhya Pradesh. The river has a course of 965 km up to its confluence with the river Yamuna in Etawah district of Uttar Pradesh (Nath 1989). From the place of its origin, the Chambal River flows for some 320 km in a generally northerly direction before entering a deep gorge which extends up to Kota and the river then flows for about 226 km in Rajasthan in a north-easterly direction, and then forms the boundary between MP and Rajasthan for about 252 km. Thereafter, the river forms the boundary between MP and UP for about 117 km, enters UP near Charak Nagar village and flows for about 40 km before joining river Yamuna (Hussain 2001). River Chambal, well known for its deep ravines, is the largest, with a catchments area of 139,789 sq.km (40% of the Yuman River basin). Arising from the northern flanks of the Vindhyan scarps in Indore district, it runs through a gorge in Malwa Plateau for about 325 km to Chaurasigarh and later through another 113-km-long narrow gorge in

Kota. The main tributaries of Chambal are Siwana, Retam, Shipra and Choti KaliSindh, Kuno and Kuanri in Madhya Pradesh; Kalisindh, Pravati, Parwan and Banas in Rajasthan. It runs through the Kota plain (215-275m altitude) to the north-east to meet River Yuman near Muradganj (Etawah district). The total length of the river upto its junction with Yamuna is 960 Km. (Gopal & Shah 1993, Krishnan 1982). The mean annual rainfall over the Chambal Basin was computed as 797 mm, of which about 93% falls during the four Monsoon months (June-September).

The Ghandhi Sagar Dam, the first and the largest dam across the river stand on the border of M.P. and Rajasthan. While Gandhi Sagar stores the Chambal water from 22,533 sq km of the catchment area and generates power, the Kota barrage on the same river releases water along the Left Bank Canal and Right Bank Canal. The Chambal irrigation project is one of the large interstate irrigation and power projects built in India soon after Independence. Its construction started in 1953 and water for irrigation became available as of 1960. The gross project area in Rajasthan is of 485000 ha, compared with a cultivable command area of 229000 ha. In (Kota and Bundi districts) and Madhya Pradesh (Kalwar 1999). The total length of branches, distributaries, etc in the project is 2342 km. The Left Main canal serves about 102000 ha of irrigated land and the Right Main canal 127 000 ha of irrigated land. In addition, the Right Main canal carries water to irrigate an area in the adjacent state of Madhya Pradesh. It is a unique example of a multi-purpose integrated project, basin wise planned through cooperative inter-state participation and also an excellent example of detailed and extensive water management. On the whole the command area is a large plain with an average slope of about one meter per kilometer or even less and has a high water table for a long time after the monsoon because of poor drainage in a pre-irrigation period.

3.9.3.2 Bharatpur and the Banganga Basin

The Keoladeo Ghana National Park the second intensive study area is in the Banganga river basin-a sub tributary to the Yamuna river basin. Banganga River Basin is located in the northeastern part of Rajasthan, between latitudes 26°40'N and 27°37'N and longitudes 75°49' and 77°39'. It lies between the Gambhir and Banas Basins to its south-southwest, Ruparail and Sabi to its north, and the Shekhawati Basin to its west. Its eastern edge borders the Yamuna River Basin in Uttar Pradesh. Banganga River Basin extends over parts of Alwar, Jaipur, Dausa, Sawai Madhopur and Bharatpur Districts. The total catchment area of the Basin is 8,878 km². River Banganga originates in the Aravali hills, near Arnasar and Bairath in Jaipur District. It flows towards the south up to the village of Ghat, then east through partly hilly and partly plain terrain. The total length of the river is 240 km. The main tributaries are Gumti Nalla and Suri River, joining the river on its right bank, and Sanwan and Palasan Rivers, meeting the river on its left bank. The mean annual rainfall over Banganga Basin was computed as 596 mm, of which about 95% fall during the four Monsoon months (June-September). The rivers has wide sandy bed which disappears in the plains of Bharatpur, the river has no continuity with river Yamuna although it lies in the Yamuna drainage. In times of flood, the waters generally flows towards east and are carried to river Yamuna through a natural drainage channel called Khari nalla/nadi which joins river Gambhir, south east of Fathehpur Sikri.

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CHAPTER 4

HABITAT USE PATTERN OF SARUS CRANE IN SEMI ARID LANDSCAPE

4.1 INTRODUCTION

Differential resource selection is one of the principal factors, which permit species to coexist (Rosenzweig 1981). It is generally assumed that animals will select a habitat that will be best able to satisfy its requirements and thus high quality resources will be selected more than low quality resources. But since availability is not uniform, use may change accordingly. Therefore, to determine resource selection used resource should be compared to available resources. Habitat according to (Odum 1975) corresponds to the address of an organism. Specifically, it refers to the physical and biological environment in which a species is usually found (Morrison *et al.* 1992). Interpreting species preference to certain habitat features from a human perspective is often ambiguous (Block and Brennan 1993) and also, describing habitat-animal association is scale dependent.

In reality species distribution/ habitat occupancy is primarily influenced by proximate and ultimate factors (Orians 1971). The proximate factors (otherwise called psychological factors) enable the species to motivate settling behavior, while ultimate factors influence the survival and reproductive success of individuals. Local habitat factors also have an important role in determining abundance and geographical distribution of species. Therefore, a clear picture on how the species is related to a given environment becomes essential to understand species biology and consequently, for conservation. Pattern of resource use and availability are commonly examined in avian ecology studies (Kevin 1990).

In order to develop, an effective conservation strategy for protecting a wild species it is often essential to know its detailed habitat requirements. Central to the study of animal ecology is the usage an animal makes of its environment: specifically, the kinds of foods it consumes and the varieties of habitats it occupies (Johnson 1980).

We need to find how habitat types within these areas and which of these are most important for its continued survival. In order to acquire this type of information, detailed studies of bird's location are required, often using such as banding of bird to get it's home range. Many studies of habitat use by wild animals use radio tracking as a source of data, to determine whether a species uses habitat available to it at random, to rank habitats in order of relative use, to compare use by different groups of animals (Aebischer *et al.* 1993).

Habitat needs for all birds including similar resources: water for drinking and bathing, food, cover for protection from the element and potential predators, and undisturbed space for meeting social and other life functions. But each group of birds adapts to general features of their typical habitat and exploits its particular resources (Weller 1999).

Cranes being long necked and long legged wading birds are adapted to life in wetlands. Their future depends upon on availability of wetland habitats (Harris 1992). The Sarus Crane is known to use a wide variety of habitats depending on breeding status, season, food availability and cropping patterns. They prefer a mosaic of natural wetlands comprising of marshes and ponds interspersed with agriculture fields (Gole

1989). They occasionally use braided stream, riverbanks and canal supported short duration wetlands for feeding purposes. Breeding pairs typically use larger wetlands wherever available but have been seen to use nearly every type of wetland, natural and manmade (Gole 1989). There have been few habitat preference studies on Sarus Crane in the recent past (Gole, 1989, Parashyra *et al.* 1989, Gole 1989, Kulshreshtha & Vyas 1989, Singh and Khan 1989, Ramachandran &Vijayan 1994, Sundar *et al. 2000b*). Gole (1989) reported that marshes and river banks and wet flood plains are the most preferred habitats of Sarus in Rajasthan, whereas cultivated fields are better frequented in Uttar Pradesh. The paddy fields are used by Sarus during monsoon and the marshes and reservoirs after November in north Gujarat (Parashyra *et al.* 1989). Moderately wet grasslands, dry grasslands and flooded grasslands are found to be most suitable habitat of Sarus in Keoladeo National Park, Bharatpur (Ramachandran & Vijayan, 1994). Interestingly a closely related Crane species of Australia, Brolga (*Grus rubcundus*) also shows similar preferences for shallow marshes and croplands (White 1983).

In areas with large wetland tracts, Sarus repeatedly use more wetlands (Vyas 1999a, Latt 2002), and in areas, where agriculture dominate, they use more crop fields (Mukherjee 1999). Information on seasonal changes in habitat use is available from only one area in Gujarat and shows that habitat use varied with season (Mukherjee 1999). Vyas 2002, studied habitat utilization by Sarus and importance of man- made wetland in Kota and his results reveals that 22.5% foraging Sarus Cranes were seen on the man made tanks and reservoir margins and 55.9% birds were associated with agriculture fields for food. Habitat use studies were conducted at a comparable time period, but data are presented as use by total number of birds counted (Sundar & Choudhury 2003), and very few studies have information for habitat use by groups

There have been no detailed habitat preference studies to date and further, it is necessary to determine if habitat changes in the landscape has any effect on the habits and survival of the Sarus.

A home range consists of a more or less restricted area within which an animal moves when performing its normal activities. Measuring an animal's, home range size, shape and pattern of utilization is important for most ecological and /or behavioural studies (Harris *et al.* 1990). The popular definition of home range is "that area traversed by the individual in its normal activities of food gathering, mating, and caring for young" (Anderson 1982). In other word home range area is often defined as the area demarcated by the minimum convex polygon (MCP) enclosing all relocations of the animal for a given period (Gautestad & Mysterud 1995).

Home range and habitat use of Florida Sandhill cranes were studied by Nesbitt *et al.*1990), the radio-marked sub adult and territorial adult cranes used home ranges averaging 21.32 sqkm and 4.47 sq km, respectively. It was influenced by season, social status and habitat quality. The size of the home range is examined in mammals and it is determined, mainly by the amount of energy expended by the species, and therefore the home range area may vary to the direct and indirect influences of weather and climate on the animal. But the kind of food that is utilized also influence home range size (Mcnab 1963). Harestad and Bunnett (1979) studied home ranges of intermediate size, but increase in body weight of omnivorous birds or mammals is not associated with as large an increase in home range or territory as is evident in either carnivorous or herbivorous forms.

The present study is first ever to study the marked individuals and to document home range and ranging pattern of breeding pairs with banded juveniles of Sarus Crane.

Besides, this chapter deals with the way the Sarus Cranes use habitat resources available to them in protected and unprotected environment.

Types of habitats used by Sarus Cranes in the study sites (Plate 1).

Marsh: The area formed by the seepage from the canal and non cultivable agricultural land turned into marshy areas due to water seepage from the reservoirs.

Agricultural fields with crops: Irrigated land and irrigation channels including rice fields, canals and ditches. Seasonally arable land.

Reservoir: These are the man made water bodies mainly for the purpose of irrigation to the agricultural area. They are perennial in nature. Human consumption with a pattern of gradual, seasonal draws down of water level.

Canals: Main and branch canal were meant for irrigation as well as drainage canal to remove excess water.

Fallow land: The fields left uncultivated for particular duration of time, commonly summer seasons in semi-arid region.

Ponds: A pond is typically a man made body of water smaller than a lake or small bodies of water impounded naturally.

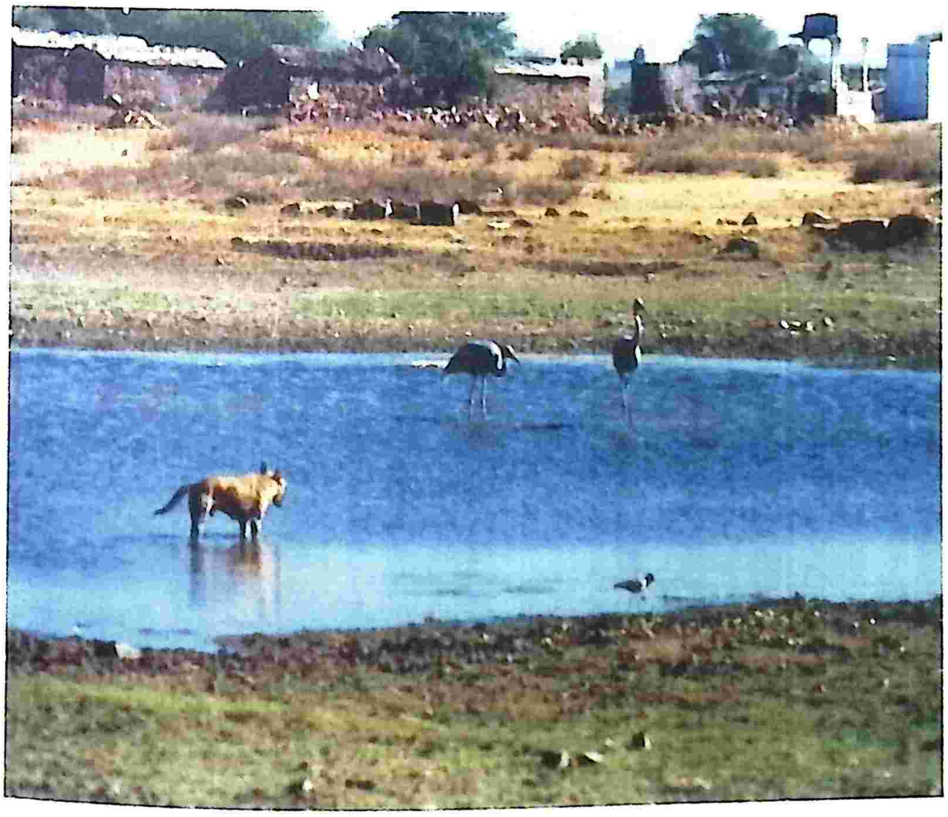
Scrub land: An area of land that is uncultivated and covered with sparse stunted vegetation.

Plate 1 **Types of Habitat used by Sarus Crane in Kota Study Area**

Marshes created by seepage of canals

Sarus Crane family in Wheat field

Sarus Crane using Reservoir



Sarus Crane in Pond

Congregation of Sarus Crane at River bed

Sarus Cranes in Scrub land

Juvenile banded with Plastic band

Since the study was conducted in the semi-arid landscape in Rajasthan state where water bodies (wetlands) are limiting factors, it was important to hypothesis and test the habitat use and home range concept in relation to periodicity of water availability and forage resources.

The Hypothesis made were

1. Home range of Sarus Crane will tend to be larger in semi-arid landscape because of lower periodicity of forage resources availability in all used habitat types.

2. In the semi-arid landscape the duration of water availability in wetlands influences the home range of Sarus.

3. In semi-arid landscape where natural wetlands are not prevalent the Sarus may use diversity of habitat types such as man-induced wetlands as well as to a larger diversity of natural and man-modified landscape including agricultural matrixes.

4.2 METHODS

4.2.1 Distribution of Sarus Crane in study area

In Kota field site where the wetlands were located mostly adjoining irrigation canal (see Chapter 3) a canal transect was carried out once every month on a motor bike at 20-25 kms/hr to check the abundance and distribution of Sarus Crane on both sides of the canal. The bike was stopped at all bridges on the canal and at the highest vantage point. The landscape around was scanned and number of Sarus Crane sighting was noted (Fig 1). Sarus Crane was sighted only from milestone number 7Km to 22 Km and 45Km to 55 Km. (Fig 1).

The data set was collected from January 2001 till May 2002 and encounter rate was calculated, by total number of Sarus Crane sighted in each month divided by total kilometer covered.

In Protected wetland site at Keoladeo Ghana National Park in Bharatpur, total count of Sarus Crane was done every week. The total count method was adopted to count Sarus Crane in Keoladeo Ghana National Park as all Sarus Crane in the wetland could easily be counted. The counts were done in all the blocks and data was collected from March 2000 till March 2002

At each observation following data was collected:

I Number of Sarus Crane pairs and families observed

II Number per group and families observed

4.2.2 Methods of banding

To determining the home range of breeding pairs with juveniles, colour banding on Sarus juveniles was carried out. They have been monitored from their natal grounds in monsoon and winter to the congregating wetland sites during peak summer during the study period at both the field sites. The rationale of tagging juveniles was to study the home range with the assumption that the breeding pairs with juveniles remain together till weaning away.

During the breeding season (July to October) of 2000 and 2001, twenty-three juveniles in Kota and five in Keoladeo Ghana National Park (KGNP) Bharatpur were captured. The juveniles were captured by running them down and each of the captured bird was color marked with unique plastic bands (Plate 1) in both the study sites (Table 1 & 2). These birds were monitored throughout the breeding season every second to third day until they weaned.

Table 1 **Detail of Colour banding of Sarus Crane juveniles in Kota during 2000 and 2001.**

Site and Types of wetland	Banding Date	No. of Juveniles banded	Location	Colour combination
Shyampura Natural wetland	15.11.2000	One par with 1 Juveniles	25°00,66N 75° 51,67E	LL Red R.L Green
Damdama Natural wetland	15.11.2000	One pair with 2 Juveniles	24°59,14N 75°52,33E	L.L Red R.L Yellow L.L Red R.L Black
Raipura Man-induced wetland	16.11.2000	One pair with 1 Juvenile	25°09,24N 75°52,97E	L.L Red R.L Blue
Ummedganj Man-induced wetland	17.11.2000	One Pair with 2 Juveniles	25°06,92N 75°5530E	L.L Red R.L Red L.L Yellow R.L Orange
Lakhava Natural wetland	10.11.01 11.11.01	One Pair with 2 Juveniles	25°05' 23N 75° 50'40E	R.L Red, Yellow (1st Juvenile) R.L Yellow, Red (2nd Juvenile)
Alynia Natural wetland	23.10.01 10.11.01	One Pair with 2 Juveniles	25°00'19N 75°52,38E	R.L Red. LL Orange (1st Juvenile) R.L White Green (2nd Juvenile)
Zetiya 1 Natural wetland	20.11.01	One Pair with 1 Juvenile	25°58,22N 75°54, 07E	R.L Red, Red (1st Juvenile)
Zetiya 2 Natural wetland	27.11.01	One Pair with 1 Juvenile	25°09,21N 75°52,47E	R.L Yellow (1st Juvenile)

Dadhdevi Man-induced wetland	27.10.2001	One Pair with 2 Juveniles	25°07,01N 75°54,55E	R.L Red, L.L Black (1st Juvenile) R.L Red L.L Green (2nd Juvenile)
Ummedganj Overflow Man-induced wetland	27.10.2001	One Pair with 2 Juveniles	25°07,03N 75°55 17E	R.L Red L.L Yellow (1st Juvenile) R.L Red L.L Blue (2nd Juvenile)
King Palace Man-induced wetland	6.11. 2001	One pair with 1 Juvenile	25°07,25N 75°56,14E	R.L Red White (1st Juvenile)
Sursagar Man-induced wetland	24.11.2001	One pair with 1 Juvenile	25° 09,21N 75° 52,47 E	R.L White Green (1st Juvenile)
Sorson 1 Man-induced wetland	21.11.2001	One pair with 2 Juvenile	25° 08,00N 76° 09,25E	R.L Red Cream (1st Juvenile) R.L Black Yellow (2nd Juvenile)
Sorson 2 Man-induced wetland	21.11.2001	One pair with 2 Juveniles	25° 07,30N 76° 09,19E	R.L Yellow Yellow (1st Juvenile) R.L Orange Black (2nd Juvenile)
Sorson 3 Man-induced wetland	12.11. 2001	One Pair with 1 Juvenile	25° 06,22N 76°09,31E	R.L White Blue (1st Juvenile)

L: Left Leg , R.L: Right Leg

Table 2 Detail of Colour banding of Sarus Crane in Bharatpur during 2000 and 2001

Sites	Banding Date	No. of Juveniles banded	Location	Colour combination
Keoladeo Ghana National Park(E-Block and L-Block)	1.12.2000	One pair with one Juvenile and one pair with 2 Juveniles	27°11,31N 77°30,68 27°09,68N 77°32,00E	L.L Blue R.L Red L.L Yellow R.L Red L.L Green, Black R.L Red
D-block	5.11.2001	One Pair with 1 Juvenile	-	R.L Red L.L Green Orange (1st Juvenile)
L-Block	5.11. 2001	One Pair with 1 Juvenile	27°09,68N 77°32,00E	R.L Red L.L Yellow White (1st Juvenile)

L.L : Left Leg , R.L: Right Leg

4.2.3 Estimation of breeding territories

Observations on the breeding pair with banded juveniles were recorded every second day using Global Positioning System (GPS) and the coordinate values were plotted on study area map. The Animal Movement 2.04 program was used for home range analysis and the estimates for both the field sites were obtained based on Fixed Kernel (95%) and Minimum Convex Polygon (100%). In the year 2001-02 breeding seasons, a total of eleven families in Kota and two in Bharatpur were monitored and home range of these thirteen families were calculated (Table 4 & 5). Seasonal home ranges of breeding pair of Sarus Crane with banded juveniles were represented by winter (September- February) and summer (March-June). A total of 13 breeding pairs with banded juveniles were monitored and most of the home ranges were stabilized at 110 location point; therefore 110 minimum points are required for home range stabilization (Table 4).

4.2.4 Habitat Use and Availability

Sightings records of Cranes were plotted on the land cover map of Kota and Bharatpur sites (See Chapter 7) and distribution of observation points in each land cover category was summarized to represent relative use of the habitat by the species. On the same images, thousand random points were generated to estimate habitat availability. Both used and availability points were compared and analyzed using Ivlev index and to understand resource use pattern by Sarus Crane in the study area.

Ivlev = (U-A/U+A), where U= Use and A= Available.

The index provided the basis for ranking the relative habitat preference by Sarus Crane for different land cover categories. Non-parametric One-Way Anova (Kruskal-Wallis test) was performed to test for significant difference in the use pattern by Sarus Crane (Zar 2003). The compositional analysis (Aebischer *et al.* 1993) and chi square (Neu *et al.* 1974) were done for habitat use and availability. The home ranges calculated by Kernel method were overlaid on the land cover category map and the proportional usage of these categories was determined. The information on habitat use by Sarus Crane was also obtained during behavioural study and these data were also used to analyze habitat use pattern by Sarus Crane.

4.3 Results

4.3.1 Distribution of Sarus Crane

In Kota Study Site

From the results it indicates that the abundance and distribution pattern of Sarus Crane is seasonal all along the canal in Kota study site and number increases during the month of summer and winter. The highest encounter rate of 2.74/Km Cranes was recorded during the month of May 2001, when Sarus congregate on river bed of Kalisindh. During winter most of the Sarus Cranes pairs were observed with the juveniles and 0.81/Km& 0.88/Km Cranes were encountered during the month of winter study area (Fig 2).

During the year 2002 canal was traversed from January till May 2002, and by comparing with previous year the encounter rate of 2.81per Km cranes was recorded during summer month. This is due to as summer starts and water starts drying up in the adjoining area the Sarus Cranes starts congregating all along the river bed of Kalisindh and Chambal (Table 3). The following two figures show the distribution of Sarus Crane all along the canal in Kota (Fig 2 & 3). The distribution of Sarus Crane in study area (Fig 1) along the canal and other surrounding wetlands.

Table 3 **Distribution pattern of Sarus Crane in Kota study area during the year 2000-2002.**

Wetland	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
In canal side wetlands	+	+	+	-	-	-	+	+	+	+	+	+
In River bed	-	-	+	+	+	+	-	-	-	-	-	-

(+): Sarus Crane present

(-): Sarus Crane not present

Fig 1 Distribution map of Sarus Crane in Kota district, Rajasthan

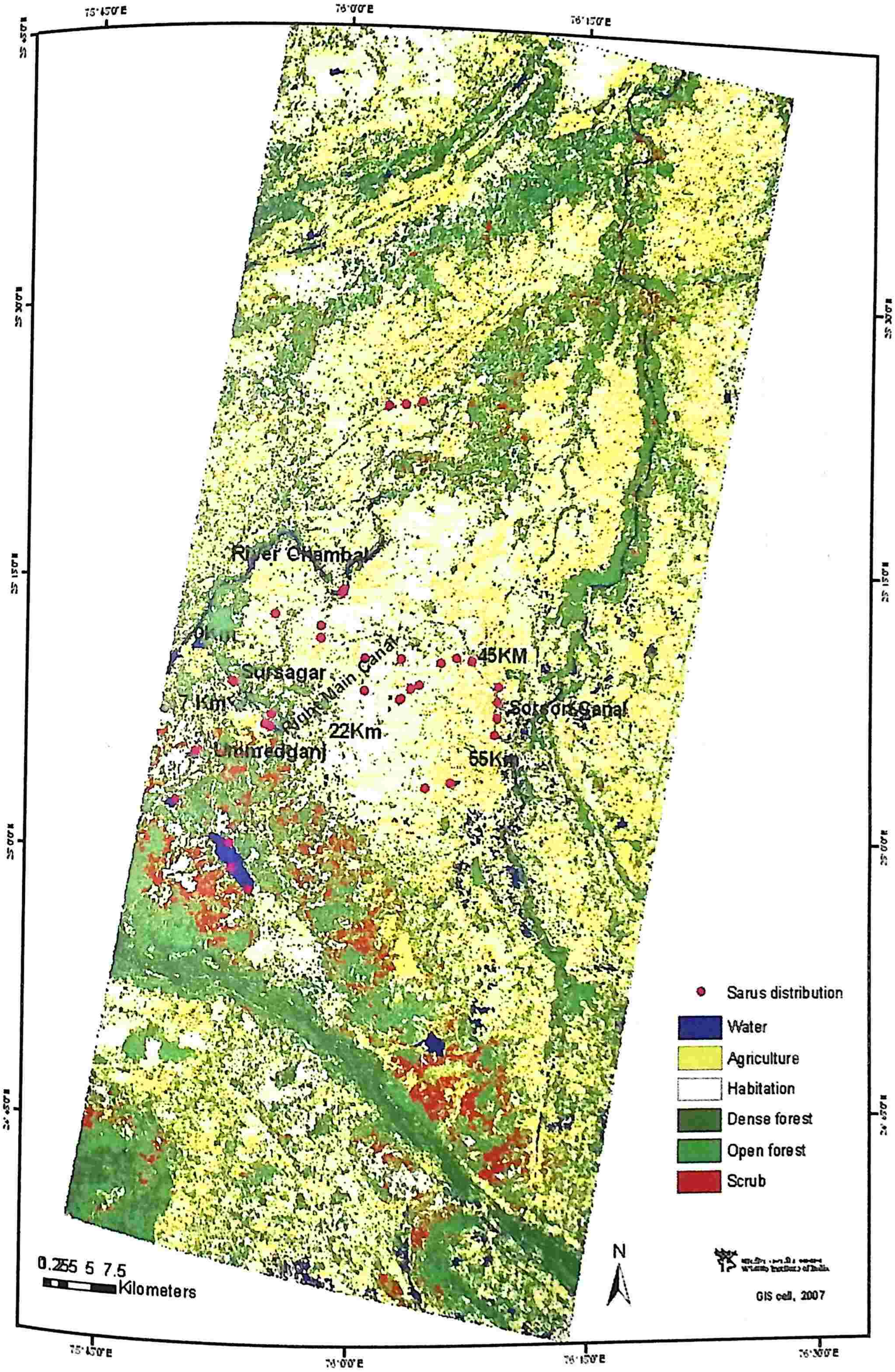


Fig 2 Distribution of Sarus Crane all along the canal in Kota (Jan2001 -Dec2001).

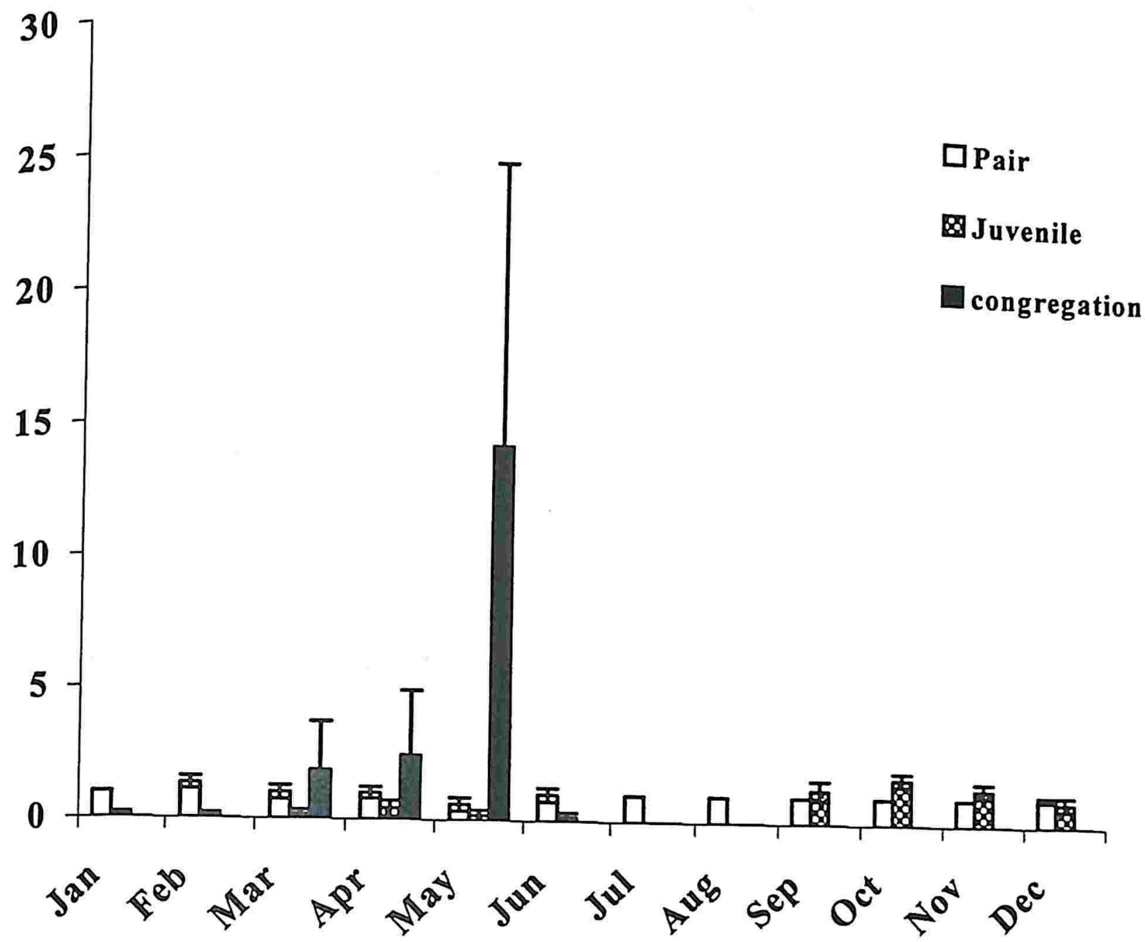
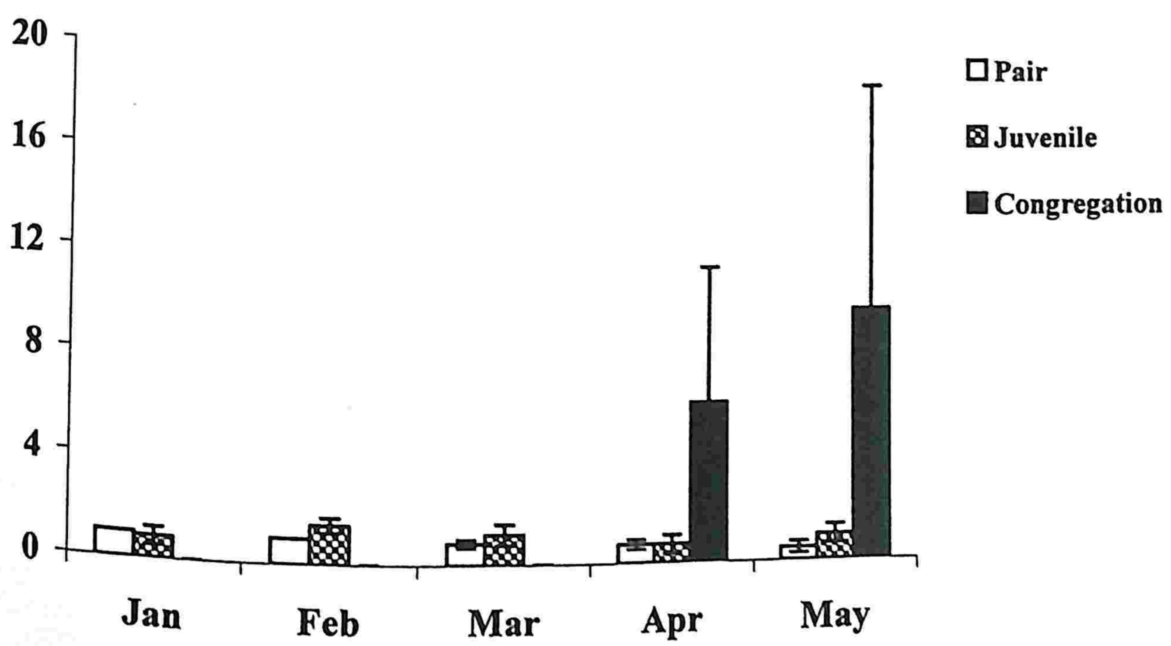


Fig 3 Distribution of Sarus Crane all along the canal in Kota (Jan-May 2002)



Keoladeo Ghana National Park

Sarus Crane being a non-migratory resident species and change in social group structure is observed was related to various factors such as availability of habitat and food. From the results it indicates that during the study period the population of the Sarus Crane remained constant inside the park and change in seasons exhibited changes in social structure of the Sarus Crane. Figure 4&5 shows the distribution of Sarus Crane in different blocks in Keoladeo Ghana National Park and release of water during the year 2000 and 20001 in different blocks. In year 2000 143mcft water was released in different D, E, L and K blocks and in year 2001 a total of 184mcft water was released in to the B, D, E and L blocks of Keoladeo Ghana National Park.

The data on Sarus abundance and distribution was pooled form March 2000- till Feb 2001 and March 2001- Feb 2002 and Sarus Cranes were seen in social families, groups and in pairs with juveniles. From the graph (Fig 6) it is very clear that congregation can be seen twice, once in November-till December and other during summer *i.e* on March till June. This influx was found to be due to the drying up of water bodies in the adjacent areas and most of the Sarus Cranes used wetland area inside the park. In year 2000 from the month of March Sarus starts congregating inside the park and maximum congregation were recorded inside the park was in month of May (67.42%) and June 2000(71.06%). In year 2000, the rainfall was good in the month of July August and September the Sarus Crane using the wetlands equally well outside the park and returning back to the park during November and December when the water bodies outside the park drying up, and in winter maximum number of Cranes were sighted during the month of November (75%) (Fig 7).

As compared to year 2000 the rainfall was very poor and congregation was seen only during the month of March 2001(61.71%) and in winter 57.80% (November) of Sarus Cranes were sighted inside KGNP (Fig 7).

Fig 4 Distribution of Sarus Crane in different blocks of Keoladeo Ghana National Park during the year 2000-2002

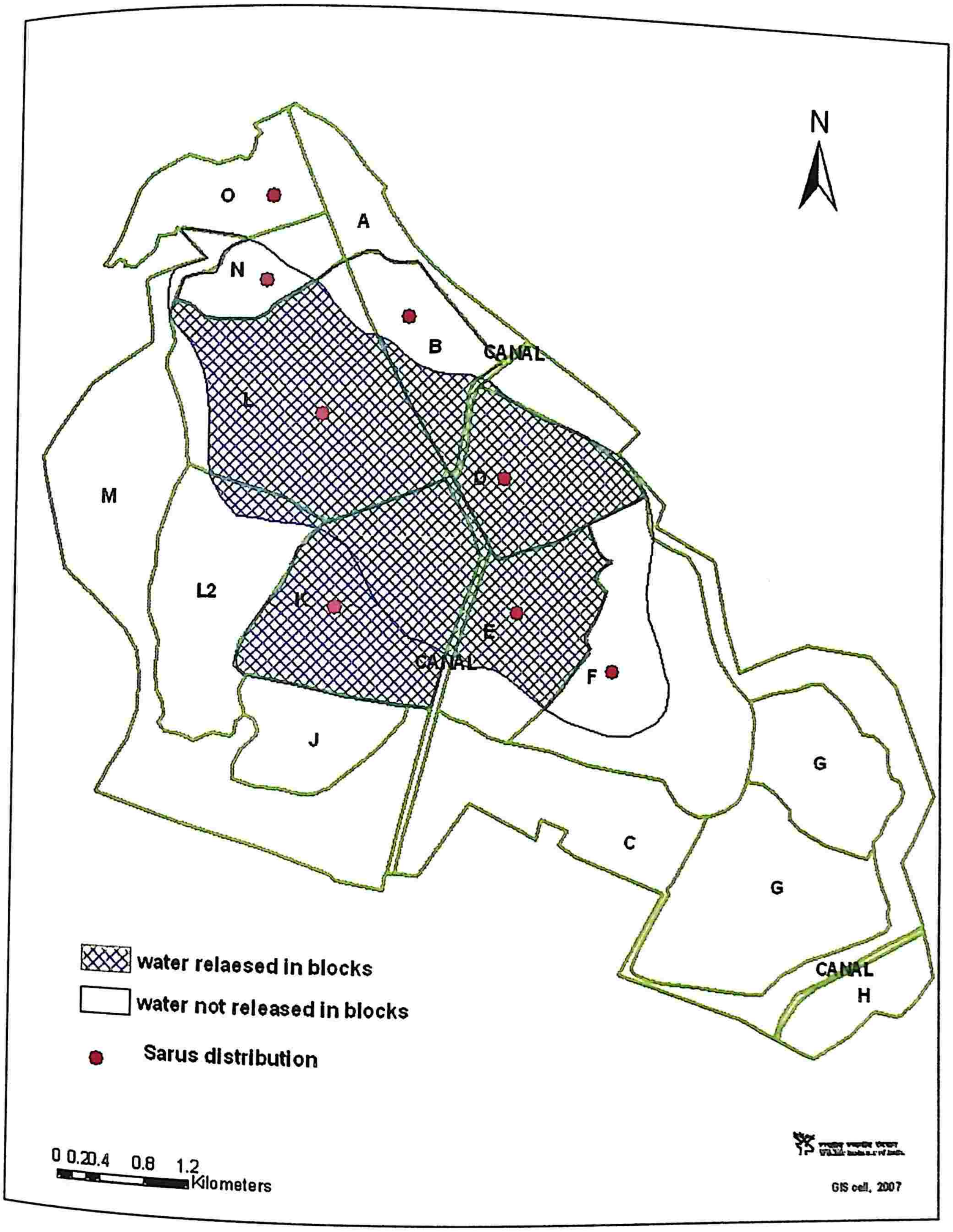


Fig 5 Distribution of Sarus Crane in different blocks of Keoladeo Ghana National Park during the year 2000-2002

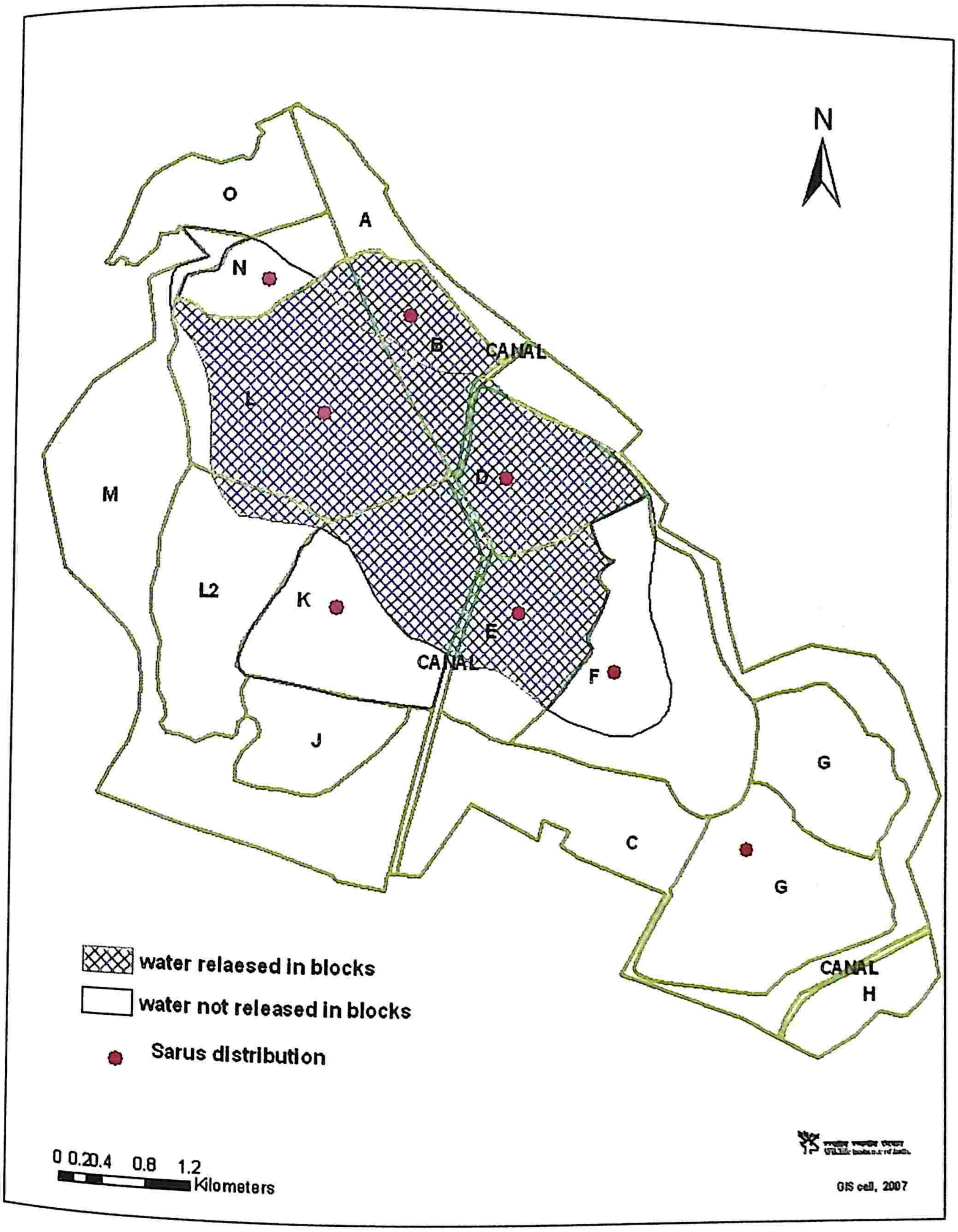


Fig 6 Seasonal Changes in Social Structure of Sarus Crane in Keoladeo Ghana National Park(Mar2000-Feb 2001)

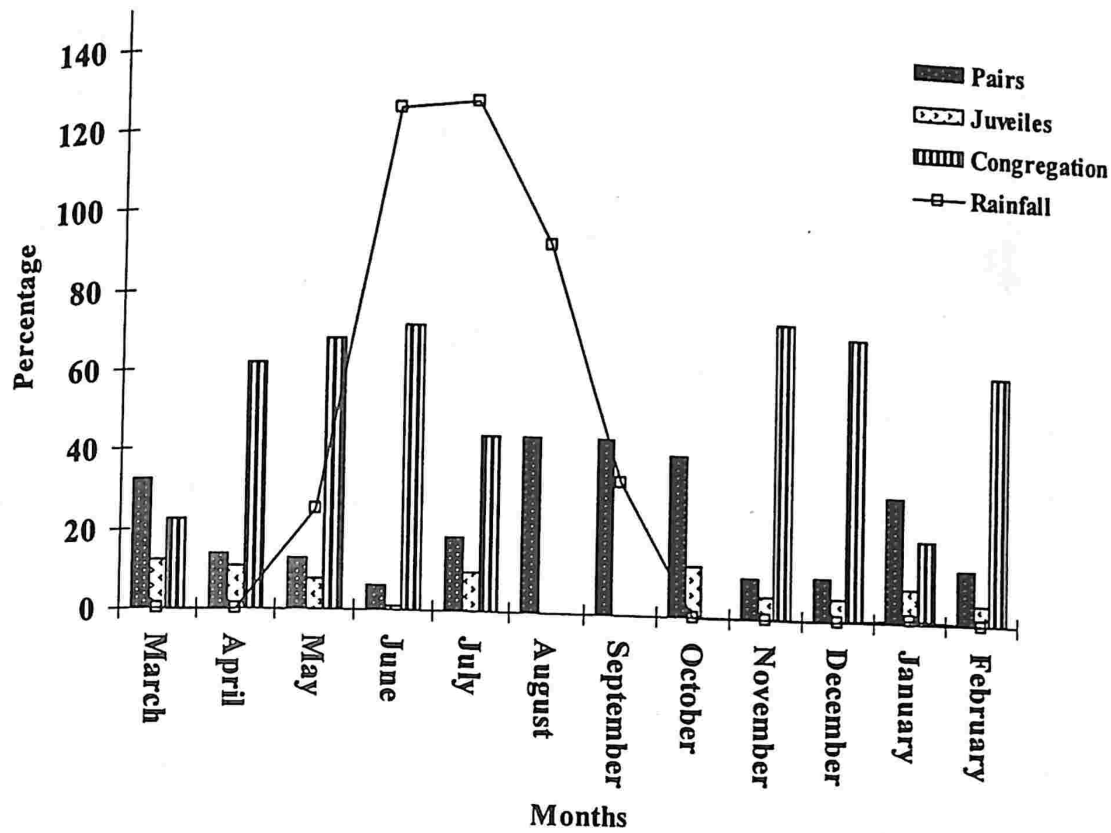
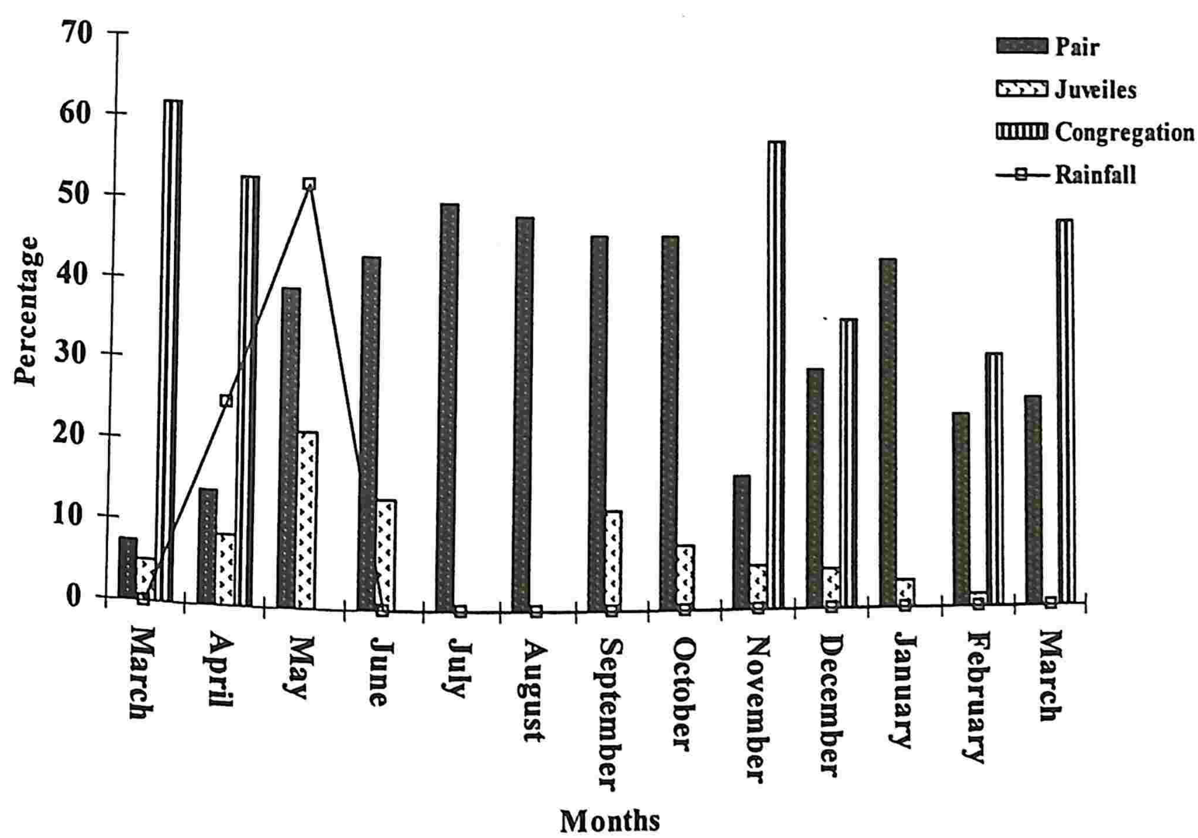


Fig 7 Seasonal Changes in Social Structure of Sarus Crane in Keoladeo Ghana National Park (Mar2001-Feb2002)



4.3.2 Home Range

The home ranges of Sarus Crane breeding pairs with banded juveniles were observed to vary among banded families. The result from kernel method showed the largest home range of 59.9 sq km (Zetiya 2) and 18.3 sq km (Lakhava) in natural wetland while the smallest home ranges were of 0.6 sq km (Sorson1) and 1.3 (King Palace) in man-induced wetlands (Fig 8, 9 & 10). The estimate from Minimum Convex Polygon (100%) had the largest of 104 sq km (Lakhava) in natural wetland and 74.3 sq km (Sursagar) in man-induced wetlands of Kota (Table 4) (Fig 11, 12 & 13).

In Bharatpur, the home range sizes of two families were quite smaller (Kernel method) of 2.3 sq km (L-block) and 0.6 sq km (D-block) respectively (Table 4), indicating that these birds did not have to travel far and expend much energy for food and other daily requirements (Fig 14 & 15).

Table 4 **Home Ranges of breeding pairs with banded juveniles in Kota and Bharartpur district by using Minimum Convex Polygon and Kernel method.**

Locality Name and wetland type	**Total GPS Point N=13**	**Kernel (95%) (sqkm)**	**MCP (100%) (sqkm)**
Kota Lakhava (Natural wetland)	326	18.30	104.00
King Palace(Man-induced wetland)	441	1.33	2.02
Sursagar(Man-induced wetland)	345	3.50	74.30
Ummedgang over flow(Man-induced wetland)	402	3.90	43.66
Alynia(Natural wetland)	442	0.80	1.12
Sorson1(Man-induced wetland)	245	0.60	1.19
Sorson 2(Man-induced wetland)	320	4.10	2.05
Sorson3(Man-induced wetland)	200	1.60	1.39
Zetiya 1(Natural wetland)	346	2.40	4.70
Zetiya2(Natural wetland)	400	59.90	46.69
Dadhdevi(Man-induced wetland)	362	0.60	4.70
Bharatpur L-Block(Natural wetland)	250	2.30	1.90
D-Block(Natural wetland)	260	0.60	0.60

Fig 8 Home Range map of Sarus Crane breeding pairs with banded juveniles in Kota District, Rajasthan (using Kernel Method).

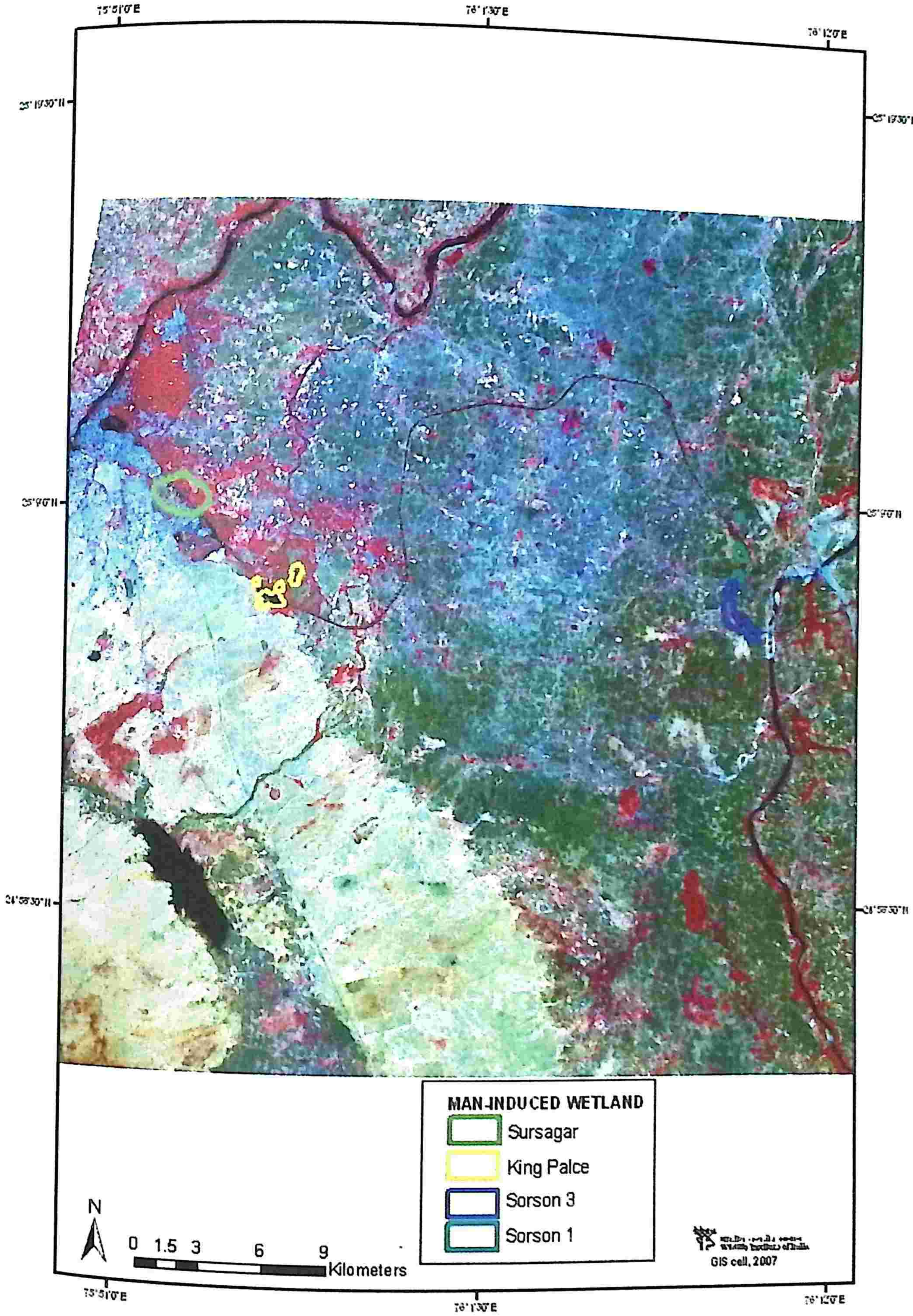


Fig 9 Home Range map of Sarus Crane breeding pairs with banded juveniles in Kota District, Rajasthan (using Kernel Method).

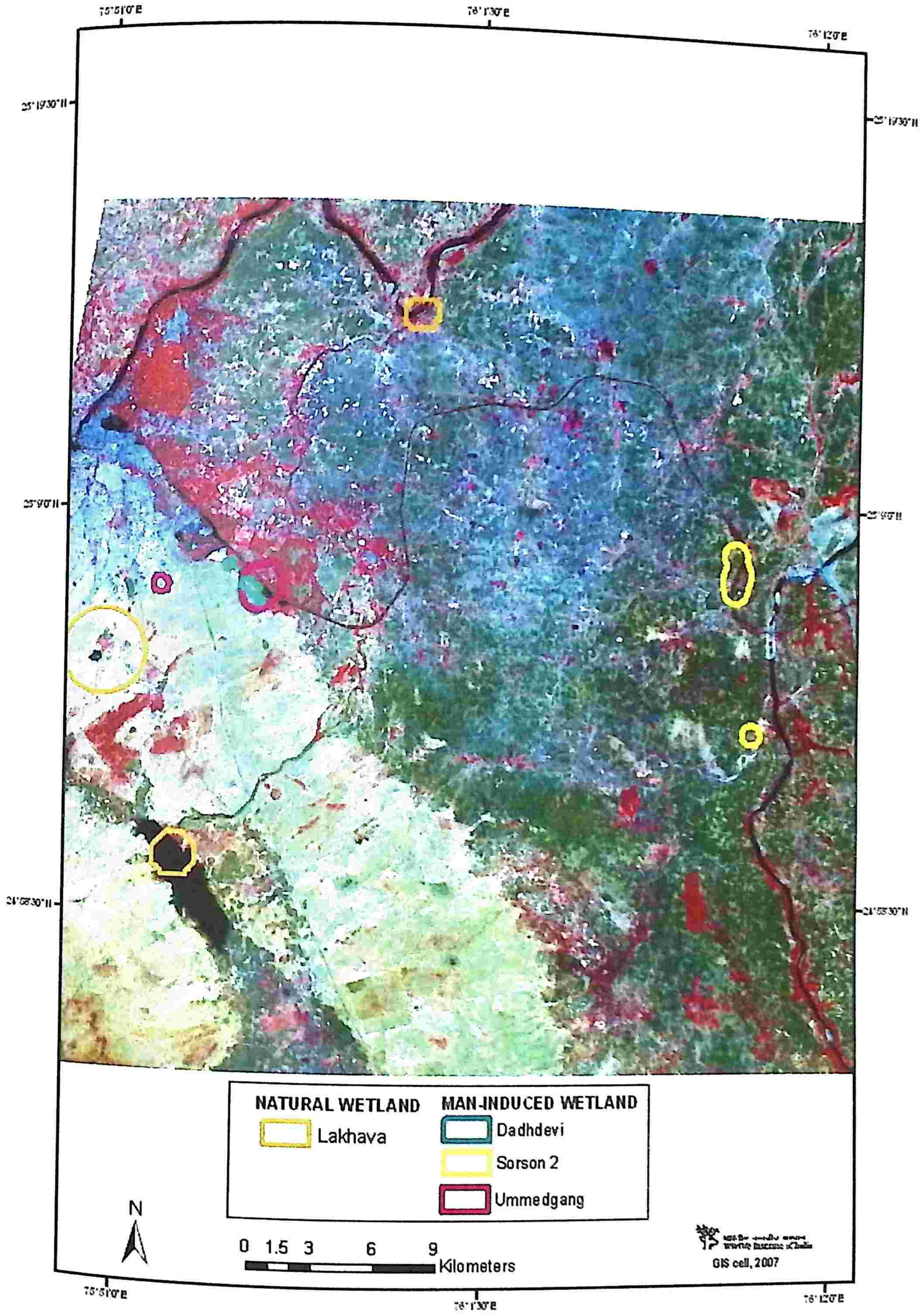


Fig 10 Home Range map of Sarus Crane breeding pairs with banded juveniles in Kota District, Rajasthan (using Kernel Method).

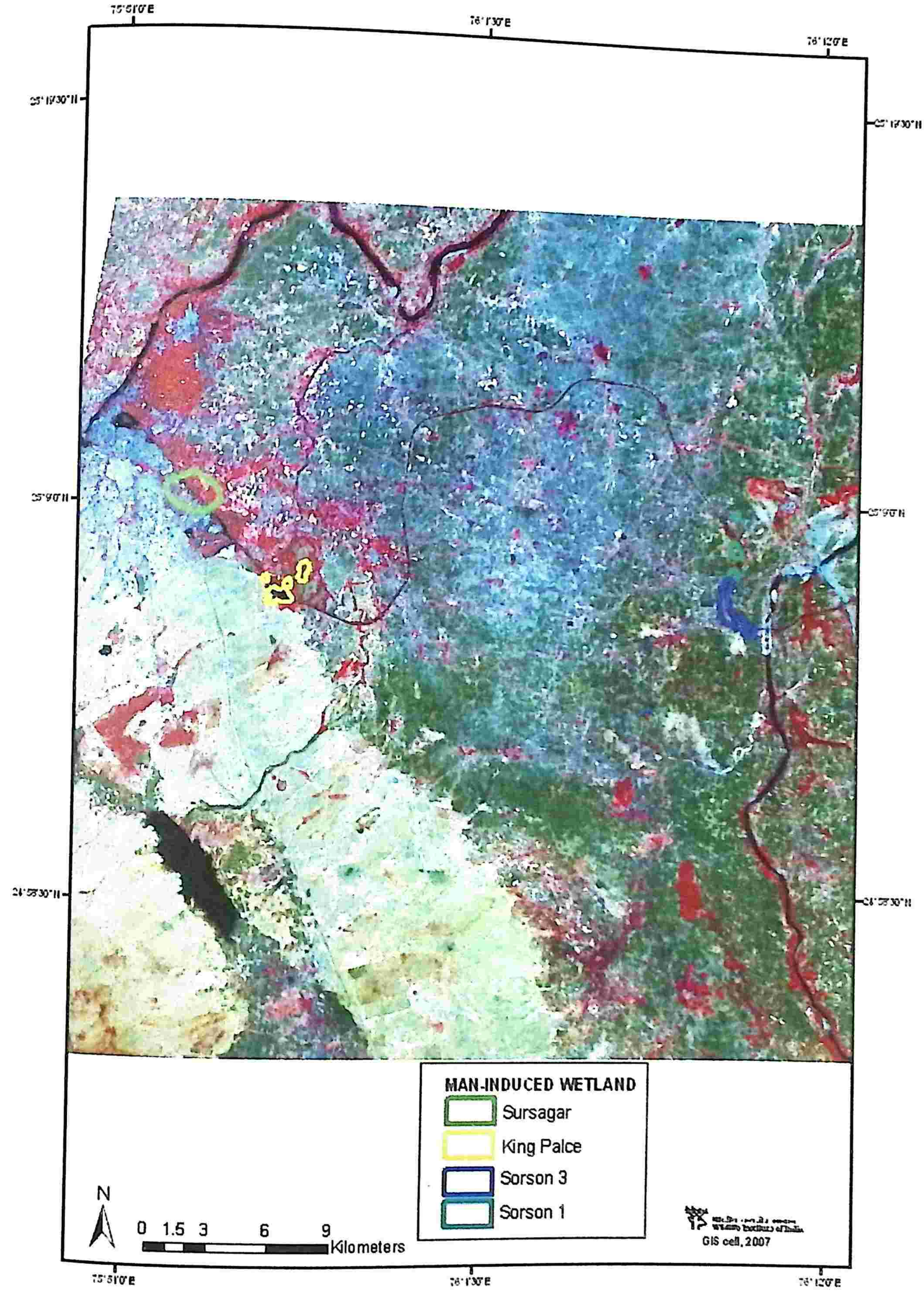


Fig 11 Home Range map of Sarus Crane breeding pairs with banded juveniles in Kota District, Rajasthan (using MCP Method).

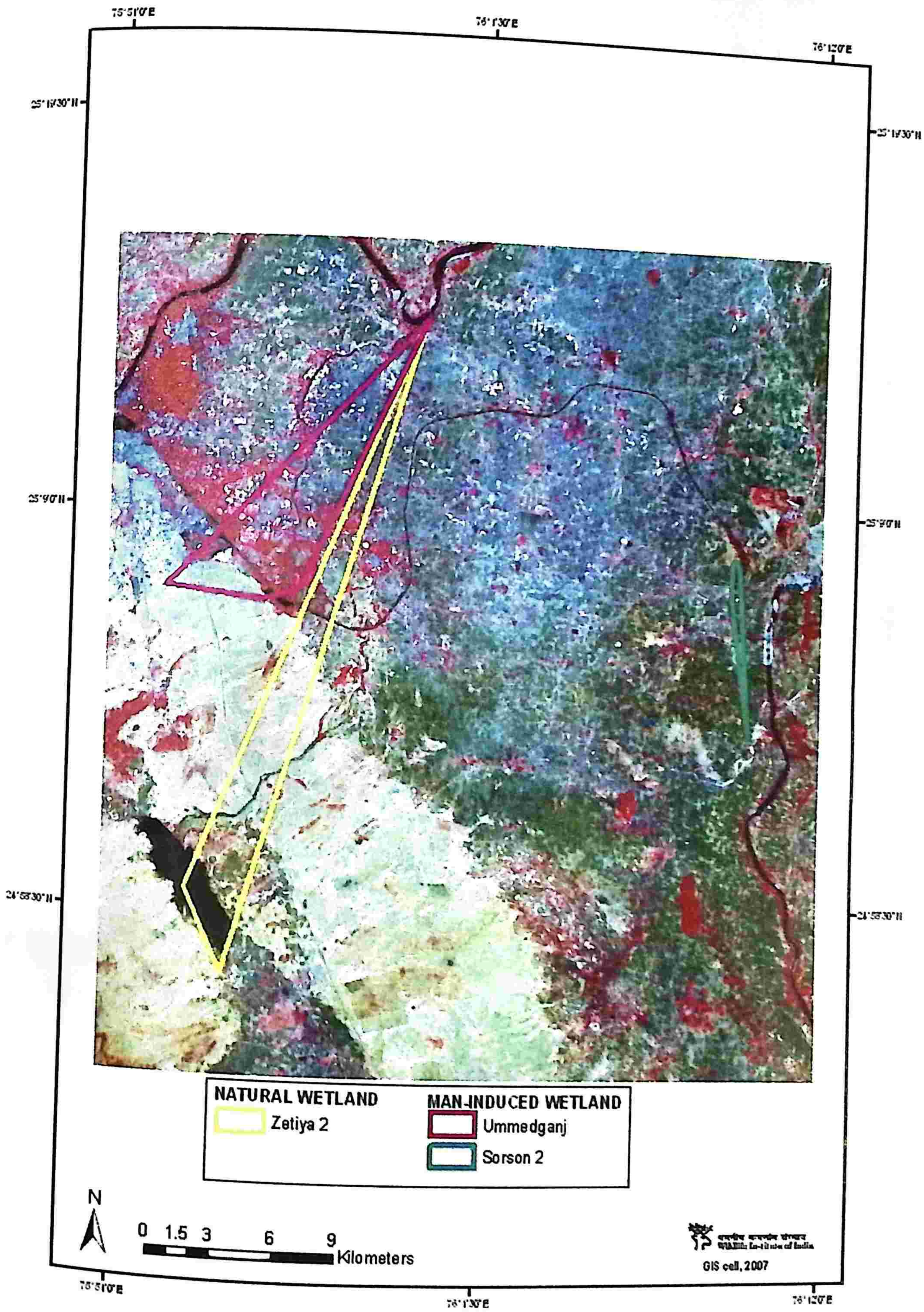


Fig 12 Home Range map of Sarus Crane breeding pairs with banded juveniles in Kota District, Rajasthan (using MCP Method).

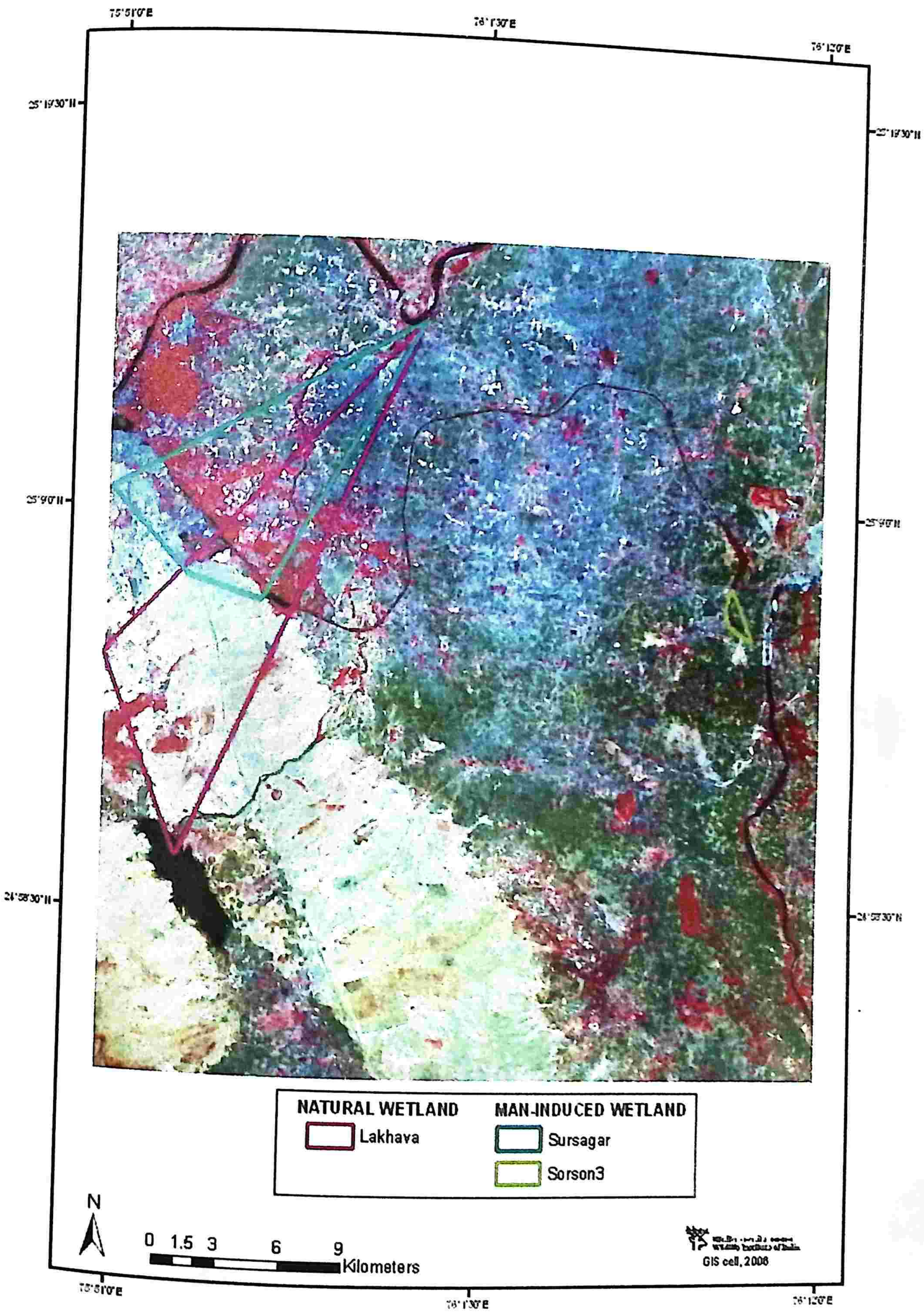


Fig 13 Home Range map of Sarus Crane breeding pairs with banded juveniles in Kota District, Rajasthan (using MCP Method).

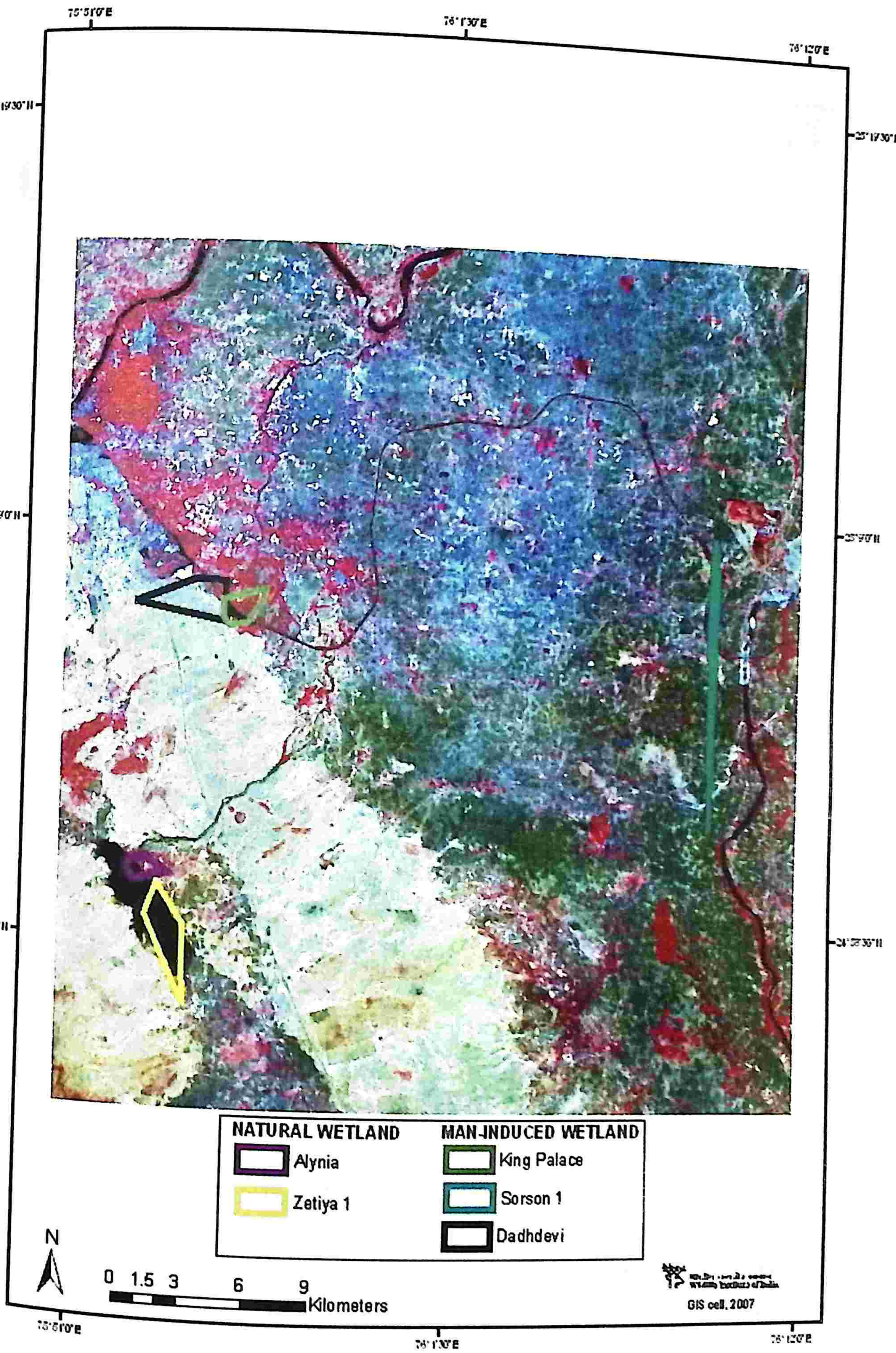


Fig 14 Home Range map of Sarus Crane breeding pairs with banded Juveniles in Keoladeo Ghana National Park, Bharatpur, Rajasthan (using Kernel Method).

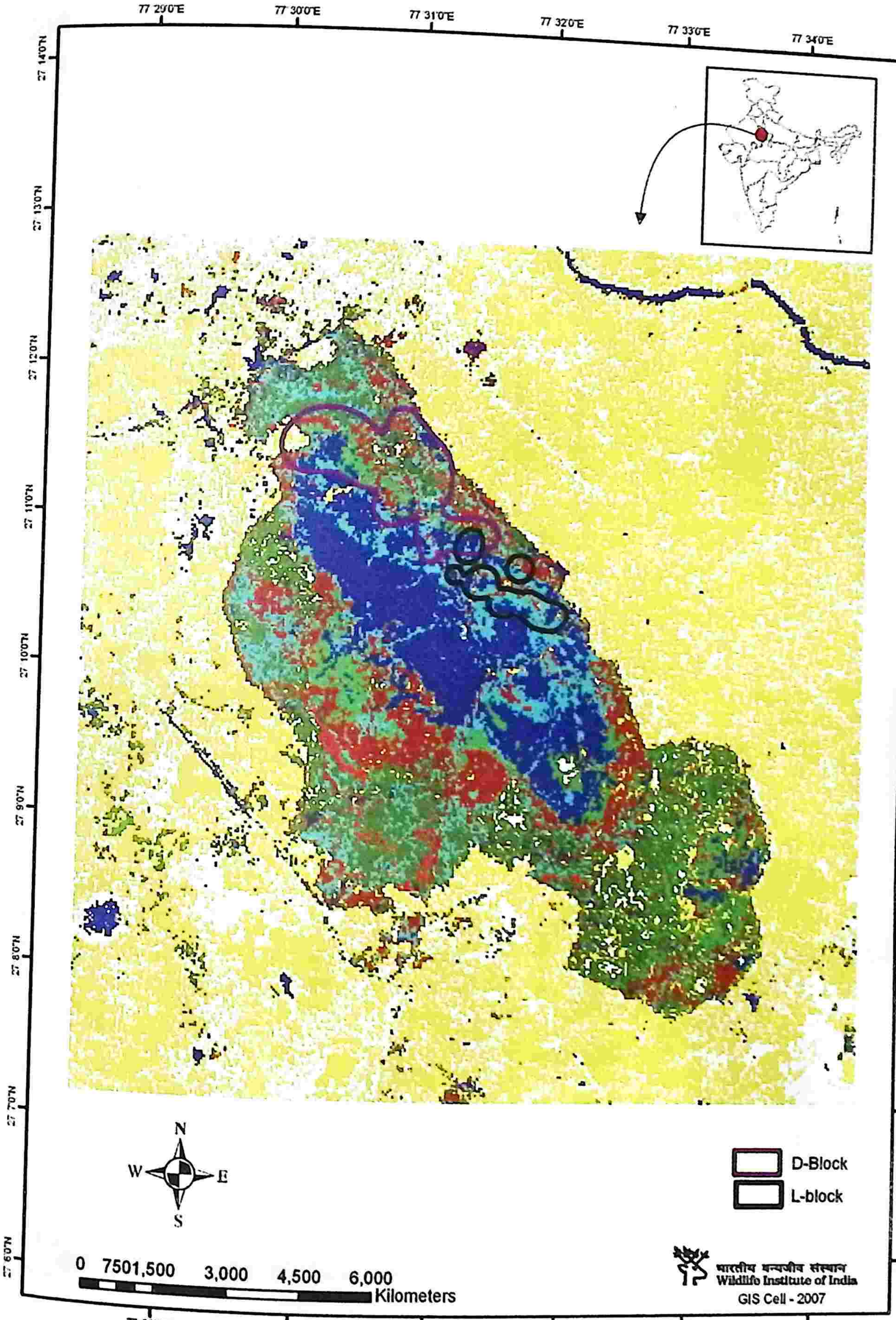
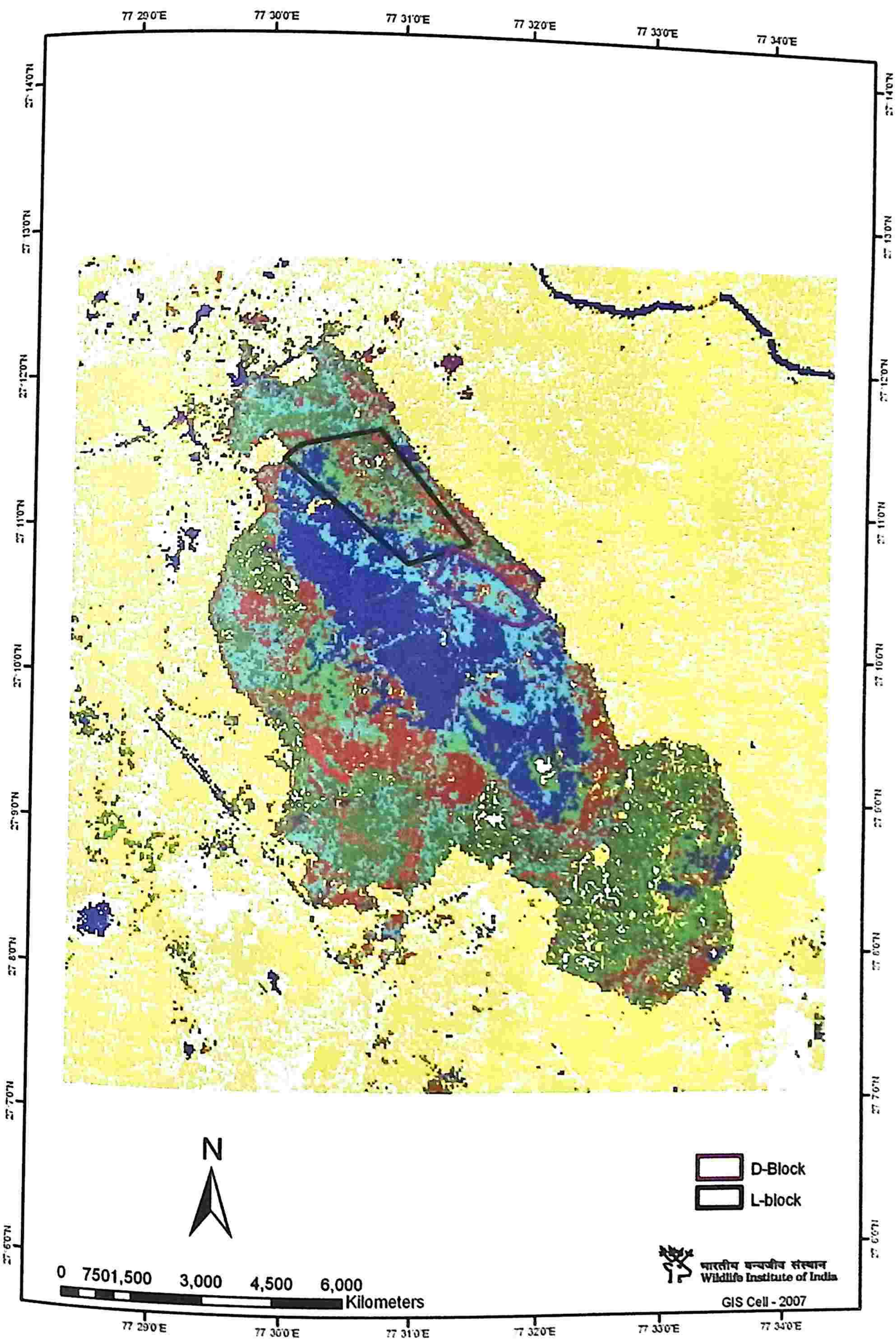


Fig 15 Home Range map of Sarus crane breeding pairs with banded Juveniles in Keoladeo Ghana National Park, Bharatpur (using MCP Method).



Seasonal estimate of home ranges of Sarus Crane breeding pairs with banded juveniles in Kota district revealed that they are more restrictive during rainy season and winter and was found to range between 0.06 sq.km. and 3.83 sq. km. Of the eleven families, eight were monitored till June and it was found that Lakhava family in natural wetland moved much widely ranging about 300 sq km, followed by Zetiya 2 (natural wetland) (273 sq km) during March to June (Table 5).

The annual calendar of the year shows the availability of water around the year 2001-2002 in both the study sites (Table 6). The juveniles are banded when they are at age of two to three months from the date of hatching and the behavioural observation on breeding pairs of Sarus crane with banded juveniles were taken (See Chapter 6). The water availability in the man-induced wetlands and in natural wetlands was monitored for the study period. Wetlands created through Seepage from the Right Main canal (RMC) of Kota barrage offered suitable condition for Sarus Cranes, but the canal is functional only during October to March and intermittently. In times of non-functioning of the canal and when the previously seepage areas become dry, forced the Cranes to move out and shift to other wetland areas, even if these new areas are poor. Same situation prevailed in natural wetlands, small water bodies drying up early as compared to large reservoir wetland where water stays for long periods, eg Alynia wetland.

Table 5 **Seasonal Variation in Home Ranges of breeding pairs with banded juveniles in Kota district by using Kernel method.**

Locality Name	September to February (sq km)	March to June (sq km)	Breeding Success
Lakhava	0.069	299.9	1
King Palace	1.63	0.26	1
Sursagar	1.16	77.24	1
Ummedgang over flow	1.22	11.94	1
Alynia	0.058	0.46	1
Sorson1	0.60	-	0
Sorson 2	3.83	1.16	1
Sorson3	1.64	-	0
Zetiya 1	1.73	3.83	1
Zetiya2	3.65	273	1
Dadhdevi	0.61	-	0

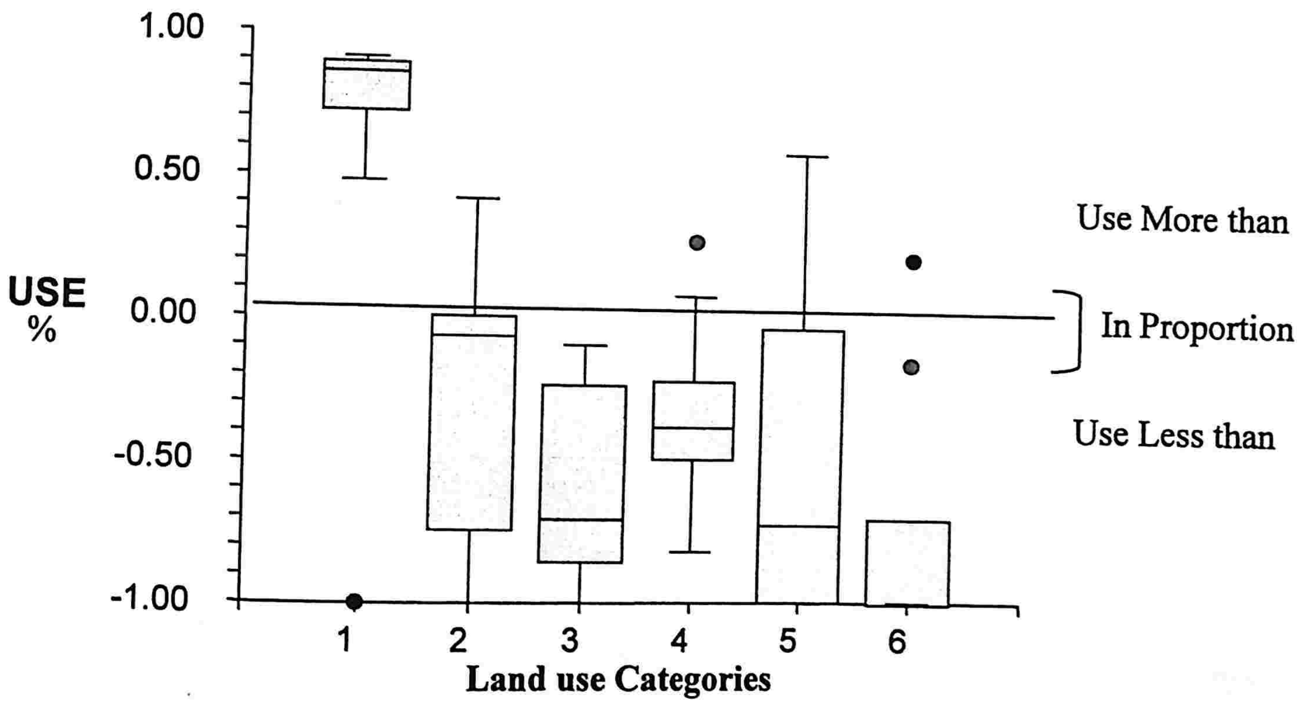
Table 6 **Annual Calendar showing the Seasonality of wetland in Kota district during 2001-2002.**

Locality	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sep	Oct	Nov	Dec
Lakhava				-	-	-						
King					-	-						
Sursagar						-						
Ummed				-	-	-						
Alynia												
Zetiya-1				-	-	-						
Zetiya-2				-	-	-						
Sorson-1						-						
Sorson-2						-						
Sorson-3						-						
Dadhdevi						-						
L-Block						-						
D-Block						-						

4.3.3 Habitat Use

Sarus Cranes breeding pairs with banded juveniles used diverse habitat types, but showed relative preference for water/marsh ($\chi^2 = 27.36$, $p < 0.001$, Fig15). It appeared that they use habitat edges such as habitation/fallow-barren; open forest, moderately dense forest and scrub land occurred possibly because these habitats are interspersed among the preferred habitats.

Fig 16 Habitat use in different Land use categories by Sarus Crane in Kota



1: Water/Marsh. 2: Agricultural, 3: Habitation/Fallow/Barren, 4: Moderately Dense Forest, 5: Open Forest, 6: Scrub.

By using Ivelev index it ranked the water/marsh (Fig 16) as the most preferred habitat and the scrub was ranked least preferred. Large area of forest land falls with in this area in Kota. Large area of forest owned by forest Department and Canal Command Area in Kota. These areas are interspersed with this preferred habitat such as water/marsh and agriculture. Because of position of these forest lands, there is large representation of these areas with in the preferred habitat, so this seem to have biased the results in favour of forest lands to the extent of bringing these otherwise unused habitat in the top ranks. This should not be construed as the preferred habitat.

Regardless of the nature of the land type, whether natural or man-induced, the Sarus Crane strongly showed preference for water/marsh. In addition, four families showed preference for agriculture areas as well. There was exception that one family in man-induced wetlands (Dadhdevi) consistently used agriculture followed by Moderately dense forest (Table 7). The following table shows the land cover categories used by the breeding pairs of Sarus Cranes with banded juvenile (Table 7).

Table 7 **Land cover Use by Sarus Crane breeding pairs with banded juveniles in Kota district by Ranking the land cover categories. (Descending order indicate magnitude of use)**

1 Water/marshes 2 Agriculture 3 Habitation/Fallow-barren 4. Moderately Dense forest/open forest 5 Scrub

Families	Preference of Vegetation Use	Breeding Success	Habitat
Lakhava	Water/Marsh>Agriculture>ModeratleyDense Forest/OpenForest/Habitation/Fallow-Barren/Scrub	1	Natural wetland
King Palace	Water/Marsh>Agriculture>ModeratelyDense forest/Open forest>Habitation/Fallow-Barren and Scrub	1	Man-Induced Wetland
Sursagar	Water/Marsh>Habitation/Fallow-barren>ModeratelyDenseforest/Open forest>Scrub>Agriculture	1	Man-Induced Wetland
Ummedgang over flow	Water/Marsh>ModeratelyDenseforest/Open scrub/Habitation/Fallow-Barren>Agriculture>Scrub	1	Man-Induced Wetland
Alynia	Water/Marsh>Habitation>Agriculture>Open forest/ModeratelyDense forest>Scrub	1	Natural wetland
Sorson1	Water/Marsh>ModeratelyDense forest/Open forest>Habitation/Fallow-Barren>Agriculture>Scrub	0	Man-Induced Wetland
Sorson 2	Water/Marsh>Open forest/ModeratelyDense forest>Agriculture>Habitiation/Fallow-Barren>Scrub	1	Man-Induced Wetland
Sorson3	Water/Marsh>Agriculture>ModeratelyDense Forest/Open Forest>Habitation> Scrub	0	Man-Induced Wetland
Zetiya 1	Water/Marsh>Habitation>ModeratelyDense forest/Open forest>Habitation/Fallow-Barren>Scrub	1	Natural wetland
Zetiya2	Water/Marsh>Agriculture>ModeratelyDense forest/Openforest>Habitation/Fallow-Barren>Scrub	0	Natural wetland
Dadhdevi	Agriculture>ModeratelyDenseforest/Open forest>Habitation/Fallow-Barren>Water/Marsh> Scrub	0	Man-Induced Wetland

Results from compositional analysis (Aebischer *et.al* 1993) and (Neu *et al.* 1974) revealed that at this coarse level the home range selection with in study area and location within home range are similar.

Similar results were obtained for compositional analysis due to strong selection for marshy habitat. Results are very similar due to strong selection for marshy habitat by the Sarus Crane in Kota study area and significant different in use of different land cover categories by Sarus Crane (G(adj) = 207.5655) ($P < 0.0001$) (Table 8). The preference ranking for each vegetation category was obtained ([illegible]) for use and availability (X^2 (5 df) = 11.4327 $P < 0.05$, Lambda = 0.3537) (Table 9). Ranking in compositional analysis is done on the basis of magnitude of use versus availability, zero indicate use in proportion to availability. Negative value show use less than available and positive indicate use more than that is available.

Table 8 **Habitat use and availability in different land cover by Sarus Crane breeding pairs with banded juveniles in Kota. (Bailey Simultaneous confidence intervals).**

Habitat use		Proportion		Df	Probability
	Lower	Upper	Available		
Water	0.4369	0.5171	0.3000	5	P<0.0001
Agriculture	0.1969	0.2646	0.2308		
Habitation	0.0720	0.1193	0.1856	5	P<0.0001
Moderately Dense forest	0.0664	0.1123	0.1455	5	P<0.0001
Openforest	0.0701	0.1170	0.0800		
Scrub	0.0094	0.0320	0.0581	5	P<0.0001

G(adj) = 207.5655 ($P < 0.0001$) G= log likelihood ratio test

Table 9 **Matrix of habitat use ranking to different land covers use by Sarus Crane breeding pairs with banded juveniles in Kota.**

Habitat use	Water	Agriculture	Habitation	Moderately Dense Forest	Open Forest	Rank
Marsh/water	1	1	1	1	3	5
Agriculture	-1	1	-1	1	3	3
Habitation	-1	-1	-1	1	3	2
Dense Forest	-1	1	1	1	3	4
Open Forest	-1	-1	-1	-1	1	1
Scrub	-3	-3	-3	-3	-1	0

Lambda = 0.3537 X^2 (5 df) = 11.4327 ($P < 0.05$)

The percentage of highest and lowest use of land cover categories used by Sarus Crane breeding pairs with banded juveniles in different location in Kota study area is given in Table 10. The wetland /marsh was preferred more by Zetiya 1 (84.04%)in natural wetland as compared to Dadhdevi family(Man-induced wetland) where agricultural area is in highest use, followed by Ummedgang overflow(Man-induced wetlands) and Sorson (Man-induced wetland), the reason being the marshes along the canal are interspersed with agricultural fields. In lakhava(Natural wetland) it is Habitation/Fallow-barren (47.86%) is highest use. Open forest 14.29% and Scrub 16.42% also showed representation in the preferred habitat of Sarus Crane families (Table 10).

Table 10 Percentage of land cover categories used by Sarus Crane families in Kota.

Families	Water/ Marsh	Agriculture	Habitation/ Fallow-Barren	Moderately Dense Forest	Open Forest	Scrub
Lakhava	18.15	8.34	47.86	6.98	4.31	14.35
King Palace	35.13	22.86	3.34	21.66	14.29	2.72
Sursagar	11.23	21.59	17.87	26.35	9.43	13.53
Ummedgang over flow	13.49	29.62	19.23	18.56	14.03	5.03
Alynia	66.65	11.78	6.68	13.11	1.34	0.45
Sorson1	26.99	25.34	14.64	18.76	11.99	2.29
Sorson 2	33.45	24.66	13.47	18.84	5.71	3.88
Sorson3	22.84	29.60	22.33	17.46	4.04	3.73
Zetiya 1	84.04	4.00	5.12	4.23	2.57	0.04
Zetiya2	17.87	16.80	27.14	9.63	12.15	16.42
Dadhdevi	0.18	59.33	26.51	4.42	8.12	1.44

4.3.4 Habitat use in Bharatpur

In Keoladeo Ghana National Park the inundated area consists of series of fresh water marshes, essentially impoundments (also called as Blocks) of different depths interconnected by an array of 16 Sluice gates. The blocks vary in size, depth and ratio of aquatic to terrestrial land. The terrestrial zone surrounding the main wetland area is predominantly dry scrub forest interspersed with patches of grassland (Chauhan & Gopal 2001). Perennou and Ramesh (1987) have, however recognised several physiognomic types such as forest, woodland, scrub woodland, savanna woodland, tree savanna, shrub savanna and low grassland, besides wetland. There are about 20 villages around the park, each irrigated by intensively cultivated farmland.

Results of Ivelev's index for use and availability in different land cover categories revealed that wetland was the most used habitat for D-block families with Ivelev's index of 0.81, followed by Grassland (0.78). The L-block family used grass savannas (0.8) and grassland (0.6) as the most preferred habitat. (Table11).

Table 11 **Ivelev Index of Sarus Crane breeding pairs with banded juveniles in Keoladeo Ghana National Park Bharatpur, Rajasthan.**

Families	Water	Savanah	Agricul-ture crop fields	Habita-tion	Grass land	Scattered scrub	Scrub wood -land	Wood -land	Grass Savanah
L-block	0.16	0.48	-1	-0.73	0.69	-0.22	-1	0.58	0.8
D-block	0.81	0.22	-1	-1	0.78	-1	-1	-1	-1

4.3.5 Activity in different habitat types in Kota

Allocation of time spent on each activities (See Chapter 6) during behavioural sampling in different habitat types, was highly variable. Marked increase in the use of natural wetlands after monsoon was observed, because of the higher availability of wetlands (See Chapter 6). Habitats were used differently due to differential availability. It was revealed that in summer pairs spent more time in man-induced (40.17%) & natural (35.8%) wetlands, compared to agricultural fields. On the other hand in winter pairs spent more time in agricultural fields (41.04%) compared to natural wetland (Fig 17). Among the agricultural crop fields, paddy and wheat fields were used most often in summer and winter respectively (Fig18). In summer the food availability in agricultural land is less, only post harvesting grains left for feeding and they remain close where water is available. The winter crop particularly wheat and chick pea are also cultivated and the remained grain after harvest of paddy crop in November, provides food to the Cranes.

Fig 17 Habitat use by Sarus Crane Pair in Summer and Winter in Kota

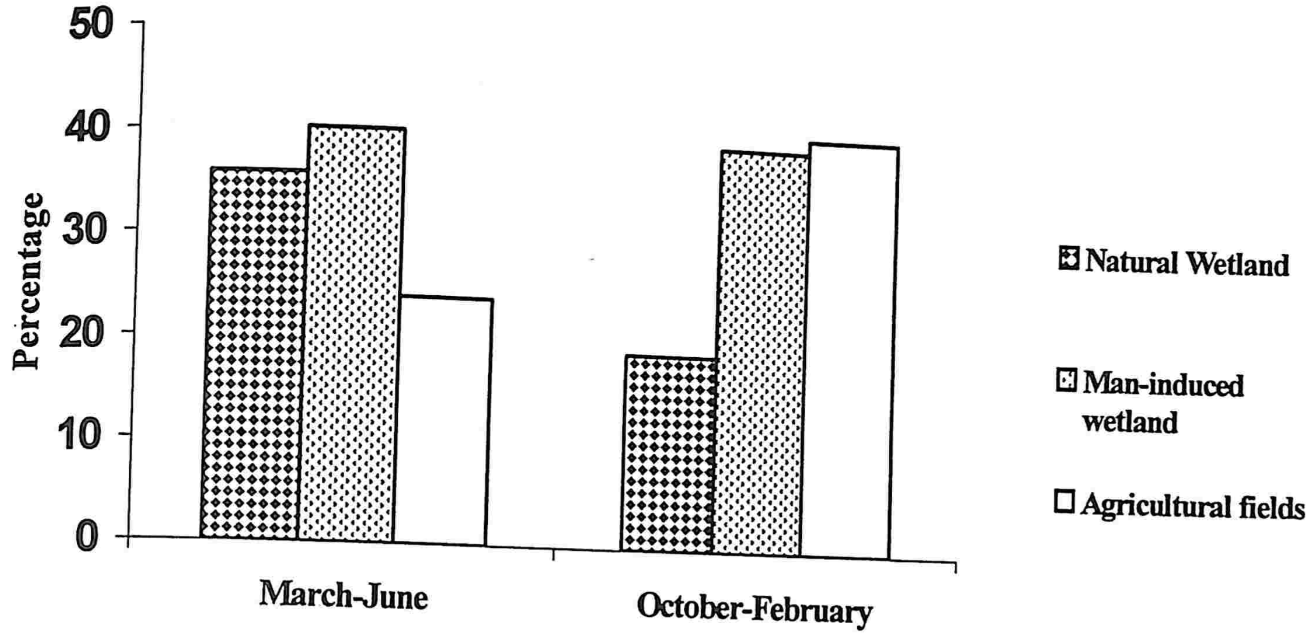
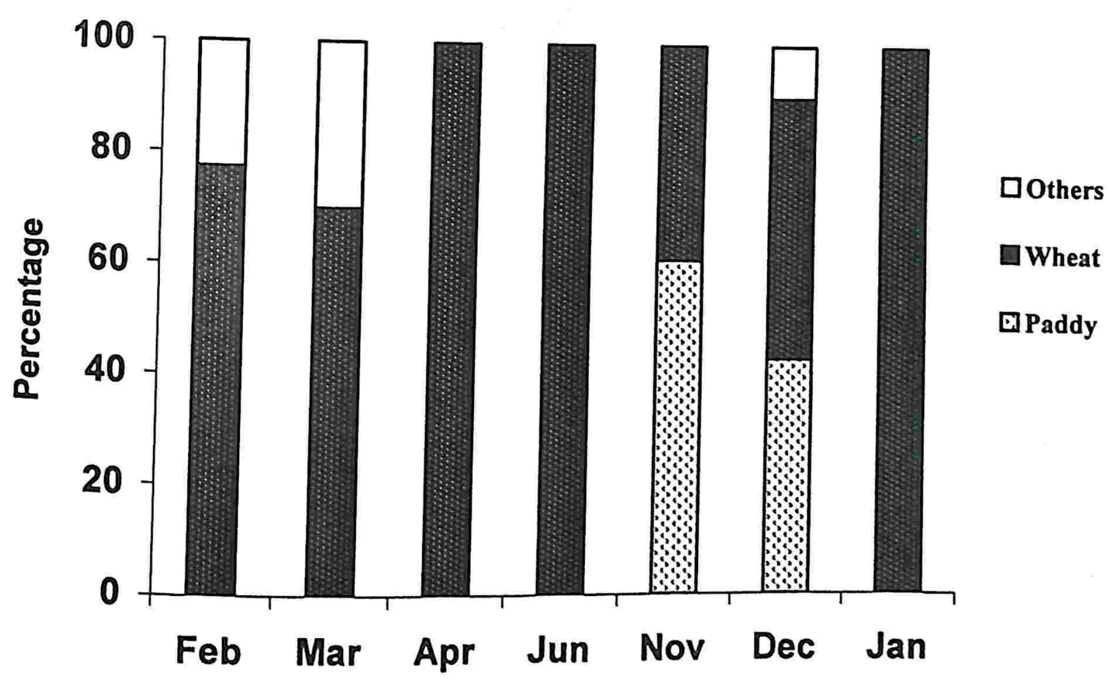


Fig 18 Crop-land used by Pairs of Sarus Crane in Kota district



Analysis on information on families showed that in rainy season families spent more time in man-induced wetlands 61.76% followed by agricultural fields 28.43%. However, in October till February (57.26%) and March-June (47.8%) families were seen more in agricultural fields (Fig 19 & 20).

Fig 19 Habitat use by Sarus Crane families in all the three seasons in Kota

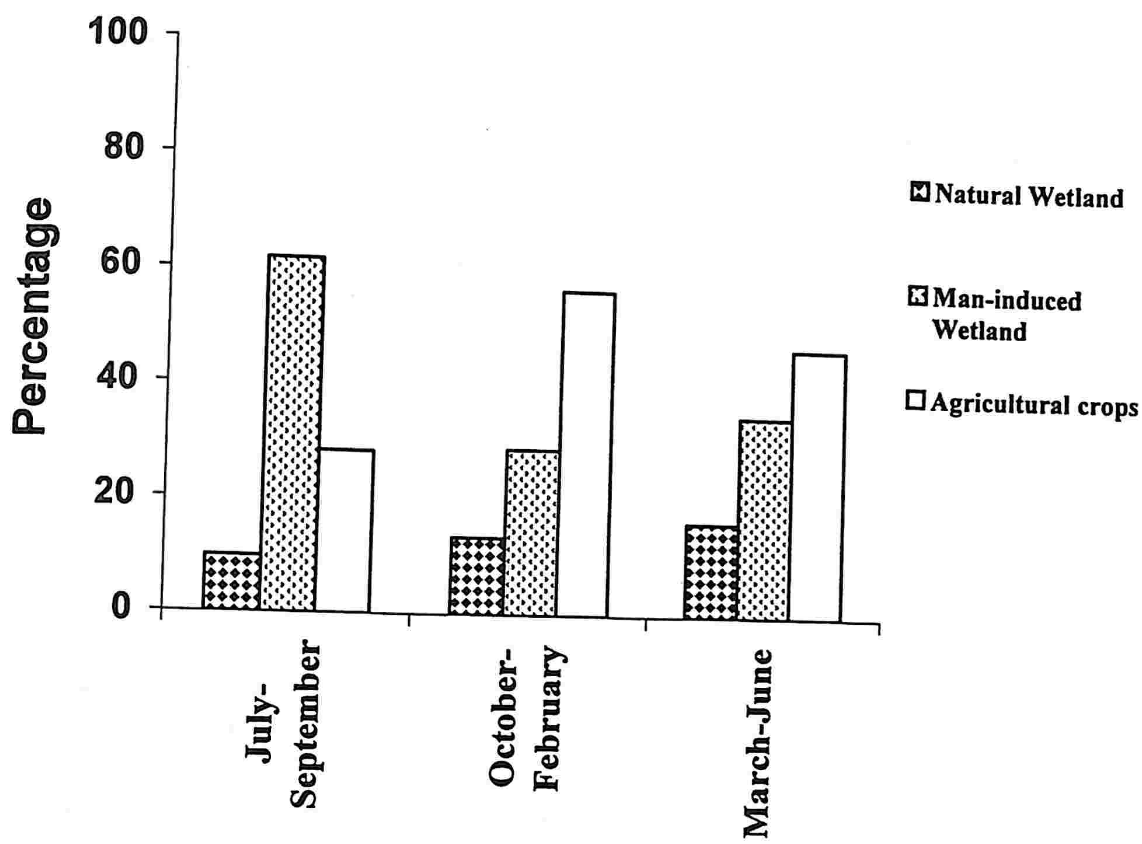
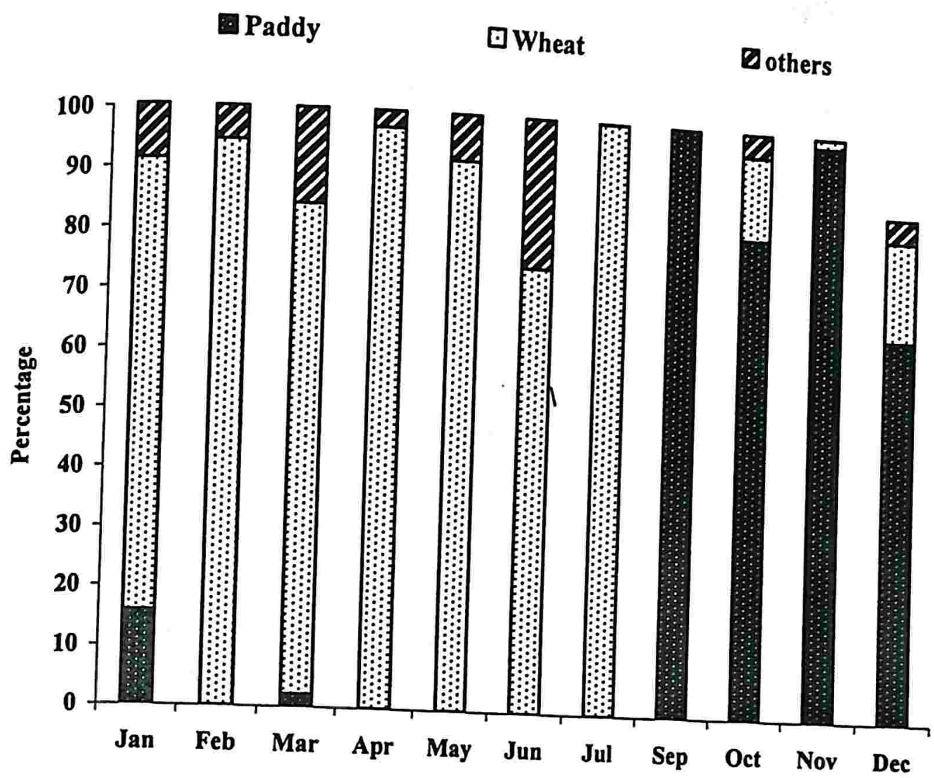


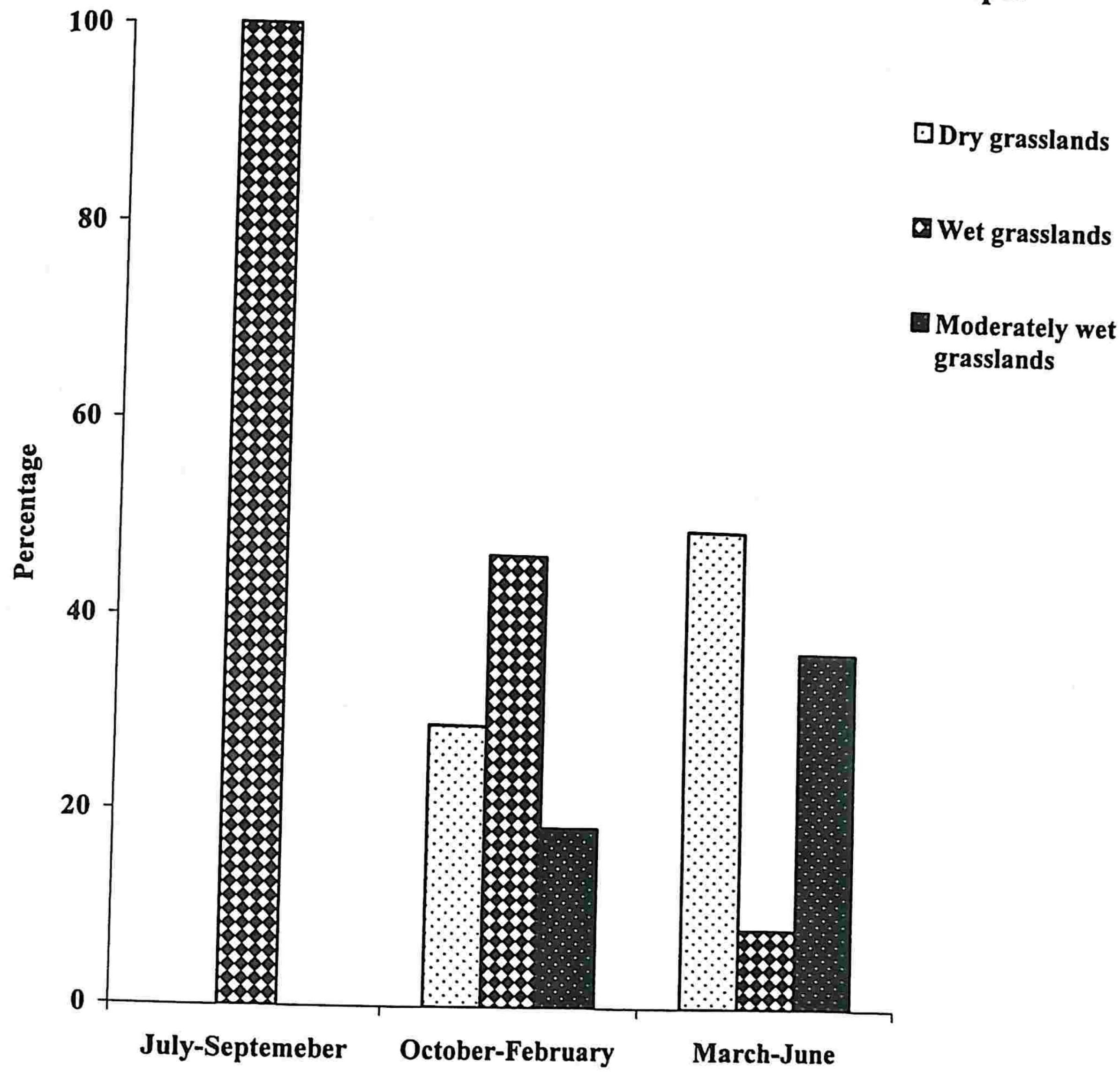
Fig 20 Crop land used by Sarus Crane families in different months in Kota



4.3.5.1 Activity in different habitat categories in Bharatpur

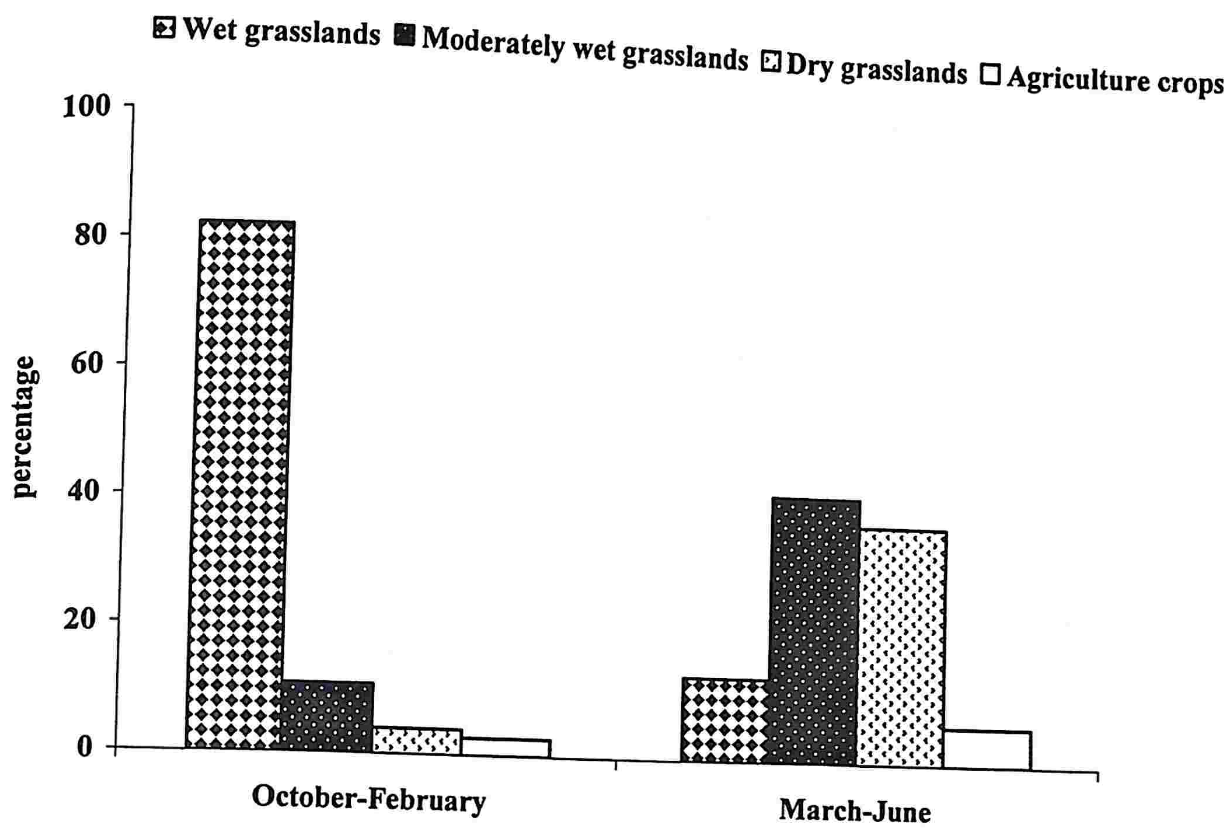
In Bharatpur, Sarus cranes spent considerable amount of time in the water logged area for feeding and individuals spent about 50% of the time in wet grassland from July to February, as compared to 30% in dry grasslands. However, in summer particularly from March onwards, they use more moderately wet to dry grassland areas (Fig 21).

Fig 21 Habitat use by Pair Sarus Crane in Bharatpur



The Sarus crane pairs with juveniles showed preference for wetland area for feeding, and used about 80% of the time in wet grasslands, against 10% in moderately wet grassland (10.09%) during September-February. As water started drying up inside the park, these birds used moderately wet grassland, significantly for feeding, thus facilitating growth of juveniles (Fig 22).

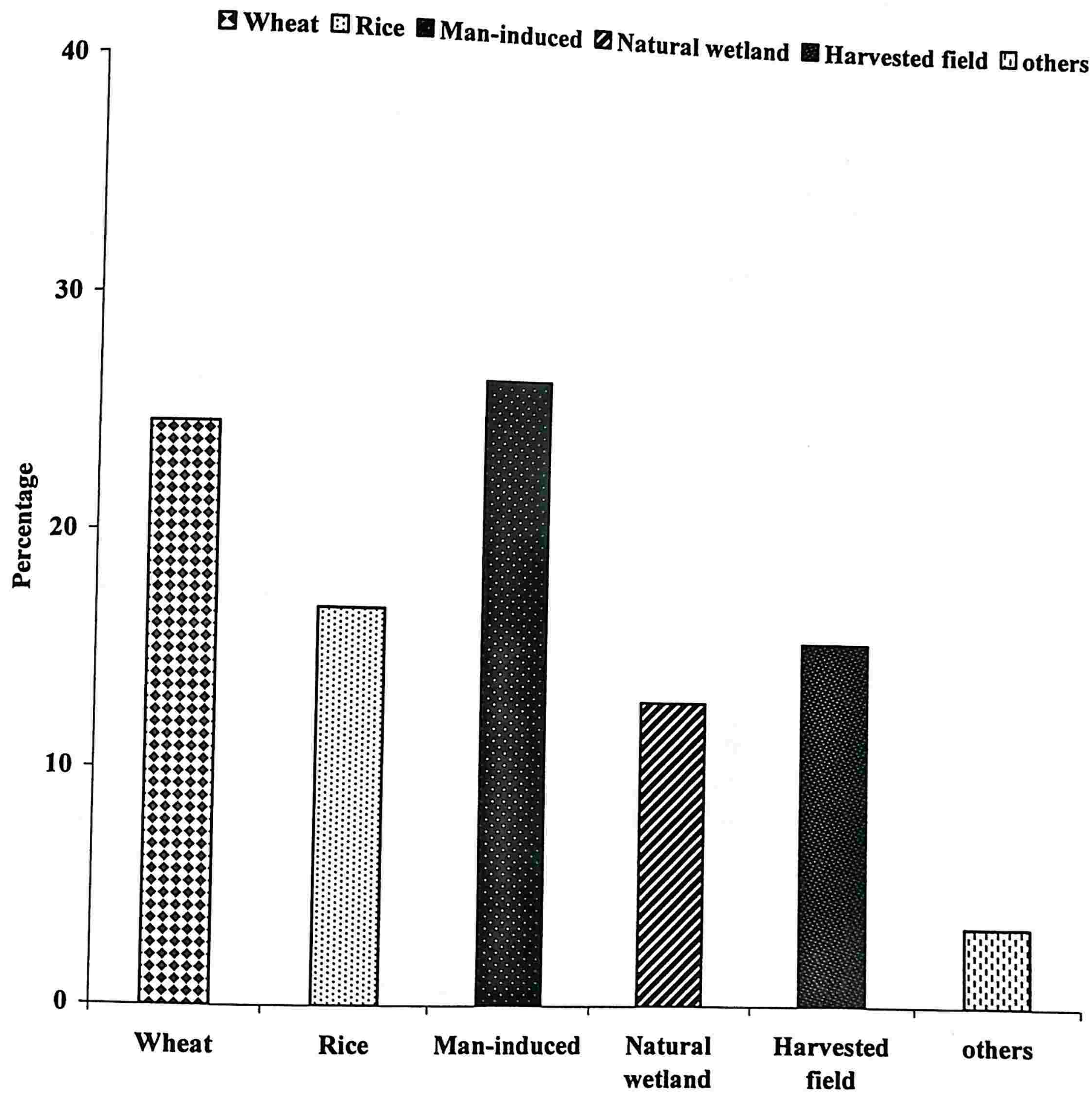
Fig 22 Habitat Use by breeding families of Sarus Crane in Bharatpur



4.3.6 Habitat use by breeding pairs with banded juveniles

The families of Sarus Cranes with banded juveniles were seen using agriculture fields more often than the other habitat types. Among the crop fields, wheat (24.55%) and paddy (16.80%) were preferred in summer and winter respectively. However, in areas with soyabean and fodder, most of the families were seen foraging in small puddles at the side of the fields and breeding pairs with banded juveniles were observed preening themselves in the middle of a soyabean fields (Fig 23). In Bharatpur (KGNP) families used natural wetlands throughout year, except in summer.

Fig 23 Different habitat used by breeding pair of Sarus Crane with banded juveniles in Kota



4.3.7 Habitat Suitability of Sarus Crane

Habitat suitability analysis was done using Environmental Niche Factor Analysis, computes suitability functions by comparing the species distribution in the species distribution in the ecogeographical variables (EGV) space with that of the whole set of cells. Species are expected to be nonrandomly distributed regarding ecogeographical variables. A species with an optimum temperature, for instance, is expected to occur preferentially in cells lying within its optimal range. The focal species may sow some marginality (expressed by the fact that the species mean differs with respect to their mean) and some specialization (expressed by the fact that the species variance is lower than the global variance. The programme Biomaper 3 was used (Hirzel, *et al.* 2004) for the habitat suitability maps; it builds on a count of all cells from the species distribution that lay as far or farther apart from the median than the focal cell on a factor axis. This is performed by dividing the species range on each selected factor in a series of classes, in such a way that the median would exactly from the global distribution.

Count the number of cells from the species distribution that lay either in the same class or in any class farther apart from the median on the same side. Normalization is achieved by dividing twice this number by the total number of cells in the species distribution. Thus, a cell laying in one of the two classes directly adjacent to the median would score one, and a cell laying outside the species distribution would score zero.

Three variables were used for habitat suitability. Habitat preference (Ranked) on compositional analysis, Euclidean distance from marsh/water and NDVI as productivity of habitat. The habitat suitability model results revealed that marshes were the most suitable habitat (Table 9) and they are restricted to an average within 116 m (SE±2.99) from these marshes. The model has predicted 83% of habitat occupancy points correctly.

Fig 24 & Fig 25. Most of these areas are under agriculture and there is always a possibility in shift of cropping pattern, which may alter the Sarus Crane habitat. The Eigen value for three variables is 9.95/ 0.32/0.32, 20.53/0.66/0.99 and 0.41/0.01 and 1.00. The marginality value= 0.64, Specialization 3.2 and Tolerance= 0.31.

The ROC (Receiver Operator Curve) indicates hade off between sensitivity and specificity. Sensitivity rate indicate true prediction while specificity indicate rate of false prediction *i.e.* Point occupancy prediction is incorrect to given evidence of absence far that point.

The closer the curve follows the left hand border and the top border of the ROC space, the more accuracies the prediction classes it comes to 45° lines (diagonal) of the ROC space, less accurate the prediction. The value above 0.80 is considered to be good prediction and value 0.6 as par or failure of relationship (Fig 24).

Fig 24 The Receiver operator curve (ROC) indicate that probability of predicting correct habitat occupancy is 83% (i.e. Area under curve)

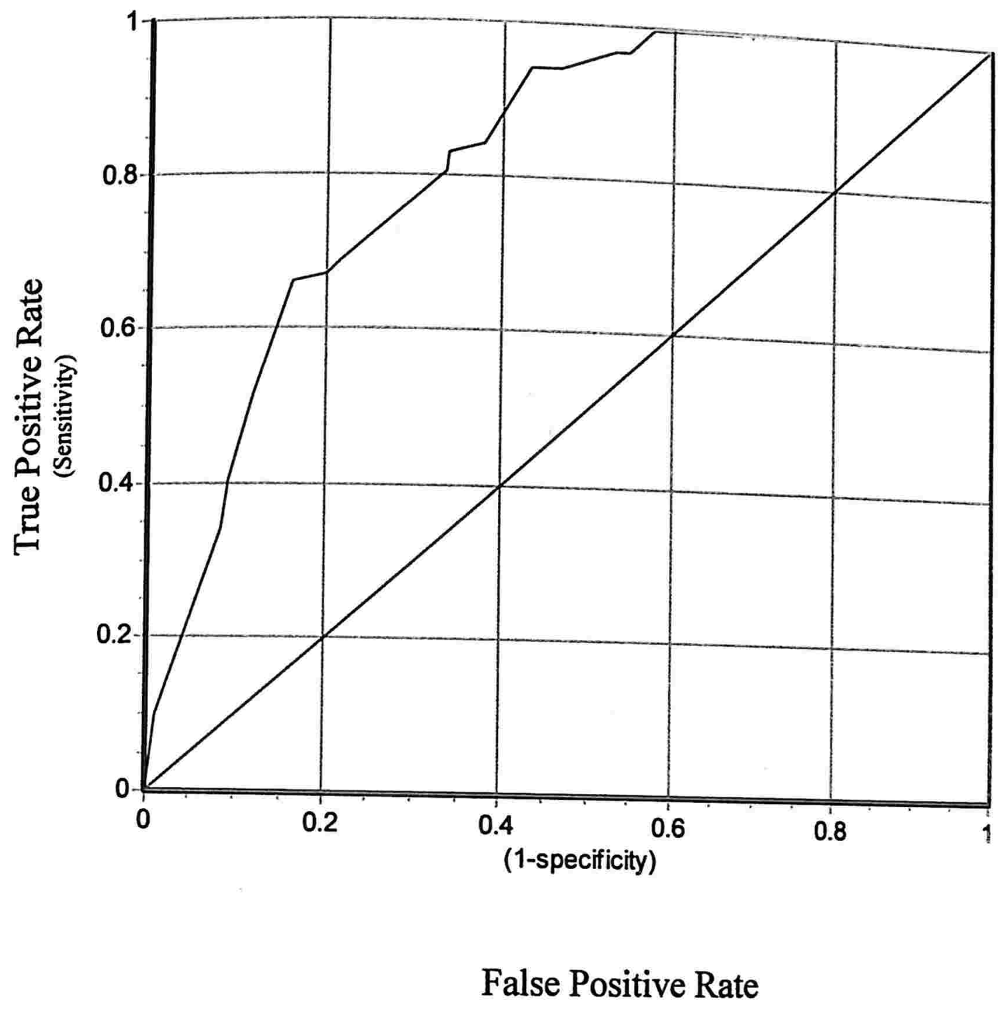
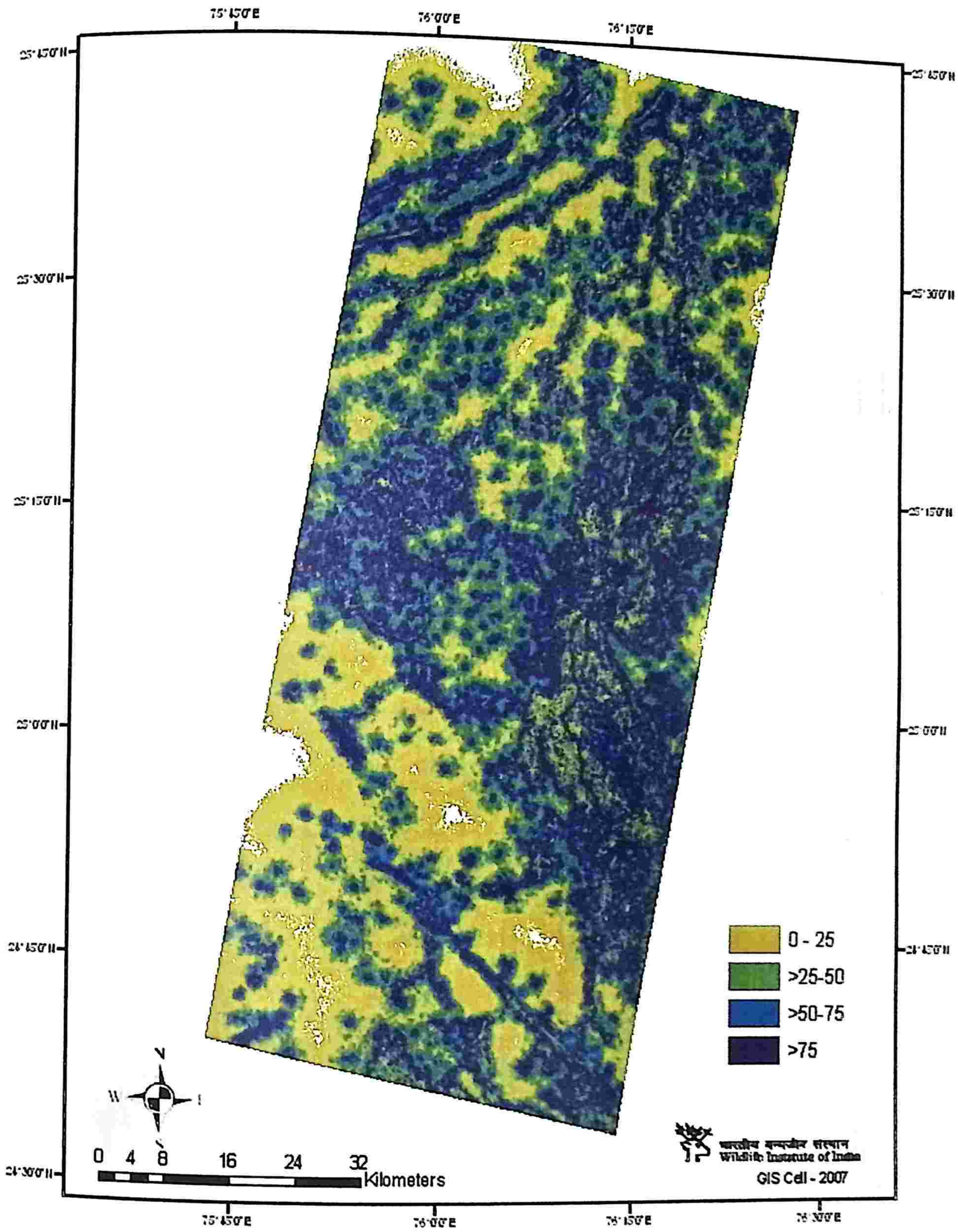


Fig. 25 Habitat Suitability map of Kota study area



4.4 Discussion

However hypothesis testing based on the small home range in Keoladeo Ghana National Park and marsh/wetland habitat were observed to be larger in Kota(Table 4&5), where they ranges from 59.9 sq.km to 18.35 sq.km depending on the condition size and duration of availability of water and forage resources. Seasonal estimate of home ranges of Sarus Crane breeding pairs with banded juveniles in Kota district revealed that they are more restrictive during rainy season and winter. Of the eleven families, eight were monitored till June and it was found that Lakhava family in natural wetland moved much widely ranging and it depends upon the seasonality of the wetland (Table 5). Therefore the hypothesis that in semi arid situation the home range will tend to larger for Sarus Crane and appears to be true.

Sarus Cranes move locally, utilizing a wide variety of habitat types depending on food availability, cropping patterns, and other seasonal factors (Archibald and Meine 1996). According to (Gole 1989, 1991b), optimal habitat for the Cranes includes a combination of marshes, ponds, fallow lands, and cultivated lands. Breeding pairs use larger wetlands wherever available, nesting in fields along the canals and irrigation ditches, beside village ponds, and in shallow marshes, rice fields, and reed beds (Gole 1989, Suwal 1995, Sundar *et al.* 1999, Sundar *et al.* 2000b, Sundar and Choudhury 2003). Adult pairs typically use cultivated fields, fallow land, and other drier habitats, as well as flooded fields, rice fields, and degraded (saline and water-logged) lands (Archibald and Meine 1996, Mukherjee 1999). Families with pre-fledged chicks, however, use wetlands almost exclusively (Gole 1989). The present study is largely in agreement with this observation.

Home ranges varied in different families in Kota and Bharatpur study area, and significantly, much larger in disturbed landscape in Kota. The abundance and distribution of food and nest sites are the key ecological factors determining the size of the home range and the extent of local and seasonal movement of the families of Sarus Cranes. It is likely that food and other resources are widely scattered in semi-arid and disturbed areas, and the birds are forced to travel much to obtain the resources. In Kota, as the man-induced wetlands and water resource contained therein are managed and maintained for human usage, the water level in these wetlands fluctuates very often affecting the activity and movement of Sarus Cranes (Vyas 2002). In response, the breeding pairs with banded juveniles in natural wetland Zetiya 2 and Lakhava family was having 273 and 299 sq km larger home-ranges during summer (March-June) and they also shifted to adjoining water bodies when faced with scarcity of water bodies in frequently used areas. Wetlands created through Seepage from the Right Main canal (RMC) of Kota barrage offered suitable condition for Sarus Cranes, but the canal is functional only during October to March and intermittently in summer months to supply water to National Thermal Power Corporation plant at Anta. In times of non-function of the Canal and when the previously seepage areas become dry, forcing the Cranes are forced to move out and shift to other areas. A total of four breeding pairs with banded juveniles moved out from the breeding territory in Kota during summer. Vyas (2002) also made a similar observation in the past regarding the dynamics of water availability. It was found that during water crisis situation, the Cranes move to Chambal River where congregation of Sarus Cranes takes place and they return to their original areas only after first rain.

Home range size of Sarus Crane in study area differs from that of other Crane species in the world. The movement and home ranges of florida Sandhill Cranes was studied by Bennet (1989), and sub adult home-range size varied from 590ha for juveniles to 329ha for three year old sub adults. Mobility and home range size were greatest in the summer and smaller in the winter, apparently in response to water level fluctuation. A qualitative estimate of home-range from unmarked Sarus Crane done by Gole (1989b, Suwal 1999a) mentioned the home-ranges to vary from 1ha in Keoladeo Ghana National Park to 27ha in unprotected areas. In Etawah and Mainpuri, the Sarus Crane has territories less than half a square kilometer in size. This is the smallest size known for Sarus Crane territories and is an indication of a superior habitat. This study didn't give any information how the territories size were calculated (Sundar & Choudhury 2006).

The present study in Bharatpur (KGNP) on Sarus Cranes home range was comparable with that of Gole 1989b & Suwal 1999a) and earlier studies conducted in Keoladeo Ghana National Park by Ramachandran & Vijyan 1994. The breeding territory ranges from 0.07sqkm to 1 sq km. The pairs remained in the same area throughout the years, except in summer. However, during non breeding season, they cover larger areas for foraging and in dry areas, they regularly move out of the wetland roost sites (Walkinshaw 1973, Ramachadran and Vijyan 1994).

The studies conducted on Grey Crowned Crane populations also concluded (Gichuki and Gichuki 1991, Gichuki 1993) that areas where food is abundant and suitable breeding sites available, home ranges are relatively small and local movements limited. They found an average breeding territory of 630 ha and an average home range of 2880 ha in Kenya, but noted that the ranges of individual birds varied with age, breeding condition, and season of the year. In Florida, the radio-marked sub adult and territorial adult Sandhill Cranes used home ranges averaging 21.32 sq km and

4.47 sq km respectively. Territorial adult range size was influenced by season, social status and habitat quality (Nesbitt *et al.*1990). In Wattled Cranes, the nesting pairs generally require wetlands with minimal human disturbance. Pairs are strongly territorial and may defend territories >1 km^2 in size (Konrad 1981). These territories are highly specialized, comprising shallow wetlands with predominantly sedge-based vegetation. Reported summer home range sizes are 2.6 (+/- 0.6) km^2 in China, 1-7 km^2 in Japan, and 4-12 km^2 in Russia (Kitagawa 1982 & Andronov *et al.* 1988). Families may use <1% of the home range at certain times of the breeding season (Kitagawa 1982), or use wholly different areas for feeding and nesting.

Most Crane species around the world select wetlands for breeding, and all species with the exception of the Siberian Crane (*Grus leucogeranus*), use dry lands as well for foraging (Johnsgard 1983). The blue Crane and the demoiselle Crane use dry land habitats throughout the year (Johnsgard 1983, Allan 1995). From the past studies and the present study, it was apparent that Sarus Cranes time their breeding to coincide with a period when food and water is in plenty. This strategy in the landscape (such as continued use of habitats converted from natural wetlands to paddy fields, but seeming intolerance to soyabean and sugarcane fields), is good for the survival of the species. The importance of maintaining natural wetlands, which are undoubtedly superior Sarus Crane habitats, cannot be overemphasized. However, given the fact that India is primarily an agriculture-based country, the development of the agricultural sector constitutes a very important agenda for the government. This invariably is done at the cost of natural wetland habitats. Other studies have documented the importance of paddy fields for water birds, and the effect of changes in agricultural practices-old practices with minimum disturbance continues to attract water birds (Lane and Fujioka 1998).

Habitat use

The Sarus Crane frequents a variety of wetland habitats, as well as cultivation, partially flooded and dry ground (Desai 1980, Gole 1989, Ramachandran and Vijyan 1994). The study conducted in Lumbini (Suwal 1999a) showed that habitat preferences varied with season, and partly according to crop rotation. Moreover, as natural wetland have diminished in extent, the species has adopted man-made wetlands as its home and the Sarus Crane use man-induced wetlands more in Kota in summer and in winter they use agricultural fields. This observation has support from the all India survey conducted by WII that majority of Crane sightings were in agricultural fields particularly rice and wheat fields, revealing the importance of man-made habitats (Gole 1989 & Sundar *et.al* 2001). Once the crops get harvested, parents spend time of the day feeding on the grains to fulfill their nutrition requirement (Kaur *pers. obs.*). In Kota district, the quantity of water extracted from the Chambal River for agricultural purposes has led to reduced flow in the drainage and the drying up of many natural wetlands previously used by Sarus Crane. These have been replaced by man-made tanks, dams, seepage marshes and inundated crop fields (Vyas 2002). Habitat use information is available for the Sarus Crane principally from Rajasthan and Gujarat where studies have been conducted at a comparable period. In areas with large wetland tracts, Sarus used more wetlands (Vyas 1999a, Latt 2002) and in areas where agriculture dominated, they used more crops fields (Table 9). The comparative account of the habitat use by Sarus Crane during different periods was shown in table (Table 10).

The habitat use by the Sarus Crane in KGNP, Bharatpur depend largely on the seasonality of the environmental regime. The most utilized habitat for the entire period of the study was wet grassland followed by dry grassland and moderately wet grassland. The percentage of birds using flooded grassland was high from July to February; they preferred flooded and moderately wet grassland. In moderately wet grassland, the soil is wet but not inundated. The water management for the Cranes should be such that a portion of the aquatic area should be kept shallow while a portion is inundated (Ramchandran & Vijayan 1994). During summer when flooded grassland and moderately wet grassland were absent in the park, they resorted to dry grassland. The wet grassland or flooded grassland was used almost in the same proportion for feeding during breeding season and these habitats are critical within the park for the survival of the species.

The presence of marshes interspersed with agriculture fields along the water bodies is important for the Cranes as this combination provide an ideal set up for nesting, feeding and escaping from predators, among several other activities including roosting. The chicks and juveniles benefit from this composition during summer breeding period when the temperatures are high and also there it will be exhaustive for the newly born to traverse long distance for foraging in the summer heat, exposing them to heat strokes and predation in the open fields (from crows, kite and dogs). During summers, the Cranes emigrate to larger water bodies around the area (e.g. dams, canals and river) and utilize these water bodies for roosting and feeding. In this season, they are most often seen in the agriculture fields near the water bodies feeding on the leftover grains of the harvested crop. An analysis of the impact of change in cropping pattern on the Sarus Crane was not possible as there are no comparative data available on the number of Cranes before the arrival of the cash crops in the area prior to this study, although the current behavioral study has indicted that they do not prefer the cash crops (e.g. mustard, soyabean) over the traditional crops of maize, paddy, peas and green gram. Given the habitat preference in the current term, it is necessary that the marshes are protected from encroachments including extension of agriculture, at least a width of 50m from the canal and about a width 20m along the wetlands need to be maintained on the margins of agriculture fields.

Table 10 **Comparative account of habitat use by Indian Sarus Cranes.**

Reference (Study period)	Study area	Crop fields	Natural wetlands	Other habitats
Individuals	Kheds district, Gujarat	%	%	%
Mukherjee 1999, (1997-98)	Monsoon:1200-1600h	85.45	12.39	1.16
	Rest of the day	73.24	26.3	0.45
	Winter: 1200-1600h	53.05	46.42	0.53
	Rest of the day	72.49	24.54	2.97
	Summer: 1200-1600h	50.98	46.04	2.98
	Rest of the day	50.64	44.47	4.88
Suwal (1999a)		57.46	40.29	2.24
Vyas (1999a) (1999)	Rajasthan and parts of Madhya Pradesh	27	73	0
Singh and tatu (2000) (1998)	Kheds and Ahmedabad Districts, Gujarat	77.86	19.55	2.6
Sundar *et al.* (2000b) (1998-99)	All-India	50.31	47.13	2.6
Latt (2002) (2000-1)	Keoladeo Ghana National Park, Rajasthan			
	Winter	5	20	59
	Summer		37	75

Vyas ((2002) (1993-4)	Kota, Rajasthan	55	22	23
Sundar (2003), (2000-02)	Etawah and Mainpuri, District, Uttar Pradesh			
	2000	37.24	60.03	2.73
	2001	51.4	36.4	12.2
	2002	49.18	46.91	3.91
Groups				
Gole (1989) (1988-89)	All India	42.55	52.15	5.3
	Gujarat	9.36	81.25	9.38
	Haryana	57.31	31.83	2.87
	Rajasthan	19.31	70.17	10.5
	Uttar pradesh	45.24	54.76	0
Mukherjee 1999, (1997-98)	Kheda district, Gujarat			
	Monsoon:1200-1600h	84.57	14.82	0.61
	Rest of the day	72.11	27.21	0.68
	Winter: 1200-1600h	60	38.46	1.54
	Rest of the day	71.62	22.97	5.41

Source: Sundar&Choudhury 2003

4.5 Summary

1. In the present study is first ever study the marked individuals and to document home range of breeding pairs with banded juvenile Sarus Crane. It also deals with the way the Sarus Cranes use habitat resources available to them in protected and unprotected environment. In semi-arid landscape in Rajasthan state where water bodies (wetlands) are limiting factors, it was important to hypothesis and test the habitat use and home range concept in relation to periodicity of water availability and forage resources.

2. Data on distribution of Sarus Crane in Kota using canal transect and the total count method was adopted to count Sarus Crane in Keoladeo Ghana National Park as all Sarus in the wetland could easily be counted. The home range of breeding pairs with juveniles was carried out. They have been monitored from their natal grounds in monsoon and winter to the congregating wetland sites during peak summer during the study period at both the field sites.

3. Based on the small home range in Keoladeo Ghana National Park and marsh/wetland habitat were observed to be larger in Kota, where they ranges from 59.9 sq.km to 18.35 sq.km depending on the condition size and duration of availability of water and forage resources. Seasonality of the home range of breeding pairs with banded juveniles of two families in natural wetland, they moved much widely ranging and it depends upon the seasonality of the wetland. Therefore the hypothesis that in semi arid situation the home range will tend to larger for Sarus Crane and appears to be true.

4. The abundance and distribution of food and nest sites are the key ecological factors determining the size of the home range and the extent of local and seasonal movement of the families of Sarus Cranes. The availability of food and wetland mosaic are widely scattered in semi-arid landscape. Due to this the foraging habitat range of the Sarus Crane is more and their survival rate is higher compared to Sarus Crane in landscape of natural wetland and agriculture crops.

5. In Kota, as the man-induced wetlands and water resource contained therein are managed and maintained for human usage, the water level in these wetlands fluctuates very often affecting the activity and movement of Sarus Cranes. The presence of marshes interspersed with agriculture fields along the water bodies is important for the Cranes as this combination provides an ideal set up for nesting, feeding and escaping from predators among several activities including roosting. It is necessary that the marshes are protected from encroachments including extension of agriculture. At least a width of 50m from the canal and about a width 20m along the wetlands need to be maintained on the margins of agriculture fields.

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CHAPTER 5

BREEDING BIOLOGY

5.1 Introduction

Sarus Crane is a monogamous species, and is known to have a similar pattern in their reproduction biology, behaviour and use of nesting habitat across their distribution range (Ali, 1958, Ali & Ripley 1980, Breeden and Breeden 1982, Gole 1987, Iqubal 1992, Ramachandran Vijayan 1994, Suwal 1999, Mukherjee *et al.* 2000, 2002). The material used for nesting is those that are available immediately around the nesting area and piling of vegetation into a roughly round heap surrounded by a narrow moat (Lowther 1944, Breeden and Breeden 1982, Gole 1987, Ramachadran & Vijayan 1994, Mukherjee 1999).

Pair formation and courtship was studied by Walkinshaw 1973a and it has been observed in Sarus Crane both during the winter months and also during the breeding season. Dancing sometimes occurs as a displacement activity when the nest, eggs or young are threatened. Territoriality and early nesting behavioural observations were taken in Keoladeo Ghana Sanctuary indicate that nesting may begins within a week after the start of the rainy season. During nesting Sarus wads of debris and vegetation out of the water and piling them on the nest site with a lateral movement. Nearly always two eggs are laid and according to Mogul emperor Jahangir, the interval between the laying of the two eggs is 48 hours (Ali 1927). Incubation is performed by both sexes and at the time of hatching the chicks is very week and they remain in the nest for two days. Walkinshaw (1973a) observed that the young birds remained with their parents for at least ten months or until the parents began breeding again.

The Wildlife Institute of India (1999) reported breeding population and the percentage of breeding pairs differed between various biogeographic region and seasons. Most breeding pairs were seen in Rajasthan, Gujarat and Uttar Pradesh in that order. Most of the breeding records were made during the winter survey (December to March) as recorded previously (Gole 1989, Parasharya *et al.* 1989, Vyas 1999a, Vyas 1999b). The data on populations of Sarus crane with two offspring's was compared with data on populations of other crane species which fledge two young (Johnsgard 1983 & Sundar *et al.* 2000a). (Sundar and Choudhury 2003) studied the proportion of young in the population is an important parameter that indicates the rate of recruitment and the extent of breeding success. The surveys used total counts of adults with young seen, and Mukherjee *et al.* 2002, used the number of young birds in flocks in the dry seasons. Grant (2005) studied the annual recruitment of Sarus Cranes in northern Queensland and mean recruitment over the 6-year period was 6.58%, with no significant variation between years. Nowald *et al.* (1996) conducted a study on common Cranes and results have shown that sibling bonds between juveniles of the same brood can last up to three years of age.

Some aspects of breeding biology of Sarus Crane have been studied by Ramachandran & Vijayan (1994) in Keoladeo National Park, Rajasthan in a protected landscape and only a few qualitative studies have been carried outside, at the protected landscape in Rajasthan (Kulshreshtha & Vyas 1989, and in Gujarat, Board *et al.* 2002 & Mukherjee *et al.* 2000). From the all-India survey by Gole in (1989) and Wildlife Institute of India (1999) and in other published literatures it has been suspected that the main reason for the decline in numbers of the Sarus Crane is egg mortality (Meine & Archibald 1996, Sundar *et al* 2000b, Kaur & Choudhury 2003).

Predation on eggs is largely by crows (Ramachandran and Vijyan 1994) and possibly by jackals (Mukherjee *et al.* 2002).Very little information is available on chick mortality. An instance of a young chick predated by marsh harriers is known from the present study in Kota (Kaur & Choudhury 2005). A possible case of cannibalism is reported by Xavier (1995), but was uncertain if it was an adult scavenging on a dead chick. Studies on chick mortality during post-fledging and post-dispersal are not available. No quantitative data on the breeding requirement of the species with respect to nest-site selection, pattern of weaning, territoriality and the like have been developed.

Nest site selection involves the choice of a site to construct nest and in marsh nesting birds, it usually occurs just prior to egg laying Cody (1985). Aucamp (1996) studied, the blue Cranes in the Southern Cape to determine the habitat preference of breeding and to got an indication of the density of pairs and their breeding success. In a mosaic of landscape, the Sarus is known to prefer natural wetlands as nesting habitats, though they are known to also use flooded paddy fields extensively for nesting (Suwal 1999, Mukherjee *et al.* 2000, Sundar *et al.* 2000b and Board *et al.* 2001a).

Single nesting season during the rainy season from July has been documented from all previous studies conducted on Sarus Crane in India. However, a second nesting seasons by the Sarus Cranes have been documented only in Rajasthan (Ramachandran and Vijayan 1994, Vyas 1999b) following the wet nesting season from July up to October and a second nesting season from February-May (dry season nesting) have been observed in Kota and Bharatpur, Ramachandran and Vijayan (1994). Renesting by Sarus pairs with unsuccessful first clutches has been recorded from captive birds for a very long time, Conway (1965), and is now known to be a common phenomenon

Ellis *et al.* (1996). In the wild, Mukherjee (1999) provided the first evidence of renesting in the Sarus. There are no studies, however, to document if renesting is advantageous in the wild.

During this present study, the nesting patterns, reproductive success of Sarus Crane in the semi-arid landscape of Kota and Bharatpur districts were studied in natural wetlands and man induced wetlands. Besides this the chapter deals with the differential level of threats to nesting Sarus Cranes in the two wetland landscapes during the two nesting periods and examines the following hypothesis.

Hypothesis:

1. Availability of water is the key factor contributing to initiation of breeding and combined with success or failure of the first nest triggered the second nest.

2. Dual nesting of Sarus Crane is an eco-physiological adaptation in semi-arid landscape.

3. Within the semi-arid landscape presence and absence of wetlands influenced the breeding success of Sarus Crane.

5.2 Methodology

Nesting seasons

Based on existing literature based information courting and breeding pair locating surveys were initiated during June/July as the summer season non breeding congregation spread out in smaller groups or pairs following the onset of monsoon into the wetlands and marshes and agricultural landscape. Efforts were made to cover exhaustively such areas to locate families of Sarus Cranes and nest in each field site. Presence of nest was also determined by observing behaviors of courting pairs and secondary information sources (farmers etc.). The study areas were surveyed for locating courting and breeding pairs by making use of the extensive metalled, non-metalled roads, and on foot. When the areas were invisible from any road they were traversed regularly during breeding season.

Most studies of nesting success of other species of Crane such as Sandhill Crane (*Grus canadensis*) had also involved periodic searches for active nests, with subsequent monitoring of the nest contents (Dwyer and Tanner 1992).The nests were also located following the birds while they prepared the nest, by locating the incubating adult and also through information gathered from the villagers.

Nest diametric

For every nest located variables related to nest site character such as nature of nest material, habitat type, status of wetland, depth of water in four points of the wetland, distance to nearest habitation, distance to the nearest motorable road. The sources of human and other disturbances were recorded based on observations during repeated visits to nest sites. These variables were also measured at randomly chosen points in marshland, wetlands within the study area. Analysis was done for the data obtained during the two years of field work in both sites to determine the influencing factors for nest site selection by Sarus Crane, nesting and hatching success and the necessity of second nest.

Egg Morphometry

The data on egg morphometry were also taken. Length and breadth of eggs were measured to the nearest 0.1mm using vernier callipers and weighed to the nearest 5 grams using a spring balance. Eggs were marked with water- proof ink pen for identification. Fates of all nests were checked until either the egg pipped, hatched or were predated.

Breeding Success

For successful nests, the date of nest initiation was calculated by subtracting the 30-day mean incubation period from the hatch date. Since cranes, have precocial young, nesting efforts were defined as successful if at least one egg was hatched. Evidence for breeding success included direct observation of one or two chicks, peeping, or a combination of length of nesting activity at the site together with the presence of eggshell fragments.

The different levels of threats were assessed on Sarus Cranes egg and chicks at the nest site. The breeding success was calculated for hatching, fledging and weaning. Success was calculated separately for eggs and nests used for both first nest and re-nests when calculating nesting success statistic.

5.3 Results of nesting seasons

5.3.1. Nest distribution and Chronology of nesting at Kota and Bharatpur

Sixty-seven nests were located during two and half year of study period from February 2000-May 2002 at both sites. The nests were initiated between 10 February and 10 May 2000-01 during dry season (second nesting) in both the study sites and from 26 July to 29 September 2000 in wet season (first nesting) with most nesting initiated towards the second week of August and beginning of September. In 2001 due to early rains nests were initiated on 9 July to 18 October in wet season with most nests initiated towards second week of July and beginning of August 2001(Table 1 & 2) (Fig 1). The breeding activity during Kota and Bharatpur district during study period is given in Table 3 and 4.

Table 1 **Initiation of nesting during dry(second nesting) and wet season(first nesting) in Kota and Bharatpur district.**

Season	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total no nest
Dry 2000	0	1	4	2	1	0	0	0	0	0	0	0	8
Dry 2001	0	0	2	1	0	0	0	0	0	0	0	0	3
Wet 2000	0	0	0	0	0	0	2	7	15	0	0	0	24
Wet 2001	0	0	0	0	0	0	6	23	2	1	0	0	32

Table 2 **Nesting by Sarus Crane during dry(second nesting) and wet season(first nesting) in Kota and Bharatpur district during February 2000-May 2002.**

Nesting by Sarus Crane	2000 Dry	2000 Wet	2001 Dry	2001 Wet	2002 Dry	Total
Kota Study Site	7	19	3	23	0	52
Bharatpur Study Site	1	5	0	9	0	15
Total	8	24	3	32	0	67

Fig 1 Nesting Chronology of Sarus Crane nests in dry and wet season in the Kota and Bharatpur district during 2000-2001

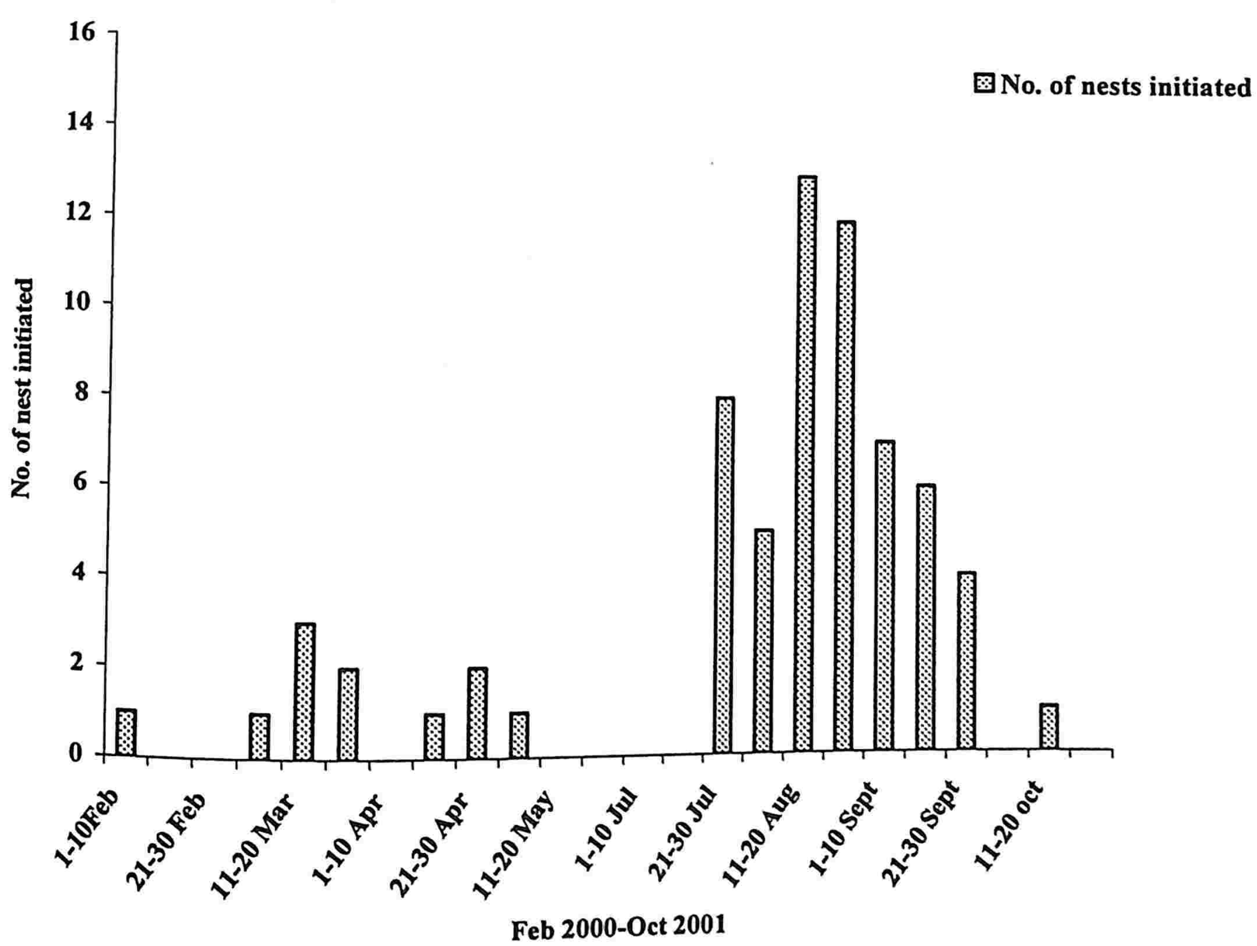


Table 3 **Observed stages of Breeding Activities in study site during the year 2000-2002**

Stages of breeding activites	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Dispersal of pairs from congregation	+											+
Pair formation and Courtship display	+	+	+						X	X	X	
Nest building and displays		+	+	+	+				X	X	X	X
Incubation		+	+	+	+				X	X	X	X
Hatching		+	+	+	+	+				X	X	X
Parental Care and Chick rearing	X	+	+	+	+	+	+	+	X	X	X	X
Weaning and dispersal	+							+	+	+	+	+

(+): Wet Season (first nesting) breeding activities

(X): Dry Season (second nesting) breeding activities

Table 4 **Observed stages of Breeding Activities in Bharatpur during the year 2000-2001.**

Stages of breeding activities	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Dispersal of pairs from congregation	+											+
Pair formation and Courtship display	+	+										
Nest building and displays		+	+	+								
Incubation		+	+	+								
Hatching			+	+	+							
Parental Care and Chick rearing			+	+	+	+	+	+	+	+		
Weaning and dispersal	+									+	+	+

(+): Wet Season (first nesting) breeding activities

5.3.2 Nest

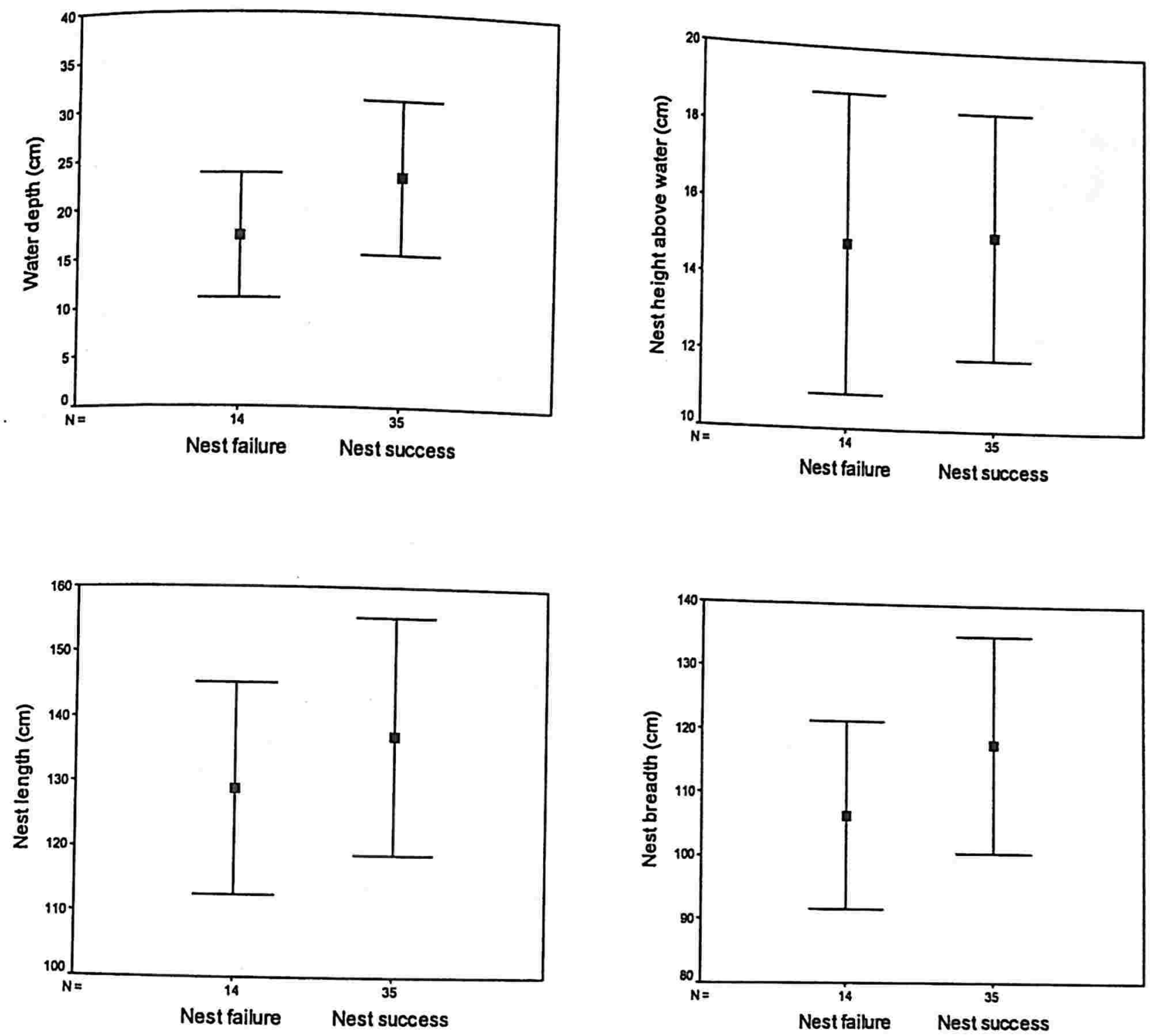
Depending upon the availability of water Sarus Crane used different habitat for constructing the nest. In Kota the nests were observed in man-induced wetland, natural wetland and agricultural fields. In Bharatpur, Keoladeo Ghana National available natural wetland was used for the construction of nest. The nesting habitat use by the Sarus Crane was measured and analysis was done using statistical package. The Sarus Crane nesting characteristic were measure and data were pooled for both the site to see if there is any difference in the length and breadth of nest made by Sarus Crane in two study sites. The mean nest length and breadth was recorded 134.73 cm (SD± 47.24) and 114.62 cm (SD±44.82) in both the study site and mean nest height above water was 15.06 (SD±8.74) and water depth around the nest recorded were 21.68 cm (SD±20.24).

To examine if the nesting success is influenced by any of the nesting characteristic, Man-Whitney T test were done and nest success and failure were not related to either nest dimensions or substrate characteristic in Kota such as depth of water (P=0.88), Nest height(0.75), Nest length (0.99)and Nest breadth (P=0.96)(Fig 2).

The nest success and failure with respect to nest dimensions by pooling data of Kota and KGNP were not related nest dimension and (P=0.73) is insignificant for Depth of water, Nest height (P=0.78), Nest length (P=0.53) and nest breadth (P=0.57).

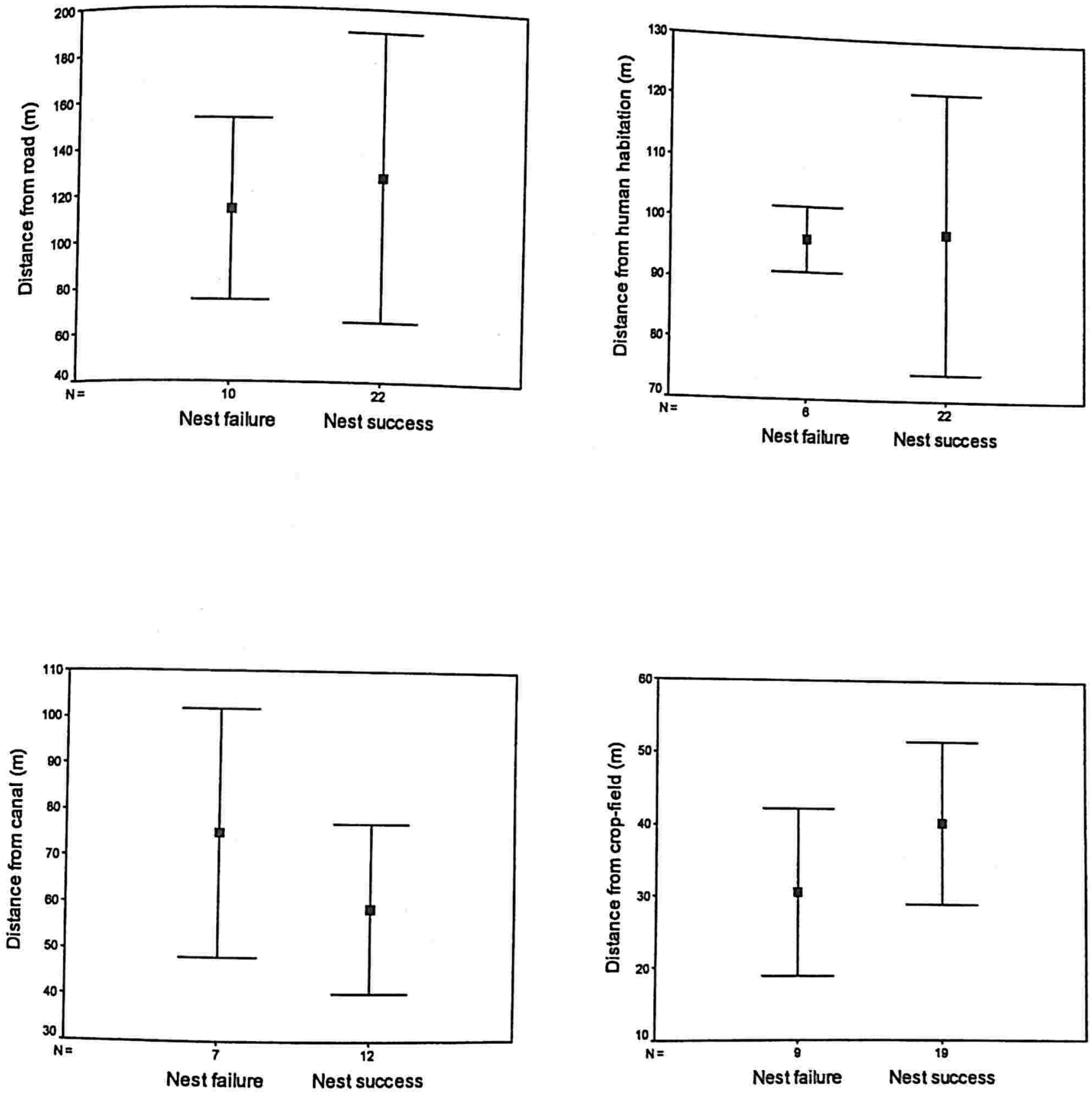
Based on four variable overall results shows that nesting success / failure in both Kota and Bharatpur are not found to have any association with nesting characteristic. The nesting success is seems to be more to do with the local and environmental condition.

Fig 2 **Comparison of nest success and failure among Sarus Crane with respect to nest dimensions and substrate characteristics. The error-bars refer to upper and lower bounds of 95% confidence intervals about the mean.**



Further analysis was done to find out if the distance of nest from chosen variable such as distance of nest from the road, canal, agricultural fields and nearby habitation is influencing the nesting success. Man Whitney T-test was done and results revealed that none of the variable showed any relationship to nest success and (P=0.32 for the distance from road, P=0.60, distance from habitation, P=0.26 distance from canal and P=0.35 distance from crop fields) (Fig 3). It seems that the nesting success in study area is more to do with a human population, around and they are more vulnerable to these factors, rather then the nesting characteristic.

Fig 3 Comparison of nest success and failure among Sarus crane with respect to distance from roads, human habitations, canal, and crop-fields. The error-bars refer to upper and lower bounds of 95% confidence intervals about the mean.



The result of nesting success in Kota was influenced by disturbance such as human being, dog, cattle and others. (Kendall's Tau-b= 0.30, P=0.026) and Kendall's Tau-b it ranges from -1 to +1.

5.3.3 Egg Mormphometric

A total of 104 eggs were measured during breeding season of 2000 to 2002 in Kota and Bharatpur field site. The data were pooled for both the sites and paired T-test was performed to see if there is any difference between Length, breadth and weight of the Sarus Crane first egg laid and second egg. Paired T-test indicate significant difference between the length, breadth and weight of the Sarus Crane first laid and second egg laids.

In Kota the comparison was done between significant difference being observed in the length, breadth and weight of the Sarus Crane in Kota. Weight of the first and second egg of Keoladeo was significantly differing and there is no difference between length and breadth (Table 5).

In dry season (second nesting) 12 eggs were measured during in Kota field sites and to see if there is any difference between first egg laid and second egg laid in Sarus Crane. Paired t-test was performed and there were a significant difference between length and breadth of the egg, but no difference in weight of first and second egg (Table 5). The comparison of the egg diametric measured by different workers (Table 6).

Table 5 **Comparison of egg morphometry of Sarus Cranes in Kota and Bharatpur district of Rajasthan**

Morphometry of egg in Kota

Total eggs	**Length (mm)**	**Breadth (mm)**	**Weight (gm)**
First egg(n=39)	111.55±1.96	73.10±2.166	209.61±5.86
Second egg (n=39)	100.85±1.98	67.21±1.39	190±5.21

Morphometry of egg of KGNP

Total eggs	Length (mm)	Breadth (mm)	Weight (gm)
First egg (n=13)	104.50±2.16	70.19±1.82	216.92±8.09
Second egg (n=13)	102.51±2.39	68.35±1.55	199.61±7.14

Morphometry of egg (Kota and Bharatpur)

Total eggs	**Length (mm)**	**Breadth (mm)**	**Weight (gm)**
First egg (n=52)	109.79±1.61	72.37±1.68	211.44±4.82
Second egg (n=52)	101.26±1.59	67.50±1.10	192.75±4.30

Morphometry of egg of Kota during dry season(second nesting) in Kota

Total eggs	**Length (mm)**	**Breadth (mm)**	**Weight (gm)**
First egg (n=	114.46±3.7	76.78±7.7	176±9.18
Second egg	96.76±4.7	63.2±3.48	171.5±7.91

Table 6 Comparison of the egg diametrics measured by different workers.

Egg diametric	Blaauw (1897) n=51	Baker (1928) n=100	Walkinshaw (1973) n=10	Walkinshaw (1973) n=73*	Mukherjee (1999) n=70
Length (mm)					
Mean	101.5	104.4	101.1	101.35	100.5
Range	-	93.2-113.2	93.2-112.3	88.3-112.7	88.7-109.0
Width (mm)					
Mean	65	64.3	62.75	64.27	64.4
Range	-	53.82-69.8	58.7-65.6	58.7-70.1	57.2-70.6
Weight (g)					
Mean	-	-	212.56	-	216.23
Range	-	-	183.4=247.6	-	164.0-286.0

* Including measurements from museum collection

5.3.4 Breeding Success

5.3.4.1 Clutch size in dry (second nesting) and wet Season (first nesting) in Kota during (2000-2001)

In dry season of 2000 (Feb-May) a total of 7 nests were observed and most of the nest had two eggs (n=6, 85.7%), while only 14.2% (n=1) of the nests had one egg. One pair renested after egg stealing took place. A total of three nests were sighted during 2001 dry season.

In wet season 2000, 19 nests were observed and most of the nests had two eggs (n=17, 89.5%) and 10.6% (n=2) of the nest had one egg each. A total of 23 nest of 2001 wet season were observed, and most of the nest had two eggs (n=18, 85.71%) and three nests (14.28% n=3) had one egg. One pair had abandoned the nest without egg laying and other nest Sarus was found dead near the nest. Three families of Sarus with chicks were found with 15-30 old chicks.

5.3.4.2 Nest Site selection in Kota

In year 2000 the most preferred nest site was man-induced wetlands (Canals) during dry seasons and both natural and man-induced wetlands support nesting during wet season, with typha or aquatic vegetation (n=10, 52.63%) and eight nests (42.10%) were in natural wetlands. Only one nest was in agricultural field during wet season.

The most used nest site was natural wetlands (n=17, 80.95%) and very few in paddy field (n=2, 9.52%) of the nest in chara (fodder) field (n=2). Of the nests in natural wetlands, most nests were in wetlands created by seepage from canals (n=9, 44.85%) and the rest were in wetlands created by flooding of rain water (n=8, 38.09%) in 2001 wet season. The dry season of 2001 all the three nests were observed in man-induced wetlands in Kota(Table 7).

Table 7 **Nest site selection during 2000-2001 Kota study sites.**

Year	**Season**	**No. of nests**	**Nests site**
2000	***Dry season***	7	Man-induced wetlands
2000	Wet season	10	Man-induced wetlands
2000	Wet season	8	Natural wetland
2000	Wet season	1	Corn field
2001	***Dry season***	3	**Natural wetland**
2001	Wet season	9	Man-induced wetlands
2001	Wet season	8	Natural wetland
2001	Wet season	2	Paddy field
2001	Wet season	2	Charra field

5.3.4.3 Nesting Performance in Kota

In dry season of 2000, three eggs got stolen and number of hatchlings was 10 and one chick died on first day.

Out of the 19 nests in wet season 2001, egg stealing was recorded in (n=9) nests i.e. 47.3% and one nest drifted away. In the 2001 breeding season egg stealing was recorded in only one nest by locals. One nest with two eggs drifted away during heavy rain. Of the 39 eggs observed, 34 (87.17%) hatched (Table 8 & 9).

Table 8 Breeding success of Sarus Crane in Kota district during wet Season 2000

	Nest (n=19)	Eggs (n=36)
Hatching Success	(9) 47.36%	(17) 47.22%
Fledging Success	(5) 26.31%	(2) 5.5

Table 9 Breeding success of Sarus Crane in Kota district during wet Season 2001

	Nest (n=21)	Eggs (n=39)
Hatching Success	(19) 90.47%	(34) 87.17%
Fledging Success	(11) 5.23%	(17) 43.58%

5.3.4.4 Survival of Young during dry season and wet season in Kota

Of 7 nests in which the egg hatched during dry season of 2000, the death of seven young was within two months of hatching and death of three after three and half month. Therefore, none of the chicks survived beyond three and half month. In 2001 a total of 3 nests were constructed and one nest was abandoned with one egg and 2 chicks were hatched. None of the chicks survived beyond one month. No nesting was observed during 2001 dry seasons in Kota (Table 10)

Table 10 **Mortality of egg and young ones in Kota during (2000-2001) dry season nesting.**

Season	Total eggs	No. of stolen eggs	Hatching success	Chick mortality
Dry season 2000	13	3	10	7(<3.5 months) 3(>3.5 months)
Dry season 2001	3	0	2	2(<1months)

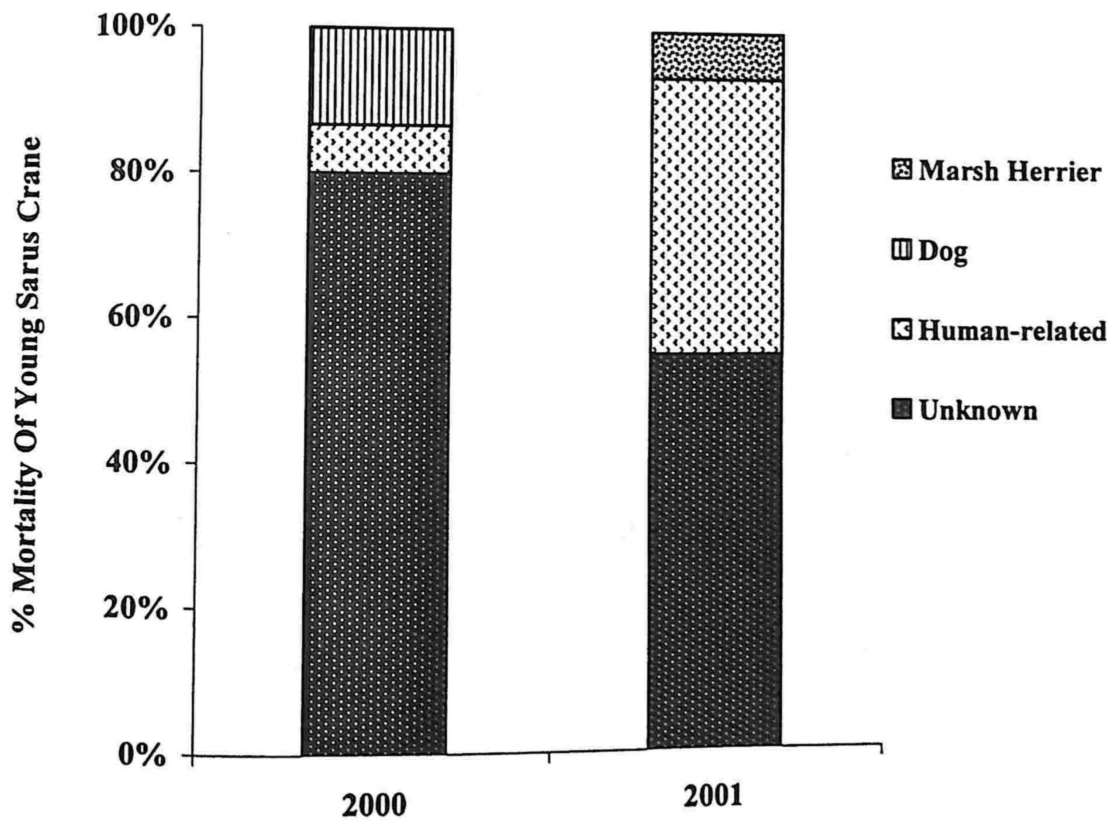
In wet season of 2000, 9 nests, 17 young ones hatched out and four survived to 20 days, five young died within one month and three died within two months of hatching. A total of 15 young one died, of which the reasons for 80% could not be ascertained. Predation by dog (n=2, 13.33%) and human related factors contributed to 6.6% each to the morality.

Of 34 young hatched during 2001 breeding season, 17 died, with reasons for most (n=16, 72.22%) being unknown. Predation by marsh harrier was recorded (n=1, 5.5%) for the first time (Table 11) & (Fig 4).

Table 11 **Mortality of Sarus Crane young ones in Kota district (2000-2001) during wet season nesting.**

Year	Total no. of chick hatched	Reasons for Mortality			
		Dog	Marsh Harrier	Human-related	Unknown
2000	17	2	0	1	12
2001	34	0	1	0	16

Fig 4 Causes of mortality of Sarus Crane young in wet season in Kota during 2000-01



5.3.4.5 Clutch size in dry and wet Seasons in Bharatpur during 2000-2001

In 2000 dry season only one nest were recorded inside the park, with two eggs. During last week of July 2000, clutch sizes of 4 nests were observed inside the park and one nest outside the park. All the nest had two eggs.

In Bharatpur (Keoladeo Ghana National Park) 2001 wet season, clutch sizes of 7 nests were observed inside the park and 2 nests outside the park. Out of 9 nests recorded, (n= 7, 77.77%) of nests had two eggs, and 22.22% (n=2) of the nests had one egg each.

5.3.4.6 Nest site selection

All nests (11) were built on a slightly raised area in submerged portions of the park. All the nests were completely constructed using aquatic vegetation like *Paspalum distichum, Ipomea aquatica* and with few twigs of *Acacia* tree. Two nests outside the park were built on raised areas using *Typha* reeds and one nest was built of mustard stalks (Table 12).

Table 12 Nest site selection during 2000-2001 in Bharatpur district.

Year	Season	No. of nests	Nests site
2000	*Dry season*	1	Natural wetland
2000	Wet season	4 inside KGNP	Natural wetland
2000	Wet season	1outside KGNP	Marsh
2001	Wet season	7 inside KGNP	Natural wetland
2001	Wet season	1outside KGNP	Marsh
2001	Wet season	1outside KGNP	Mustard stalks

5.3.4.7 Nesting performance

Of the 5 nests of 2000 wet season breeding in which the eggs were laid, young of one nest died within 15 days of hatching. Three pair had abandoned the nest after egg laying. Of the 9 nests in which the egg were laid (2001), one egg got stolen outside the park. In Bharatpur, (KGNP) two pairs abandoned the nest after egg laying and in one nest, two eggs were there, but only one chick was hatched out. One chick was found dead near the nest. A total of 8 chicks were hatched inside the park and 3 chicks outside the park from three nests. Of the 16 eggs observed, 11 (68.75%) hatched (Table 13 & 14).

Table 13 **Breeding success of Sarus Crane in Bharatpur district during wet Season 2000**

	Nest (n=5)	Eggs (n=10)
Hatching Success	(2) 40%	(4) 40.7%
Fledging Success	(2)40%	(3) 30%

Table 14 **Breeding Success of Sarus Crane in Bharatpur district during wet Season 2001**

	Nest (n=9)	Eggs (n=16)
Hatching Success	(7) 77.77%	(11) 68.75%
Fledging Success	(2) 22.22%	(3) 18.75%

5.3.4.8 Survival of young

During 2000 breeding season, only two families were being monitored. The mortality of 9 young ones was recorded during 2001, and the reasons of mortality could not be ascertained.

5.4 Discussion

Based on the nest in wet and dry season (Table 1 & 2, Fig1) in Kota and Bharatpur, the Sarus appears to have adapted to a dual nesting pattern, synchronizing with the man-induced flooding of landscape through canal waters in semi-arid zones. Sarus Crane in the study area condition showed a distinct dual nesting pattern, one in (February-May) and the other in (July–Oct), during our study duration in Kota. In Bharatpur only one nest was observed during 2000 dry season nesting. While nesting initiation synchronizes with the monsoon season in general, onset of monsoon rains (See Chapter 3) and availability of water for nesting area, wetland (natural), man-induced, crop fields and preserve of water nearby were the most important for nesting of the Sarus Crane in the semi-arid landscape. Though natural wetlands were observed to be the most crucial requirement for the survival of the Sarus Cranes, a mosaic of wetlands in agricultural landscape appears to be the changed. Wetlands created through seepage from the Right Main canal (RMC) of Kota barrage offered suitable condition for Sarus Cranes, breeding during dry and wet season, but the canal is functional only during October to March and intermittently in summer months to supply water to National Thermal Power Corporation plant at Anta.

During monsoon when the entire landscape remains inundated with water for four to five months, it creates a suitable nesting ground and ensure easy food for the Cranes and their chicks which is the major nesting period. However, in wet season higher incidence of egg and chick mortality and predation results in low reproductive success (Table 10 & 11). As a result of the low fledging success in the wet season triggered by high level of predation mortality for Sarus Crane in semi-arid zone. This makes the pairs to be physiologically ready for a second nest and the man induced wetlands in dry season provide a sub optimal breeding habitat for the second clutch. The occurrence of second nesting in dry season is hypothesized to be an adaptation, but due to less number of nests in dry season (Table 2) the hypothesis can't be proved. However, the survival of the second nests was governed by factors such as predation, hydrology and availability of food. During dry season all the resources become limited and there in no insect and tuber during that period. The pairs have to invest more time in search of food and the only easy available food is post harvesting left over grains. Use of insecticide in agriculture fields during the seed sowing is an additional threat to the nesting Sarus Crane. One pair of Sarus Crane along with other birds was found dead due to rat poison (carbon tetrachloride) in agriculture field. The second clutch results in larger parental investment for chick rearing, all these factors lead to low or non survival of chicks during dry season nesting.

The studies conducted on Sarus Crane shows main nesting season is during July to September (Walkinshaw 1973a), However, Walkinshaw (1973a) records showed that clutches were in all months of the year except April and May. The studies conducted by other authors (Kulshreshtha & Vyas1989, Ramachandran & Vijayan 1994), recorded second nesting during February to April in Kota and Bharatpur. The detailed investigation is not done in their studies. Nesting in Gujarat state shows that Sarus breeding is synchronized (Mukherjee 1999, Mukherjee *et al.* 2000).

Birds use their nest chiefly to protect themselves, their egg, and particularly their developing young from predatory animals and from adverse weather during the breeding season. For protection against predators, birds rely mainly on nests that are inaccessible, armored, camouflaged. Either through their construction or placement, many nests protect their inhabitants from rains, flood. A second major function of a nest is to maintain the warmth that promotes incubation of eggs and rapid development of young. Most of the nest in Kota and Bharatpur were recorded in man-induced wetlands and natural wetland and very few nests were recorded in agricultural field (Table 7 & 12), compared to earlier studies conducted by Mukherjee (1999) & Borad *et al* 2001a. According to them, the non-cultivable land within agricultural marshland proved highly beneficial to the breeding Cranes because there were less human interferences and predation risk compared to paddy fields Mukherjee (1999). The significance of specific water depth around the nest was chiefly to prevent the approach of ground predators to the nest. Certain height of the nest above ground helped the incubating Sarus Crane in maintaining a continuous vigilance against predator at a distance and the human disturbance. From the results nest success and failure are not having any association with nesting characteristic. The water availability and disturbing factors is the key factor to contribute nest success or failure. The mean depth around the nest recorded was 21.68cm in study area. Walkinshaw (1973a) recorded about one meter water depth around the Sarus nest in Keoladeo Ghana national Park. In several other cranes particularly in common crane, minimum water depth around the nest was ca. 50cm (Neumann 1987).

The breeding success of the Sarus Crane was primarily hampered at all stages by human-related causes in semi-arid landscape. Direct persecution was most apparent in the egg stage and in both the study sites, natural wetlands were observed to be crucial for the survival of Sarus Cranes, as they primarily use aquatic vegetation for constructing nests. The only other habitat to be used by Sarus in study area was man-induced wetland, crop fields and few in paddy fields and one rarely recorded for the first time in cornfield and one on stone debris at Kota. Most Cranes nest in wetlands, sometimes in agricultural marshland (White, 1987, Pivovarov 1995) and the Demoiselle Crane (*Grus vigro*) is known to nest in crop fields (Kovshar 1987, Winter 1991).

Egg size data obtained in Kota and Bharatpur study sites were comparable with those obtained (Table 5). For a given study area, all else remaining constant, food is thought to be the most important factor determining egg size in semi-arid landscape. Larger egg contains more absolute amounts of nutrients than do smaller egg and egg size may play a more distinctive role in hatchling survival than egg content. The same result was further confirmed in the present study and several factors are known to affect egg size including size of female, genetic constraints, age and condition of female (Carey 1996).

Earlier workers collected data from the larger area of its distribution whereas ours was from a specific study site and hence the range of values was less (Table 6). The egg constituted 2.8% of the average adult female Crane body weight 7.4 Kg, Ellis et *al.* (1996). The observation agrees with the earlier established fact that large birds lay proportionately smaller eggs than small birds (Pettingill 1971; O'Connor, 1985). Board (1998) and Mukherjee (1999) had established that the first egg of a clutch was always larger compared to the second egg.

Breeding Success

Sarus Crane is originally a marshland bird and have adapted to a system of crop fields interspersed with natural marshlands. It was found that breeding success was affected both by natural causes such as predation, food availability as well as anthropogenic causes such as egg robbing and prevalent agricultural practices. The egg mortality in Kota was mostly seen to have occurred when children removed the eggs to play and egg stealing by local farm labourers and migrant for food and medicinal use for curing diseases. Mortality of Sarus chicks and juvenile recorded in the study area for two consecutive years in Kota has been shown in Table 10&11. There is one observation of our banded juvenile being shot dead in the year 2002. The house crow *Corvus splendense* was an opportunistic predator; the incubating cranes were disturbed and compel to leave the nest. In response to flooding, the nesting pairs attempted to raise the nest platform by adding fresh material. However, when the area was suddenly flooded, the nests were submerged and eggs were drawn. In dry season one pair was incubating for 45 days and then left the nest, however hatching failure due to infertility has been reported in Sandhill cranes Walkinshaw (1973b) and in Whopping Cranes.

Predators previously recorded for Sarus crane chicks include jackals (Walkinshaw, 1973a, Ramachandran and Vijyan, 1994) and dogs (Mukherjee & Board, pers.obs.). Although an observation of a male Sarus Crane calling loudly and chasing Marsh Harrier from its nesting territory has been recorded previously, indicating the possibility of chick predation by large raptors (Iqubal 1992, Mukherjee *et al.* 2002), the present study confirms and records incidence of predation by marsh harrier (Kaur & Choudhury 2005).

5.5 Summary

1. During this present study, the nesting patterns, reproductive success of Sarus Crane in the semi-arid landscape of Kota and Bharatpur districts were studied in natural wetlands and man induced wetlands. Besides this the chapter deals with the differential level of threats to nesting Sarus Cranes in the two wetland landscapes during the two nesting periods and examines the following hypothesis.

2. Data on nesting season were collected where efforts were made to cover exhaustively such areas to locate families of Sarus Crane. The nests were also located following the birds while they prepared the nest, by locating the incubating adult and also through information gathered from the villagers. Nest diametric and egg morphometry data were collected. For successful nests, the date of nest initiation was calculated by subtracting the 30-day mean incubation period from the hatch date. The different levels of threats were assessed on Sarus Cranes egg and chicks at the nest site.

3. I derived that the Sarus appears to have adapted to a dual nesting pattern, synchronizing with the man-induced flooding of landscape through canal waters in semi-arid zones. Sarus Crane in the study area condition showed a distinct dual nesting pattern, one in (February-May) and the other in (July –Oct), during our study duration in Kota. The availability of water for nesting area, wetland (natural), man-induced, crop fields and preserve of water nearby were the most important for nesting of the Sarus Crane in the semi-arid landscape.

5. During monsoon when the entire landscape remains inundated with water for four to five months, it creates a suitable nesting ground and ensure easy food for the cranes

and their chicks which is the major nesting period. However in wet season higher incidence of egg and chick mortality and predation results in low reproductive success. The result of the low fledging success in the wet season triggered by high level of predation mortality for Sarus Crane in semi-arid zone. This makes the pairs to be physiologically ready for a second nest and the man induced wetlands in dry season provide a sub optimal breeding habitat for the second clutch.

6. The survival of the second nests was governed by factors such as predation, hydrology and availability of food. During dry season all the resources become limited and there in no insect and tuber during that period. The pairs have to invest more time in search of food and the only easy available food is post harvesting left over grains.

7. Breeding success was affected both by natural causes such as predation, food availability as well as anthropogenic causes such as egg robbing and prevalent agricultural practices. The egg mortality in Kota was mostly seen to have occurred when children removed the eggs to play and egg stealing by local farm labourers and migrant for food and medicinal use for curing diseases.

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CHAPTER 6

BEHAVIOURAL ECOLOGYOF SARUS CRANE IN SEMI ARID LANDSCAPE

6.1 INTRODUCTION

All Cranes are basically diurnal in their habits and through the day they forage, rest and preen, attend to their young during the breeding season, and socialize within flocks in the non breeding season. At night during the breeding season, cranes stay on or near their nests, brooding their chicks and standing guard against predators and other dangers. In the non breeding seasons cranes roost at night in more or less flocks at traditional roost sites (Meine & Archibald 1996). Like most species, the behaviour of individual Cranes can be divided into those activities that are self-directed and those that are undertaken in response to other Cranes and other external stimuli. In addition to such fundamental activities as eating, drinking, sleeping, walking and flying, self-directed activities include preening, bathing, shaking, stretching, ruffling, scratching and feather painting.

Time-activity budget studies are useful for knowing, how birds cope with varying energy demands and various environmental changes on a daily, seasonal, and year to year basis (Maxson & Pace 1992). Reviewing the literature shows that general behaviour of cranes has been well documented but very little is known concerning the time and activity budget of Cranes (Eguchi *et al.* 1991, Sparling and Krapu 1994). It is also not known whether cranes adapted to different climatic regimes exhibit different behaviour patterns.

Behavioral studies of Cranes have revealed some 90 or more specific behavioral patterns within these categories (Ellis *et al.* 1987). There exists a fundamental need for standardizing terminology in describing animal behaviour and several descriptive terms are often used even for clearly homologous behaviour acts (Ellis *et al.* 1998). The units of animal behaviour are hereafter called a "ethons" given in (Lehner 1979). The behavioural repertoire for the world's 15 species of cranes include over 100 behavioural acts with social significance (Ellis *et al.* 1998). Each species performs at least 60 discrete social postures, vocalization, displays and activities. An attempt to prepare specific ethogram of Japanese Crane (*Grus japonensis*) has probably never been carried out except a few by (Masatomi and Kitagawa 1975). (Archibald 1976a) used social displays, especially the Unison-call in an attempt to decipher crane phylogeny.

An ethogram is a prerequisite for any behavioural study on a species. For a long time, crane biologists were lacking this basic information and two recent publications by (Ellis *et al.* 1987) & (Ellis *et al.* 1998) are based on observation of captive cranes. The social ethogram consists of two parts, first is the sociogram, which is a description of all social displays, including higher-level behaviour sequences, termed as activities. The second is the presence and importance of each social ethon as simple as a reflex or as complex as an activity.

Mukherjee 1999 classified the behaviour patterns of Sarus Crane observed in Kheda district of Gujarat into egocentric and social behaviour. The results helped in understanding the impact of the environmental factors like period of the day, season etc. on various behaviour changes. An ethogram for Sarus Crane based on observation carried out during the study period from 2000-2001 has been prepared in the present study. Besides thi, the chapter deals with the range of behaviour patterns observed on Sarus Crane in the study area, as also an examination of differences in behaviour patterns of Sarus in the semi- arid landscape. For confirmation through observations, the following hypothesis have been tested.

Hypothesis

1. The Sarus will exhibits a lower range of behaviour pattern and reduced time-activity budget adapting to the semi-arid nature of the landscape as a great deal of behaviour will be diverted to specific activity.
2. In a semi-arid landscape Sarus Cranes will spend a greater amount of the time foraging and maximizing opportunity of food availability in a wider range home range.
3. In an attempt maximize chick survival Sarus pairs will spend more time in foraging and searching for food in a water deficient area, the parental investment on chick protection will be less and chick survival will be low.

6.2 Methods

Prior to initiating the present study, a detailed compendium of behaviour containing defined and described behavioural activities was prepared (Table 5). Once the main behavioural forms were fixed, a scan animal sampling (Altman 1974), was carried out on different age group individuals to document activity budgets for each of the sexes and the juvenile(s). First few months in the field were used to standardize the sampling scheme, identify the potential sites for observing Sarus Crane and design the basic ethogram for the species.

A day was divided into five time zones (0500-0800h; 0801-1100h; 1101-1400h; 1401-1700h; 1701-2000h) and in each time zone, scan samples (3-15 min) were carried out on pairs and families (adult with young). Six to eight scan samples of each category of Cranes in each time zone per month were carried out and the sampling was carried out during the summer and winter seasons in both the study site during the year 2000 and 2001 (Table 1).

This approach was replicated in Keoladeo Ghana National Park, Bharatpur, except that data collection began a bit later in April 2000. Considering the local climatic condition; the behavioural data for the pairs were represented into two seasons; summer (March-June), and winter (October to February) for further analysis. The observation of nine different pairs consisting of male and female in Kota and six different pairs in Bharatpur was observed during the different scan samples. During the rainy season *i.e.* during Jul-Sept. most of the area becomes inaccessible and effort was searching more nesting pairs and many a times pairs (male and female) were not sighted hence the behavior observation during this period was restricted to record for the pairs consisting of male and female.

A total of twelve families in Kota and five families in Keoladeo Ghana National Park were observed during the breeding seasons, for two year of study duration.

Table 1 **Sample size and observation in Kota and Bharatpur during 2000-2001.**

Study Site	Summer				Rainy (Breeding Season)			Winter			
	MF	*Fam*	*Juv.*		*Fam*	*Juv.*		*MF*	*Fam*	*Juv.*	
			J1	*J2*		*J1*	*J2*			*J1*	*J2*
Kota 9 Pairs and 12 families	216	557	358	94	91	46	29	182	1266	765	409
Bharatpur (6 Pairs and 5 families	75	116	116	-	-	-	-	200	200	200	52

* MF Male and female Sarus Crane

* Fam. J1 J2 Family unit comprises of male female and Juveniles.

6.2.1 Ethogram of Sarus Crane

The behaviour repertoires for Sarus Crane were recorded with the description and were being illustrated by referring the papers on captive studied Cranes, (Ellis *et al.* 1987, & Ellis *et al.* 1998, and Masatomi and Tamaki 1975). The ethogram was prepared by pooling all the behavioural activities recorded during the sampling of pair and family units and incubating Sarus. The data was pooled and percentage calculated for all the activities recorded. The sketches of earlier studies conducted on captive crane species were used for the terminology (Appendix 1) and where ever possible picture were taken of the different behaviour repertories and collage was prepared (Plate 1 & 2).

Plate 1 **Different behaviour patterns in Sarus Crane recorded during the study period**

Caption:1. Wing Preening, 2. Back preening, 3. Dorsal Preening, 4 &5 Leg Plumage Preening, 6. Body wing shake, 7.Wing spread hold, 8. Rise flap, 9. Wing flapping, 10. Standing (Loafing), 11. Feeding, 12. Feeding and walking, 13. Searching, 14. Drinking water, 15. Intentional Posture, 16.Alert call, 17. Flapping flight, 18. Juvenile trying to fly, 19. Display, 20. Sarus crane dance, 21. Unison call, 22& 23. Pre mating

Plate 2 **Different behaviour patterns recorded during the nesting season of the Sarus crane**

Caption: 1.Incubating, 2. Collecting nesting material, 3. Rock down, 4. Standing on the nest, 5. Turning egg, 6. Standing on the nest, 7. Pipping, 8. One day old chick, 9. Feeding the chick, 10&11. Diversionary display

Analysis

The data were converted into Arcsine transformation to correct for the normality of data and analysis was done for individual field sites using SPSS 8.0 Software. One way and Two-way analysis of variance (Zar 2003) at alpha 0.05 were performed to test the significance of the activity pattern between different time zone of the day, across sex, pairs, and family into different season and sites and seasons and in two different sites on pairs and families of the Sarus Crane.

6.3 Results

6.3.1 Ethogram of Sarus Cranes

A total of twenty seven behavioural patterns were recorded during the study period of two years covering the breeding and non breeding seasons. Table 2 shows the range of behaviour pattern observed on other Crane species compared to the range of behaviour patterns observed on Sarus Cranes in the semi-arid landscape in India.

The comparison of behavior in protected and unprotected landscape shows that Sarus Cranes in Bharatpur (Protected Area) spend more time in feeding and less time in searching, maintenance and loafing. While in Kota (Unprotected Area) the Sarus has to spend more time in searching, maintenance and loafing (Table 3). Secondly in natural wetlands like Bharatpur the availability of food is good compared to man - induced wetlands in Kota which dry up during summers and hence the availability of food is for a short period, due to this the Cranes have to spend more time on searching for food and need to be more alert while moving in other areas.

After pooling the incubation data of two sites results show that Sarus Crane spends maximum time in incubation followed by feeding and rest of the time in other activities during nesting (Table 4) The detailed table explains the behavioral repertoires recorded in both the field sites (Table 5).

Table 2. Range of behaviour pattern observed in other Crane species

Behaviour Patten observed in Japanense Crane in Wild (Masatomi & Kitagawa 1975)	**Behavioural Pattern observed in 15 species of Crane in Captivity** (Ellis *et.al* 1998)
A.Maintenance Behaviour	**A Vocalization**
1 Resting: Sleep like resting, Neck Shortening resting 2. Sitting: Back sleeping, Down sleeping, Sit back sleeping	Peep, Food-begging, Nesting call, Contact call, Pre-flight call, Flight call, Alarm call ,Guard call, Unison call, Location call, Stress call, Distress call, Moan, Hiss, Pre-copulatory call, Thoracic-click,
B.Comfort movement: Preening, Preening usually with bill, Neck preening, Back preening, Wing preening, Breast preening, Wing preening, leg plumage preening, Oiling, Scratchig, Head scratchig, Neck scratching, Head rubbing, Crown rubbing Shaking, Head shaking, Body wing shaking, Wing shaking Leg shaking, Tail-waging, Leg stretching, Wing raising, Wing flapping, Bathing, Head & beak washing, Sunning, Wing spread sunning, Soiling, Panting, Yawning,	**B Agonistic call:** Alert, Iris-expansion, Bare-skin expansion, Bare-skin present, Feather-tuft-erection, Gular expansion, Tertial elevation, Head rub, Pre-strut, Strut, Head flick, Dorsal preen, Ventral preen, Wing-flick-flight, Bill down growl, Bill down hold, Bill down sweep, Blow bubbles, Stab nibble tug, Head lower ruffle, Ruffle bow, Wing spread hold, Wing spread flap, Tail wag, Stomp, Leq-quiver, Butterfly, Arch, Hoover or neck-crane, Crouch, Pre-attack, **C Attack and mob:** Run flap, Hiss, Gape, Bill stab, Jump rake, Wing thrash **D. Defensive and submissive displays:** Wing-flare-cower, Cower, Cower crouch, Distraction display, Bunching, Flee, Pre-copulation
C Locomotion: Walking, Slowing walking, Rapid walking, Running Flying, Taking off, Soaring, Landing	**E. Concordant Behviour:** Contact call, Pre-flight, Pre-flight-call, Flight call, Flight, Allopreen
D Food intake: Food searching, Foraging, Sticking, Eating, Small food, Medium food, Eating moving animal, Large size food Drinking	**H Pair related behaviour** :Unison-walking, Unison-call, Dance, Spread hold, Gape Gape-sweep, Tuck bob, Leap, Object-toss, Run-flight-glide, Hoover, Bill stab, Pre-copulation Copulation call, Copulation

E Defecation	**I Nest preparation:** Sideways toss, Weep drop, Nest probe, Tread, Incubation Brooding, Shading, Tread, Nesting-call, Parental morsel, Distraction display
H: Gazing: Neck raised gazing, Neck curved gazing, Sit gazing	**K** Filial behaviour: Peep, Contact call, Food begging, Wing-quiver, Accept morsel, Stress call, Distress call
I Social Behaviour: Agnostic behaviour, Adornment, Down adornment, Forward adornment, Lowered adornment Arching, Forward dancing Arching display, Bowing Attacking, Chasing, Pecking, Alert, Escape, Submission, Neck retracted submission, Head down submission, Avoiding, Fleeing, Running, Jumping, Following	
J. Defensive Behaviour: Mobbing Diversionary display	

Table 3 **Percentage of different behaviour patterns of Sarus Crane recorded in the study sites in the semi-arid landscape.**

S.no	Behavior	Kota	Bharatpur	Pooling both sites
1	Feeding	38.29	66.3	47.54
2	Searching	14.74	6.75	12.10
3	Maintenance	13.37	8.01	11.60
4	Loafing	27.4	14.44	23.12
5	Alert	0.92	0.642	0.82
6	Resting	4.56	2.06	3.73
7	Unison call	0.068	0.231	0.12
8	Chasing	0.0052	0.0048	0.005
9	Pre Flight Posture	0.014	0.0016	0.009
10	Wing Spread Hold	0.0012	0.00081	0.001
11	Flying	0.1	0.338	0.18
12	Wing Flapping	0.03	0.092	0.05
13	Wing leg Stretch	0.01	0.034	0.01
14	Display	0.021	0.032	0.02
15	Scratching	0.027	0.071	0.042
16	Drinking	0.073	0.36	0.16
17	Solicit Female	0.184	0.36	0.2
18	Solicit Male	0.143	0.22	0.2
19	Yawn	0.008	0	0.01

Table 4 **Activity budget of incubating Sarus in Kota and Bharatpur.**

Behaviour	**Percentage**
Incubation	67.45
Arranging nesting material	0.81
Side way toss	0.44
Turning Egg	2.52
Feeding	10
Searching	3.92
Maintenance	7.93
Alert	0.46
Loafing	4.85
Unison Call	1.60
Display	0.03
Chasing	0.02
Scratching	0.03
Drinking	0.06
Wing Flapping	0.08

Table 5 **Ethogram of different behaviors in Sarus Crane recorded during behavioural sampling.**

S.No.	Behavior patterns	Description
General Posture		
1	Loafing	Standing and gazing their feeding territory remaining alert which ends in preening.
2	Sitting (Resting, other then incubation)	The breast of the Crane is lifted above substrate and tarsus is parallel to the substrate.
Defensive Behaviour		
3	Chasing	The wings are spread and drooped during chasing. Sometimes head is held low with the neck fluffed and curved down and forward
Maintenance		
4	Dorsal preening	Different postures are recognized depending upon the part of body to be preened. Preening was confined to the neck and head feathers. Use their uropygial gland repeatedly and most often by rubbing the bottom of the beak and underside of the head over the gland. Crane flicks its foot against it head and try to remove debris from feathers, skin or bill.
5	Ventral preening	
6	Scratching	
Comfort movement		
7	Yawn	The mandibles are involuntarily stretched and activity was observed more during incubation.
8	Wing Leg stretch	Crane extends back both its wings and leg of one side. Chick or young one when they sit they perform this activity more often.
9	Wing Flap	Sarus sweeps its wing back and forth strongly and seen during or after preening and foraging activity
10	Wing Spread Hold	Sarus spread both its wings widely and mostly seen during bird perform dance, during attack, when they see predator approaching near nest or when they're young ones.
Food Intake		
11	Feeding	Walk foraging, and dig-foraging was observed. Active searching for food from the surrounding environment.
12	Searching	
13	Drinking	

		Drink water by scooping water into the bill, then lifting the head and opening and closing the bill.
Social Behavior		
14	Alert	Crane becomes aware of a distant intruding conspecific, a predator. Head of the crane extended maximally up and somewhat forward while watching the stimulus and bird remain still, briefly.
15	Unison Call	Duetting is normally made by a couple and female initiates the unison call, throwing her head back with her beak pointing straight up.
16	Display	
Concordant behaviour		
17	Pre flight Posture	The head is elevated and the bill is held horizontal,neck is arched slightly and extended maximally forward. Wings are held closed or slightly depressed.
18	Flying	An activity comprised of several actions patterns: Soar, Glide, Flap, intentional posture, taking off.
Nest, hatching, Rearing		
19	Carry(nest material)	Transport a nesting material during nest preparation. Male Sarus digs the nesting material and female carried the object to drop onto the nest.
20	Sideway toss	The stems or twigs moved toward the nest site and onto the nest platform using sideways-toss. During nest building it is being observed when incubation is going on and when one bird is incubating other one is putting the nesting material.
21	Incubation and arranging nesting material	Crane incubate on the nest remain there from a few minutes to several hours and keep on standing and rearranging the eggs in the nest, change its orientation, walk around the nest and again come back to the nest and rearrange the egg and then incubate the egg.
22	Turning Egg	Sarus with its bill keeping on turning the egg/or reorienting them in the nest.

23	Rock -down	Parent bird stands with its feet naturally apart with the eggs between them, and then lowers its breast to the eggs, rocking from side to side as it alternately adjusts its feet and legs until it is comfortably.
24	Hatching and Rearing	Sarus remain closer to the nest, when the chick hatched out. It was noticed that first day the chick was just on the nest for the half day and parents was feeding close by and in the afternoon female approaches the nest and gave the shade to the first day old chick. Chick is fed by both parents by carried food to their chicks holding it at tips of beak. Providing water snake to chick for feeding. In Keoladeo Ghana National Park Sarus were doing competition with Painted stork to take out the small fish from the water and giving to young ones.
25	Chick-covering	Sarus expanded the wings spread fully to sides and beak direct upwards to the enemy when a crow, kites flies around over the early stages of chick growth.
26	Bill touching	Male and female Sarus Crane has been observed touching the beak and full grown juvenile sometimes tries to touch the tip of the beak of the parents.
27	Diversion display	When dog, man or any other animals approach the nest or the early stage chick, the parents take an alert posture and proceeds to the enemy with a slightly quick pace and make hissing sound.

6.3.2 Activity budget of Pairs

The main activities of male and female recorded were Feeding, Loafing, Maintenance, Searching and Alert. No significant difference was observed when time-activity budget was compared in individual sites. In Kota, in both the seasons, summer and winter females spent more time in feeding (42.9% & 48.7%) compared to male

(34.04% & 43.76%). On the other hand, males spent more time in loafing (42.25% & 40.24%) in both the seasons. However, at Kota both the sexes spent more time in maintenance behaviour in summer compared to winter and, minimum time was spent on alertness in both the season by both male and female Sarus Crane (Table 6.).

Table 6 **Percentage time spent in percentage in different activities by Male and Female Sarus Crane in Kota during Summer and Winter.**

Activities	Summer		Winter	
	Male	Female	Male	Female
Feeding	34.04	42.9	43.76	48.7
Loafing	42.25	34.11	40.24	33.67
Maintenance	16.09	15.4	6.92	7.72
Searching	6.97	7.15	8.78	9.73
Alert	0.66	0.43	0.31	0.18

In Bharatpur (Keoladeo Ghana National Park) also the same pattern was observed in case of feeding and loafing. However, in winter, time spent by both the sexes in activities related to feeding had increased, and loafing had decreased. Both the sexes spent more time in maintenance behaviour (17.03% and 15.91%) in summer compared to winter (Table 7).

Table 7 **Percentage time spent in different activities by Male and Female Sarus Crane in Bharatpur during Summer and Winter.**

Activities	Summer		Winter	
	Male	Female	Male	Female
Feeding	44.6	48	73.12	73.48
Loafing	31.26	28.18	12.96	13.17
Maintenance	17.03	15.91	7.29	8.55
Searching	6.34	6.21	5.42	4.28
Alert	0.69	1.68	0.82	0.85

Two way analysis of variance with sex and time zone of the day and activity as main effect showed that there was no significant difference between sex (F=0.130, df=1, P=

0.72) and time zone (F=.131, df=4, P=0.97) of the day between season. However a significant difference in activity pattern (F=4.857, df=1, P=0.028) was observed while comparison between two season (Fig 1and 2).

Fig 1 Activity Pattern of Male and Female Sarus Crane in Summer in Kota and Bharatpur district of Rajasthan

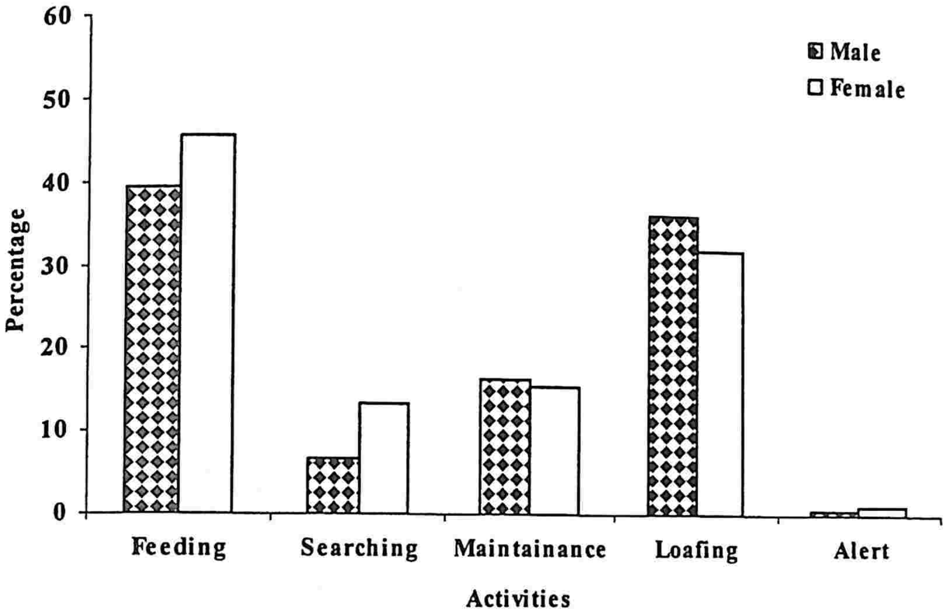
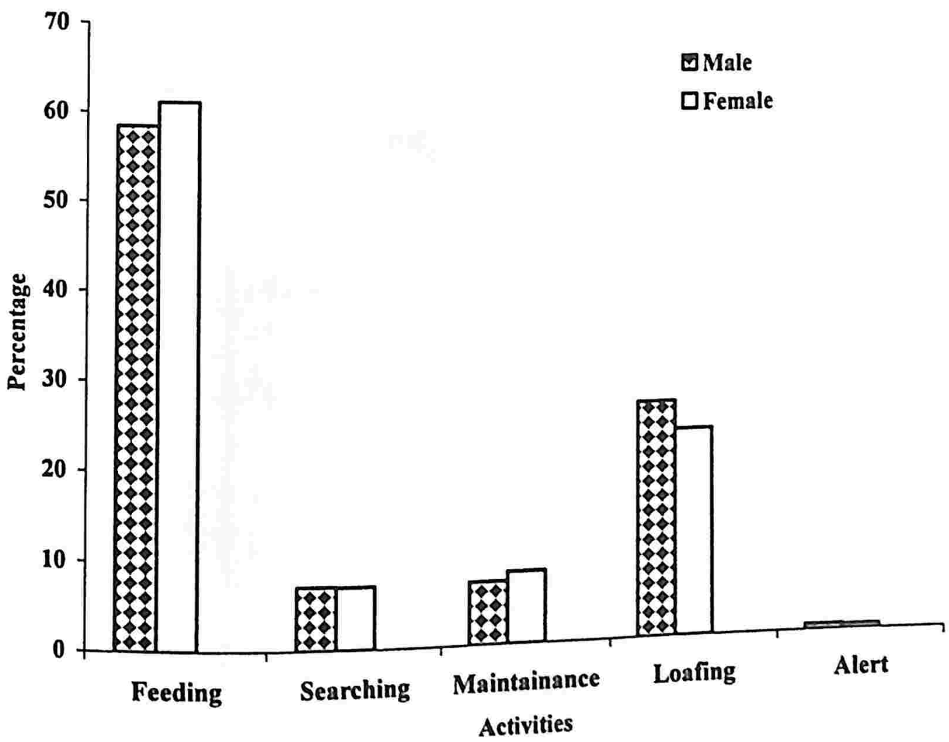


Fig 2 Activity Pattern of Male and Female Sarus Crane in Winter in Kota and Bharatpur district of Rajasthan



6.3.3 Activity budget of family units of Kota

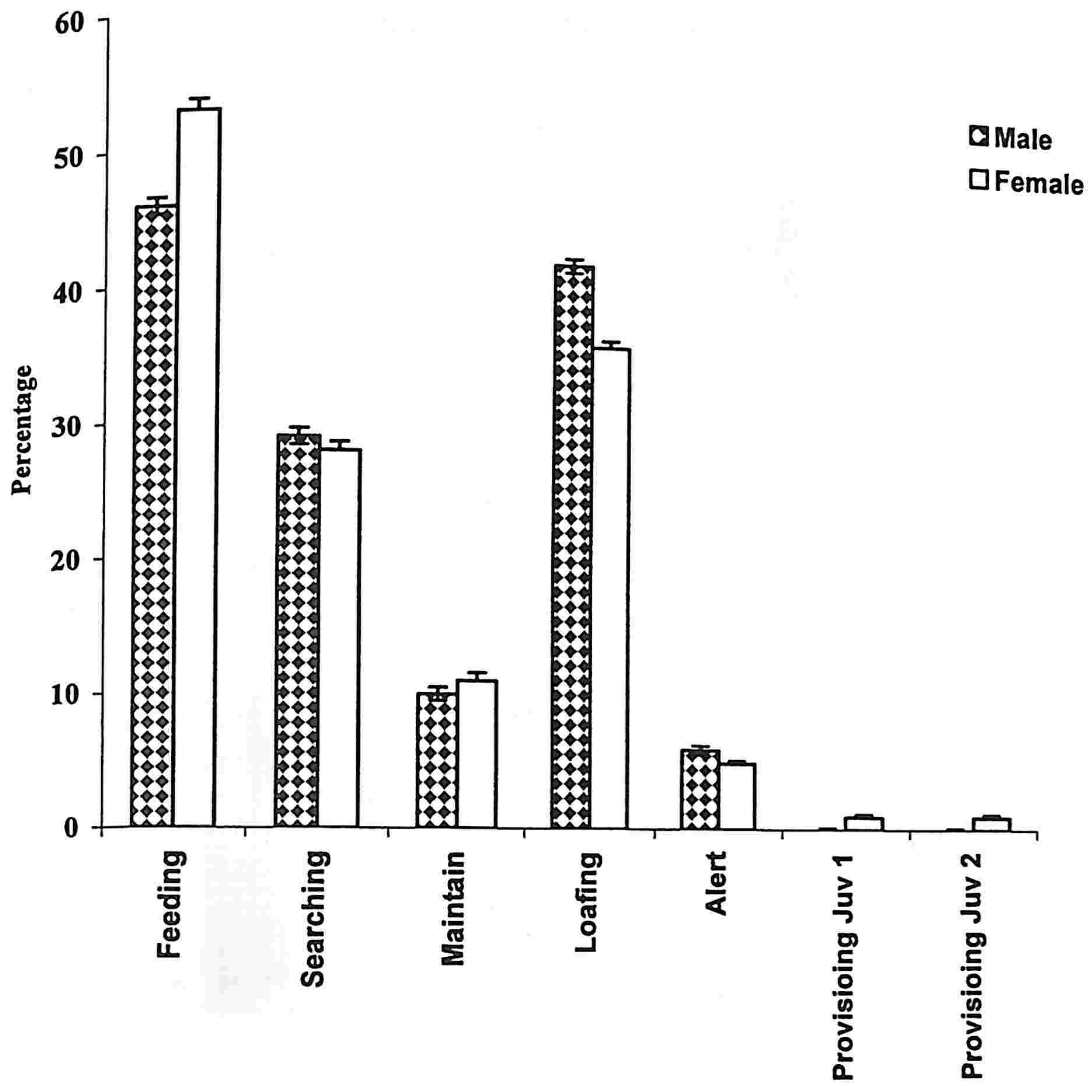
Results revealed, that in family units consisting of male, female and chicks, female parent spent more time in feeding to fulfill nearly all nutritional requirements during the day (Female : 52.94% v/s Male : 46.47%), while the male parent spent more time in loafing (M:42.99% v/s F: 39.62%) and in searching for the food (M: 29.9% v/s F: 27%). The pairs spent only a little time on other activities such as maintenance and alert behaviour (Table 8).

There was a significant difference between the activities such as feeding, loafing and alert behaviour of male and female in the families (F=38.145, df= 1, P=0.000, F=66.546, df=1, P=0.000, F=6.454, df= 1, P= 0.011), and difference was insignificant for the activities such as searching (F=3.359, df=1, P=0.067) and maintenance. (F=.025, df =, P= 0.873). The provisioning by male and female parents to first juvenile is insignificant (F=.663, df =1, P=0.416) and significant difference indicates in feeding to second juvenile in the families (F=37.122, df=1, P=0.000) (Fig 3).

Table 8 Percentage time spent by family units of Sarus Crane in different activities in Kota

Activities	Male	Female	Juvenile 1	Juvenile 2
Feeding	46.47	52.94	49.25	51.26
Loafing	42.99	39.62	40.8	38.52
Maintenance	17.62	10.85	7.60	6.23
Searching	29.9	27	27.87	27.09
Alert	0.5	0.5	-	-
Provisioning to Juvenile 1	1.00	0.97	-	-
Provisioning to Juvenile 2	0.32	1.0	-	-

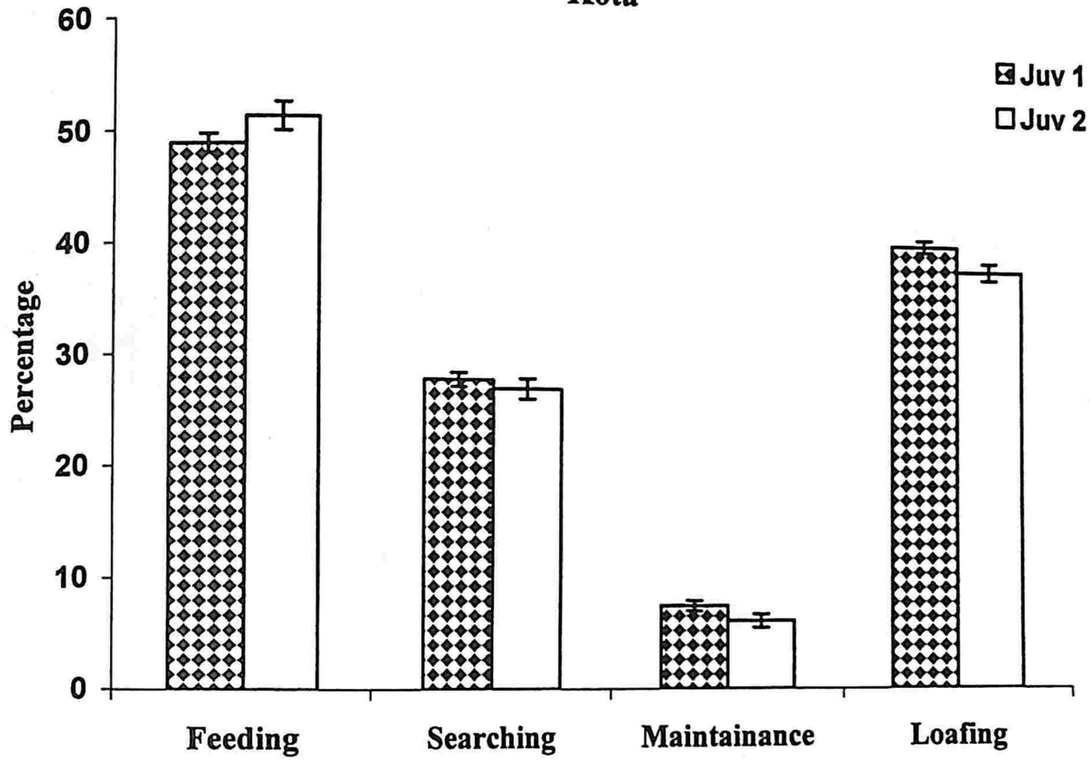
Fig 3 Activity Pattern of family units of Sarus Crane (*Grus antigone*) with chicks in Kota



At pre-weaning stage as the juveniles required more nutrition for growth, they appeared to spent more time in feeding (49.25% & 51.26%). However, both the juveniles 1 and 2 spent a significant time in loafing (40.8% & 38.52%) followed by searching for the food (27.87% & 27.09%). Minimum time was spent on maintenance activity by all the members in the family (Table 8).

The data collected on both the first and second juveniles of the families were pooled and ANOVA was run to compare time spent in different activities by juveniles when they are along with their parents. Results showed that there is no significant difference in the time spent in activities such as feeding, (F= 1.894, df=1, P=0.169), searching (F=.506, df=1, P=0.477), maintenance (F=2.953, df=1, P=0.086). However, a significant difference was found in loafing (F=5.888, df=1, P=0.015), (Fig 4).

Fig 4 Activity pattern of juvenile Sarus Crane (*Grus antigone*) in Kota



6.3.4 Activity budget of family units of Bharatpur

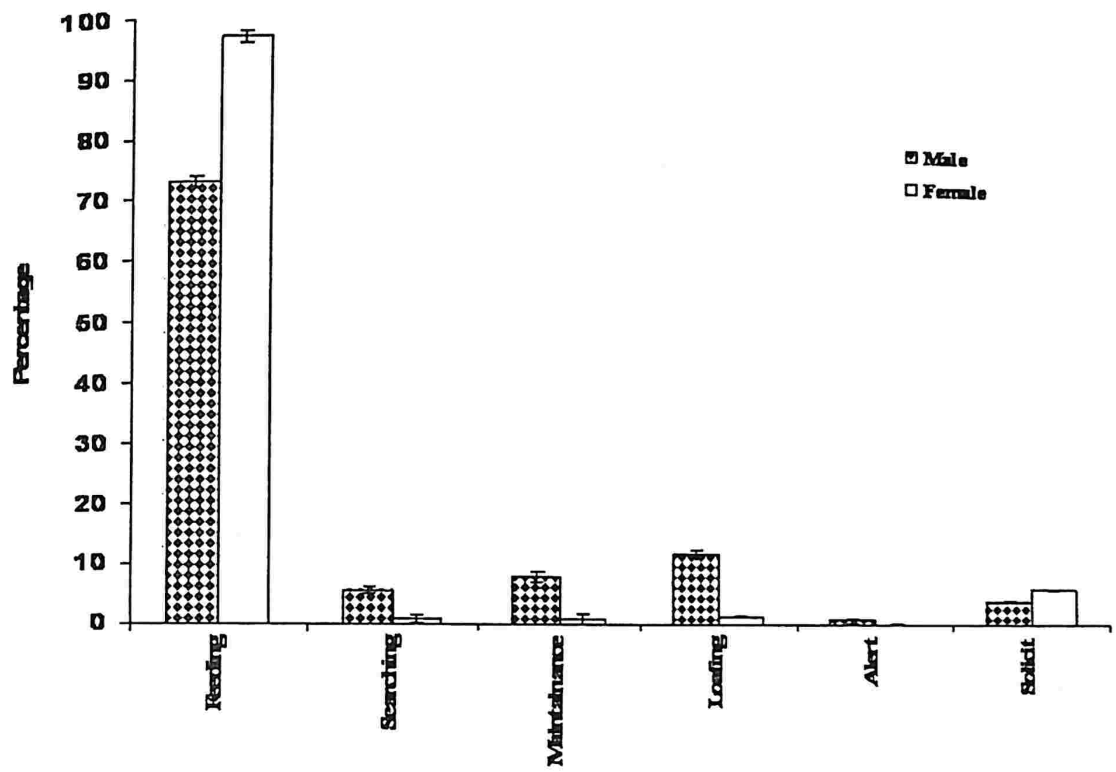
In Bharatpur (Keoladeo Ghana National Park), five families were monitored, the female spent maximum (96.95%) time in feeding as compared to all other activities. However male also spent 73.07% time in feeding followed by loafing which is 11.7 9%. Very less time was spent in other activities when parents were with juveniles (Table 9 & Fig 5). Both the juveniles in the families spent more time in feeding to fulfill their nutritional requirement for the growth (Table 4). There was no significant difference being observed in the different activities performed by parents such as feeding (F=.105, df =1, P=0.746), searching (F=.058, df =1, P= 0.809), maintenance (F= 1.807, df =1, P=0.179), and alert (F=1.743, df 1, P=0.187) in the families. Significant difference in loafing (F=20.157, df =1, P=0.000) and provisioning by parents to the juvenile (F= 10.594, df =1, P=0.001) in the families were observed.

Both the juveniles with the parents spent maximum time in feeding (64.9% & 51.62%), searching (11.58% & 21.45%) followed by loafing (16.34% & 18.4%) (Table 4) .

Table 9 **Percentage time spent by Sarus Crane families in different activities in Keoladeo Ghana National Park.**

Activities	Male Parent	Female Parent	Juvenile 1	Juvenile 2
Feeding	73.07	96.95	64.9	51.62
Loafing	11.79	1.27	16.34	18.4
Maintenance	7.87	0.74	7.16	8.52
Searching	5.52	0.74	11.58	21.45
Alert	0.648	0.05	-	-
Provisioning to Juvenile 1	1.04	0.2	-	-
Provisioning to Juvenile 2	0.03	0.01	-	-

Fig 5 **Activity pattern of families of Sarus Crane (*Grus antigone*) in Keoladeo Ghana National Park, Bhartpur**



6.3.5 Disturbance during activity pattern

A total observations of disturbance factors for pairs (n=286, n=328) and for the families (n=2476, n= 388) in Kota and Bharatpur were obtained. Results show that human activities were the major source of disturbance to cranes. (Fig 6). In pairs, the male was more disturbed by farmers (30.41%) as compared to female (17.48%). Vehicle movement was the second factor which caused disturbance to male (19.23%) & female (13.28%). In families, female spent maximum time in taking care of juveniles and male spent most of the time in alertness. They got disturbed most of the time by vehicle (26.77%) and farmers (23.78%) as compared to female (17.44% & 14.9%). Dogs, Jackal, bird of prey and cattle were the other factor causing disturbance to the Sarus Cranes (Fig 7).

Fig 6 Disturbance of male and female Sarus Crane in Kota

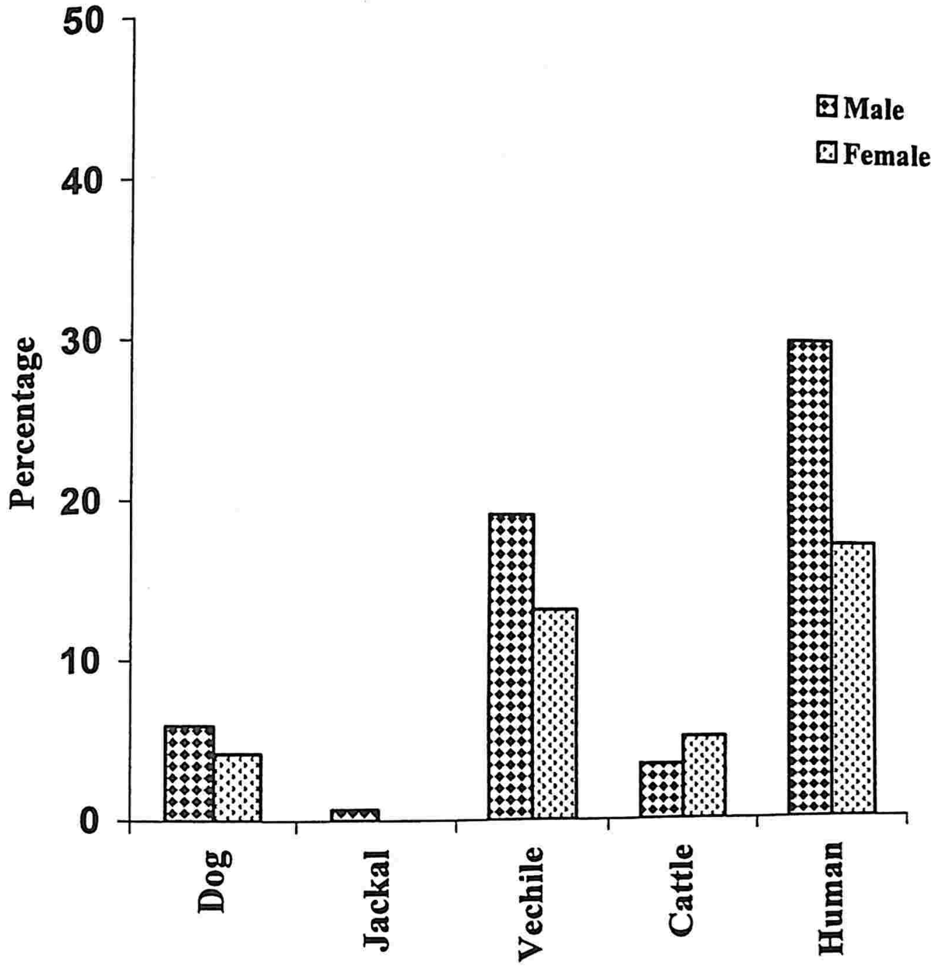
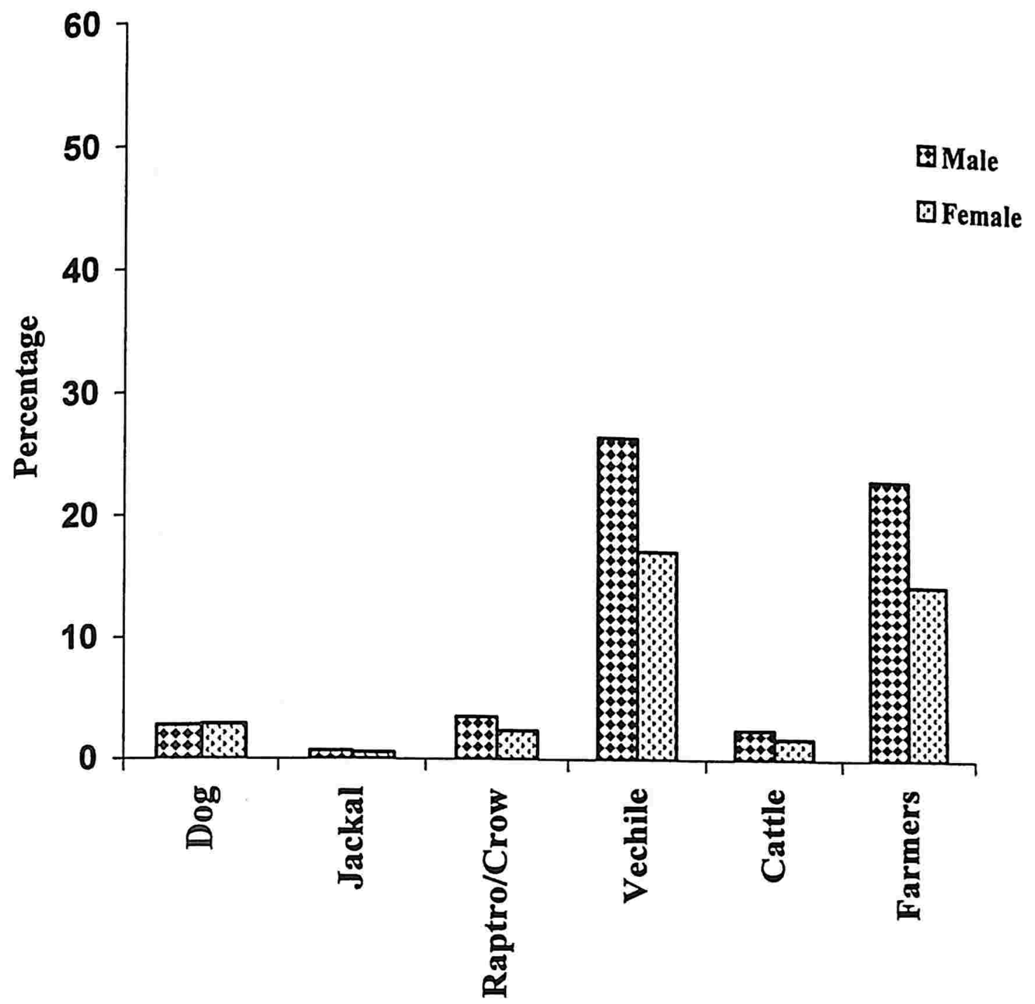
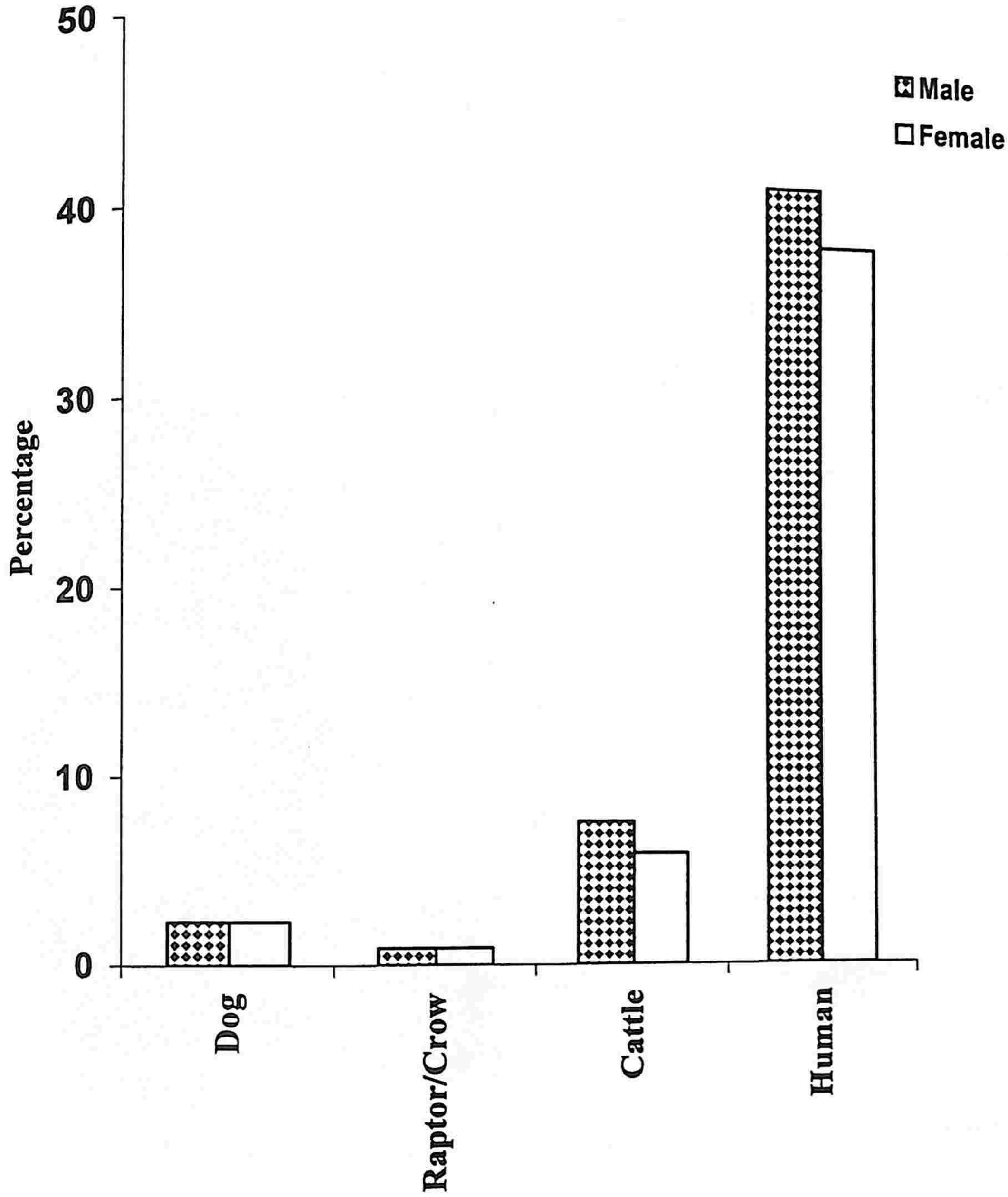


Fig 7 Disturbance in families of Sarus Crane in Kota



In Bharatpur, male in the pairs as compared to the female (M: 55.78% v/s F: 44.19%) got mostly disturbed due the grass cutters working in the different blocks of the park. Disturbance created due to feral cattle was minimal during the study. A total observation of (n=388) on families of Sarus Crane were taken and man-made disturbance contributed significantly in male and female parents when they are with juveniles (M:42.01% v/s F:38.9%) (Fig 8).

Fig 8 Disturbance in families of Sarus Crane in Bharatpur



6.4 Discussion

From the present study it was possible to conclude that in semi-arid landscape the range of behaviour pattern recorded will be low and great deal of time was diverted to specific activity. In the study area Sarus Crane spend greater amount of time foraging, standing and searching for food (Table 3&4). The behaviour pattern of Sarus Crane in the study area divided into main eight different categories General Posture, Defensive, Maintenance, Comfort, Food intake, Social behaviour, concordant behaviour and Nest, hatching and rearing. A total of twenty seven behaviour pattern were recorded during the sampling and around 15 other different behaviour pattern were recorded during field the visit and pictures were taken for the behaviour pattern whenever it is possible to record during the sampling(Fig1 & 2).

The results were compared with other studies conducted on other Cranes and it was revealed that study on Japanese Crane (*Grus japonensis*) in eastern Hokkaido, a total of seventy two different behaviour patterns was recorded in natural condition and behaviour pattern was divided into Maintenance behaviour, Comfort movement, Locomotion, Food intake, Defecation, Gazing and Social behaviour. Other studies by Ellis *et al* (1998) on all the 15 species of crane in captivity, they documented some behaviour was perform by the species, some species does not performed this behaviour and some are performed in great degree. The behaviour patterns was put into eight different categories, *i.e.* Vocalization, Agonistic call, Attack and mob, Defensive and submissive behaviour, Concordant behaviour, Pair-related behaviour, Nest preparation and Filial behaviour. However they stated that comparisons of the number of displays between taxa is difficult, because one author may divided a complex display into several components while another author treats each display as a single unit. Mukherjee (1999) conducted a study on Sarus Crane in Kheda district of Gujarat and prepared a list behaviour pattern recorded in the study area. Henceforth it is proved that from our study in semi-arid landscape Sarus will exhibits a lower range of behavioral pattern and great diversion of time spent in foraging.

Behaviour in birds, as in all animals, is largely directed toward self and racid survival. It is, in effect, an internally directed system of activities that strive to maintain the physiological stability of the body in face of many environmental hazards such as heat and cold, sun and rain, food, competition, predators and parasites Welty (1982). The diurnal movement of demoiselle Cranes increases during morning and decreases during mid-day when the cranes gather in large flock to roost and again increases towards evening. Cranes feed in cropland during morning and evening, and roost at freshwater reservoirs, riverbeds and on the seashore in the afternoon. They return to the roosting site between 10hr30 and 11hr30 to spend the afternoon, and go to feed again at 16hr00 to 17hr00, returning to roost at dusk Soni *et al.* (1993). Sarus Crane is omnivorous, foraging in wetlands on dry land, and in agricultural fields for a wide variety of plants and animal foods (Meine & Archibald 1996, Sundar *et al.* 1999).

From the present study result, it was possible to conclude that the Sarus Crane spent most of the time in feeding during the daylight hours, and this pattern was similar across pairs and families in both the study sites Kota and Bharatpur. The earlier study on Sarus Crane and Siberian crane also reveled similar results that feeding was the principal activity throughout the day (Gole 1987, Sauey 1985, Country Report India 1998, Mukherjee 1999).

After feeding, the dominant activities was loafing, where bird just stand without being alert, but keep on gazing the feeding territories and sometime that ends up in preening usually began with feathers below the neck and nape and those on the chest and continued with lesser, median, and greater wing coverts. Crown, nape are rubbed on the back and rump, probably to transfer oil from the uropygial gland to these parts. Claws were used to scratch under the chin and near eyes Gole (1987). Sauey (1985) observed similar pattern on Siberian crane in Keoladeo Ghana National Park. However, in semi-arid landscape Sarus Crane maximizing the opportunity of food availability in a wider home range (See chapter 4) and from the results it is very clear that in present study Sarus Crane spend more time in feeding in both the seasons (Table 6&7). The study on Sarus Crane in Kheda district Gujarat, results showed that there is a seasonal variation in activity budget amongst the members of the flocks and family of Sarus Crane. No distinguished variation in the time allocation for feeding as an activity was observed Mukherjee (1999).

The parental investment is defined as 'any investment by the parents in an individual offspring that increases the offspring's' chance of surviving Smith (1977). It was conclude from the results (Table and Fig), male and female Sarus Crane spend more time in feeding and for the searching of food in water deficient area. Sarus Crane in this study spent maximum time in provisioning the first juvenile, then the second one and the same observed in other species of Cranes Meine & Archibald (1996), and even when two young are hatched it is seldom that more than one survives for more than a few days and in few regions parents have successfully raised two offspring Birdlife International (2001). It has been observed juveniles of many avian species experience higher mortality rates than older individuals. Higher juvenile mortality is often due to the inexperience of young animals in avoiding predators, obtaining adequate food supplies and establishing appropriate social relationships Aviles (2003). Alert behaviour was shown by the Sarus family during this study, with an increase in openness of the habitat and reduction in food resources, the parents had to pay more attention towards defending their territory Mukherjee (1999). In protected area, where disturbance factors were very low, little alertness were being of parents on chick protection (Table 9.)

Similar study on Hooded Crane (*Grus monacha*) in Japan showed that's a family had to spend more time being Alert than the flock Eguchi *et al.* (1991). Defending a territory requires more energy and thus individuals in group allocates less time in vigilance than individual in family Krebs and Davies (1981). It has been observed that juvenile cranes devote less time to vigilance and spend more time feeding than adults (Table 8). That juveniles devote less time to vigilance and spend more time feeding than adults have also shown from studies conducted on time budget and habitat use of the Common Crane wintering in Southwestern Spain by Aviles in (2003). Given that time is limited, any change in time spent in one activity must be reflected in a corresponding change in time spent in other activities. Relationship between food levels and the amount of time spent foraging have been noted in other waterfowl as well as in non-waterfowl species Maxson and Oring (1980).

Disturbance

Human were clearly the most important cause of disturbance for Sarus Cranes during the study period in Kota and Bharatpur. In Kota, the farmers work in agricultural fields and vehicle continue to pass the whole day on canal road cause disturbances to pairs and families of Sarus crane. Earlier studies on Siberian Crane (Country Report India 1998, Sauey 1987) showed similar results and this was not surprising, given the large human population in the immediate vicinity of the sanctuary in Bharatpur, Sauey (1987). Water Chest- nut cultivation in Sarus nesting area cause more disturbance when people use explosives to scare water birds feeding their crops and they constantly chase the birds forcing them not to come closer to the cultivated area. Grazing Cattle walking inside the marshes, and farmer working close to the seepage marshes often disturb the birds. The anthropogenic pressure to one of the field site in Kota increased during Navratari festival when from early morning till late evening people visit temple on foot, vechile, tractor and bullock cart and pairs and families of Sarus Crane get more alert during this time of the year (J.Kaur Pers.Obs.).

The canals water supply in Kota stopped in mid February and from first week of March when small pools are left in the canal bed people with sticks and fishing net get inside the canals during the day time to catch fish by throwing explosives inside the water. This factor contributed disturbance to Sarus Crane in the study area.

In Bharatpur, the grass cutters removing the grasses are the major disturbing factors and they disturb the birds at all the level from the nest preparation till chick wean out. Locals most often caused cranes to take flight when they entered the water, usually with their livestock. Tourist on other hand often caused flight by stooping on the bunds to watch the cranes themselves sometimes remaining for several minutes in full view of nervous birds. Many a time observation was made when tourist entered the blocks for photography.

6.5 Summary

1. I investigated the behaviour patterns observed on Sarus Crane to various disturbance stimulus in the study area. In semi-arid landscape Sarus Cranes will spend a greater amount of the time foraging and maximizing opportunity of food availability in a wider range home range. I also examined an attempt maximize chick survival Sarus pairs will spend more time in foraging and searching for food in a water deficient area, the parental investment on chick protection will be less and chick survival will be low.

2. Data on detailed compendium of behaviour containing defined and described behavioural activities was prepared. Scan animal sampling was carried out on Pairs and breeding pairs with juveniles to document activity budgets. Six to eight scan samples of each category of Cranes in each time zone per month were carried out. The ethogram was prepared by pooling all the behavioural activities recorded during the sampling of pair and family units and incubating Sarus Crane.

3. From the present study I derived that in semi-arid landscape the range of behaviour pattern recorded will be low and great deal of time was diverted to specific activity. A total of twenty seven behaviour pattern were recorded during the sampling and around 15 other different behaviour pattern were recorded.

4. Sarus Crane spend greater amount of time foraging, standing and searching for food. After feeding, the dominant activity was loafing. In semi-arid landscape Sarus Crane maximizing the opportunity of food availability in a wider home

range and from the results it is very clear that in present study Sarus Crane spend more time in feeding in both the seasons. Male and female Sarus Crane spends more time in feeding and for the searching of food in water deficient area. Sarus Crane in this study spent maximum time in provisioning the first juvenile, then the second one.

5. Human were clearly the most important cause of disturbance for Sarus Cranes during the study period in Kota and Bharatpur. In Kota, the farmers work in agricultural fields and vehicle continue to pass the whole day on canal road cause disturbances to pairs and families of Sarus Crane. Water chest- nut cultivation in Sarus nesting area causes more disturbance when people use explosives to scare water birds feeding their crops and they constantly chase the birds forcing them not to come closer to the cultivated area. Grazing cattle walking inside the marshes and farmer working close to the seepage marshes often disturb the birds.

6. In Bharatpur, the grass cutters removing the grasses are the major disturbing factors and they disturb the birds at all the level from the nest preparation till chick wean out. Many a time observation was made when tourist entered the blocks for photography.

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CHANGES IN LAND USE PATTERN AND ITS POSSIBLE IMPACT ON SARUS CRANE LIFE HISTORY PARAMETERS

7.1 Introduction

Land cover denotes the physical state of the land including the quantity and type of surface vegetation, water and other features. Land use, on the other hand defines the human employment of the land (Turner and Mayer 1991). Diversity of different land uses should be understood to perceive and analyze changes in land-cover that links them to many aspects of global environment change. Changing land use is the most important cause of land cover change especially if the time horizon is limited to decades (Leeman and Zuidema, 1995). Availability of food resources, climatic conditions and biotic disturbances are highly variable in space and time. As a result, species distribution is generally aggregated in patches, thus exhibiting relative preference to such areas even with in a geographic range of land cover. The burgeoning human population and associated land use changes have played decisive role in affecting the distribution of several species (O'Connor and Shrubb 1986, Gill *et al.* 1996, Vitousek *et al.* 1997, Liu *et al.* 1999, Osborne *et al. 2001).*

Land cover changes fall into two types viz., conversion and modification. The former is a change from one class of land cover to another whereas the latter is a change of condition within a land cover category. Both conversion and modification occurs at local as well as global scale and have significant environmental consequence (Turner *et al.* 1990).

Historical approaches for documenting land cover and its long term changes used revenue and land records. These approaches were constrained by sparse sampling in space and time (Skole 1994). In recent years, Remote Sensing (RS) coupled with Geographic Information System (GIS) has come as an efficient tool for mapping and monitoring land cover (Lillesand & Keifer 1987, Burrough 1986). Application of RS and GIS are wide ranging from simple inventorying and mapping of land classes to complex, modeling (Schultink 1992, Zhou 1998, Sen 2000). It has opened up a new paradigm in mapping spatial pattern of species distribution and wildlife habitats (Worah *et al.*1989, Mladenoff *et al.* 1995, Nagendran and Gadgil 1999). Remote Sensing is the science and the art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in contact with the object (Lillesand & Kiefer, 1987). The principle of remote sensing rests on the fact that every object absorbs some part of radiation received from sunlight.

Agricultural intensification had been one of the most important forms of land cover modification to the extent that intensification in land use most often, though not always, refers to changes brought about by agricultural practices. Meyer and Turner 1992, suggests that world total of cultivated land is estimated to have increased by 46.6% from 1700 to 1980 with a greater than average cultivation occurring in the former USSR, Southeast Asia, Latin America and North America. In India by the 1870s, the Gangetic flood plains, the Gangetic-Brahmaputra delta, and the coastal regions of southeast India were quite heavily cultivated, and a rapid cropland expansion was seen between 1850 and 1990 (Ramankutty and Foley 1999).

As the greatest cropland expansion occurred in South Asia (11% of the total land area was cleared for cultivation in the 20th century), it matched human population growth

(Ramankutty *et al.* 2002). Since beginning of the human civilization, flood plains of rivers and wetlands have been associated with attracting humans; the oldest-dated earth-mound complex on the Ouachita river in Louisiana is associated with back water swamps and small-stream environments (Nicholas 1978). Because of their high productivity, presence of fresh water and rich soils, they have attracted the first farmers and the evolution of much of modern agriculture and spread of modernization the world over has been possible due to these habitats and resources they provided (Hoffmann 1996). As a result, floodplain and other forms of inland, freshwater wetlands are among the most endangered ecosystems in the world today (Brawn *et al.* 2001). It is estimated that 65% of wetlands have been drained in Europe for agriculture; figures for other areas are 27% for Asia, 6% for South America, 53% for North America, and 2% for Africa (Richardson 2001).Agriculture run-offs, in turn, have been known to have serious deleterious effects on a variety of wetland biota, and wetlands often perform as sinks to many chemicals that are applied in agricultural systems. Effects to fauna are only just being documented in India, and beyond recent information on episodes of mortality due to intake of pesticides (Murlidharan 1993).

The present study aimed at mapping the land cover in the study area relevant to Sarus Cranes in type and extent and to compare the present pattern with past years to evaluate the degree of change with respect to the critical terrestrial habitat requirements of Sarus Cranes so that appropriate conservation measures could be directed more efficiently. The following are the specific objectives;

To map and describe various land-cover/land-use types.

To compare and detect changes in the Sarus Crane preferred habitat and its effect on Sarus Cranes populations.

7.2 Methods

The study involved extensive use of satellite data and image processing techniques, suitably supported with ground control points (GCP). Satellite Data of IRS-1A, IRS-1C and Landsat for three year period was used for assessing temporal and spatial changes in landcover/landuse in the two study areas.

7.2.1 Data used

Satellite data of IRS 1A/L2 (36.5m spatial resolution) and IRS 1C/ L3 (23.5m spatial resolution) for winter season were used for Kota site, and three bands in combination were used for further analysis. For Bharatpur, one time data of Landsat (30m resolution), were used (http://glcf.umiac.umd.edu/ index.shtml.) (Table 1).

Table 1 Characteristics of Satellite data used

Satellite	Sensor	Resolution	Month and Year
IRS-1A	LISS II	36.5m	9-10-1989, 11-10-1993
IRS-1C	LISS III	23.5m	5-11-2001
Landsat	ETM^+	30m	22-10-1999, 29-10-1999

7.2.2 Rectification

Geo-referencing is an integral part of spatial modeling. The images acquired for the study area were geo-referenced such that they were compatible with each other and the other spatial datasets. Toposheet no. 45O/16, 45O/15, 45P/13, 54C/4 cover the study area, which were geo-referenced first using ERDAS IMAGINE 8.7. These geo-rectified top sheets were used for the rectification of the satellite images, namely IRS-1A, and IRS-1C. The rectified images were again referenced using *image-to-image* geo-referencing technique, so as to reduce discrepancies within the overlap areas of the adjoining images. Compatibility among the other spatial datasets was achieved by rectifying them with the geo-referenced topo sheets and satellite images. Subset of the study area was made from the satellite imageries.

7.2.3 Unsupervised Classification

The images were digitally classified into 40 classes using Unsupervised Classification. The Isodata (Iterative Self-organizing Data Analysis) technique is iterative in that it repeatedly performs an entire classification and recalculates statistics (Lillesand and Kiefer 1994). Convergence threshold i.e. the maximum percentage of pixels whose cluster assignments can go unchanged between iterations was set to 0.95.

In Kota study area the image obtained after running the algorithm was recoded from 40 classes into 6 classes such as (1) Water body/Marsh, (2) Agricultural crop fields, (3) Habitation/ Fallow-Barren, (4) Dense forest, (5) Open forest and (6) Scrub based on the tonal variation of the pixels. This image was later refined by knowledge based classification. In Keoladeo Ghana National Park the image obtained after running the algorithm was recoded from 100 classes in to 9 classes such as (1) Water, (2) Savannas woodland, (3) Agriculture, (4) Habitation, (5) Grassland, (6) Scattered scrub, (7) Scrub woodland, (8) Woodland and (9) Grass savannas.

7.2.4 Normalized Difference Vegetation Index (NDVI)

NDVI is the difference of the surface reflectivity between two wavelengths [in the red (R) and in the near infrared (NIR)], normalized by their sum. The differential reflectance in these bands is strongly correlated to the photosynthetic activity of vegetation canopies, because of the large spectral shifts of the leaf optical properties. In the visible, green leaves strongly absorb the solar radiation, in proportion to the chlorophyll content in the red, more than 80% of the incoming energy is absorbed. In the near infrared however, the photosynthetic pigments are transparent and the absorption (by the dry matter) is reduced to about 10% (Lillesand and Kiefer 1994). On the other hand, the reflectance of bare soils is only slightly larger in the near IR than in the visible. Although NDVI varies theoretically between −1 and +1, measured values range between −0.2 and 0.05 for snow, inland water bodies, deserts and exposed soils, and increase from about 0.05 to above 0.7 together with the density and greenness of vegetation (Bacour *et.al* 2006).

7.2.5 Land Cover Change

Focusing on suitable habitat, it was necessary to target changes in the specific land units that are relevant for the Sarus Crane. The areas such as in Kota that are outside protected environment are under tremendous human pressure, often impinging on the Sarus Crane habitat. The changes have been for over several years and therefore, multi-date images were used to critically analyze the habitat changes. Change detection was performed on the classified images using IDRISI Kilimanjaro (Clark University) and ERDAS IMAGINE 8.7 software (Eastman 1993). Time series sequence of observations in combination with Standardized Principal Components Analysis were performed to produce an ordered set of component images and then to compute and highlight the differences between the earlier and the later image (Eastman 1994)

Cross tabulation table was used to summarize the changes in the each of the classes and this essentially shows the frequencies with which classes have remained the same (frequencies along the diagonal) or have changed (off-diagonal frequencies). Kappa Index of Agreement (KIA) was done to represent percentage changes in each category and in the entire image. A Chi-square statistic (likelihood of classification), and Cramer's "V" statistic (degree of association) were used to evaluate change. The KIA measure could be evaluated both as an overall value and on a per category basis-examining change in qualitative data sets (Jensen 1996). The analyses were done on all the three images, 1989, 1993, and 2001 which were recoded classified image. Specialized Kappa measures that discriminate between errors of quantity and error of location was done for validation of change detection (Eastman 1997). The change vector analysis was performed to compare red and infra red band images for two dates to create both magnitude and direction of change images. The two images of 1989 and 2001 for change analysis were taken and the number of spectral bands selected for change analysis was same in both images.

7.2.6 Cropping Pattern

Data on cropping pattern was collected from 1966 till 2001 and 1967- 2000 from the Statistical Department office (SDO) at Kota and Bharatpur. The major crops in the study area were chosen and the area under different crops was analyzed by pooling data for five year blocks.

7.3 Results

7.3.1 Land Use Characterization of Kota

The extent of 6895.84 Sq.Km total land area were being evaluated for the change pattern in percentage. The study area in Kota could be broadly categorized into six land cover/land use relevant to Sarus Crane critical habitat requirement, use and preference (See Chapter 4) and these are (1) Water body/Marsh, (2) Agricultural crop fields, (3) Habitation/ Fallow-Barren, (4) Dense forest, (5) Open forest and (6) Scrub (Fig 1, Fig 2.& Fig 3.) (Table 2).The vegetation here is mostly composed of mixed deciduous type, indicating adverse effects from climatic, edaphic and biotic factors. *Anogeissua pendula* is the dominant tree species in these forests extending right from the base to the top of the hills. In the peripheral region, the destruction of the forest has resulted in scrubby jungle of *Acacia catehu, A. nilotica, A. leucopholea* and *Butea monosperma.* Besides the tree species, the perennial shrubs like *Lantana camara, Zizypus nummularia, Carissa congesta, Calotropis procera,* and *Capparis decidua* are very common in dry and waste lands. However, *Prosopis juliflora* is rapidly spreading through the area in the past few years (Sharma 2001).

The Chambal River and its tributaries Kalisindh and Parvan rivers, and numerous seasonal rivers, rivulets, *nalas*, ponds along with other water reservoir support rich aquatic vegetation, mainly free floating leaves and marshland plants. The dominant plants in this vegetation type are *Pistis stratiotes* and *Utricularia stellaris*. Submerged hydrophytes are *Hydrilla verticillata. Potamogeton pectinatus, Ceratophyllum demersum* and *Najas minor* commonly found in the water reservoirs of the area (Sharma 2001).

Amongst rooted emergent plants, *Nymphoided cristata,* and *Nymphaea* spp (with floating leaves) are most common species, although *Nelumbo nucifera* appears overwhelming as emergent leaves and flowers stay up much above water surface. Common hydrophytes in the area with attached roots and floating leaves and shoots are *Eichhornia crassipes*, and *Ipomoea aquatica* mostly seen in water reservoir.

These aquatic vegetation (Macrophytes) in the natural and man-made wetland habitats of Sarus Crane serve to meet the nest making requirement of Sarus Crane during the wet season. Their availability, therefore has a major role to play on the successful nest building by Sarus Crane and resultant hatching success

Table 2 **Percentage of major land cover type in Kota during 1989 - 2001.**

Years	**Water/ Marsh**	**Agriculture**	**Habitation/ Fallow-Barren**	**Moderately Dense Forest**	**Open Forest**	**scru b**
1989	0.9	29.4	51.8	8.2	5.2	4.5
1999	1.9	31.6	52.9	5.8	2.3	5.6
2001	3.5	32.5	31.1	13. 8	11.2	7.5

There has been perceivable change in all land use categories from 1989 to 2001 (Table 2). Water/marsh, dense forest, open forest and scrub categories increased over the years, particularly during the recent years. While agricultural area remains largely constant, habitation/fallow-barren areas showed a drastic declining trend and more significantly, between 1999 and 2001(Fig 1, 2 &3).

Fig 1 Land cover map of Kota district, Rajasthan (1989)

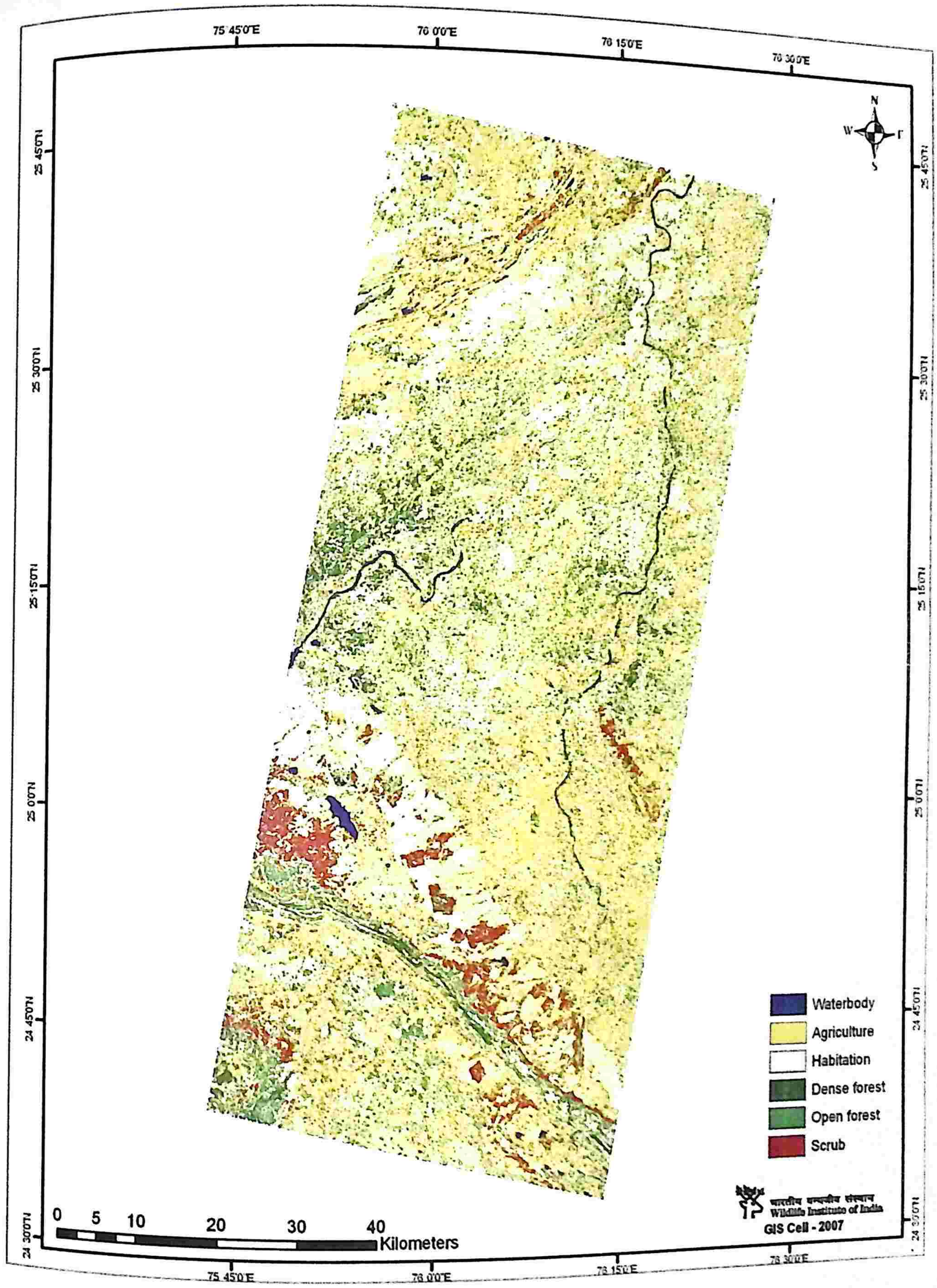


Fig 2 Land cover map of Kota district, Rajasthan (1993)

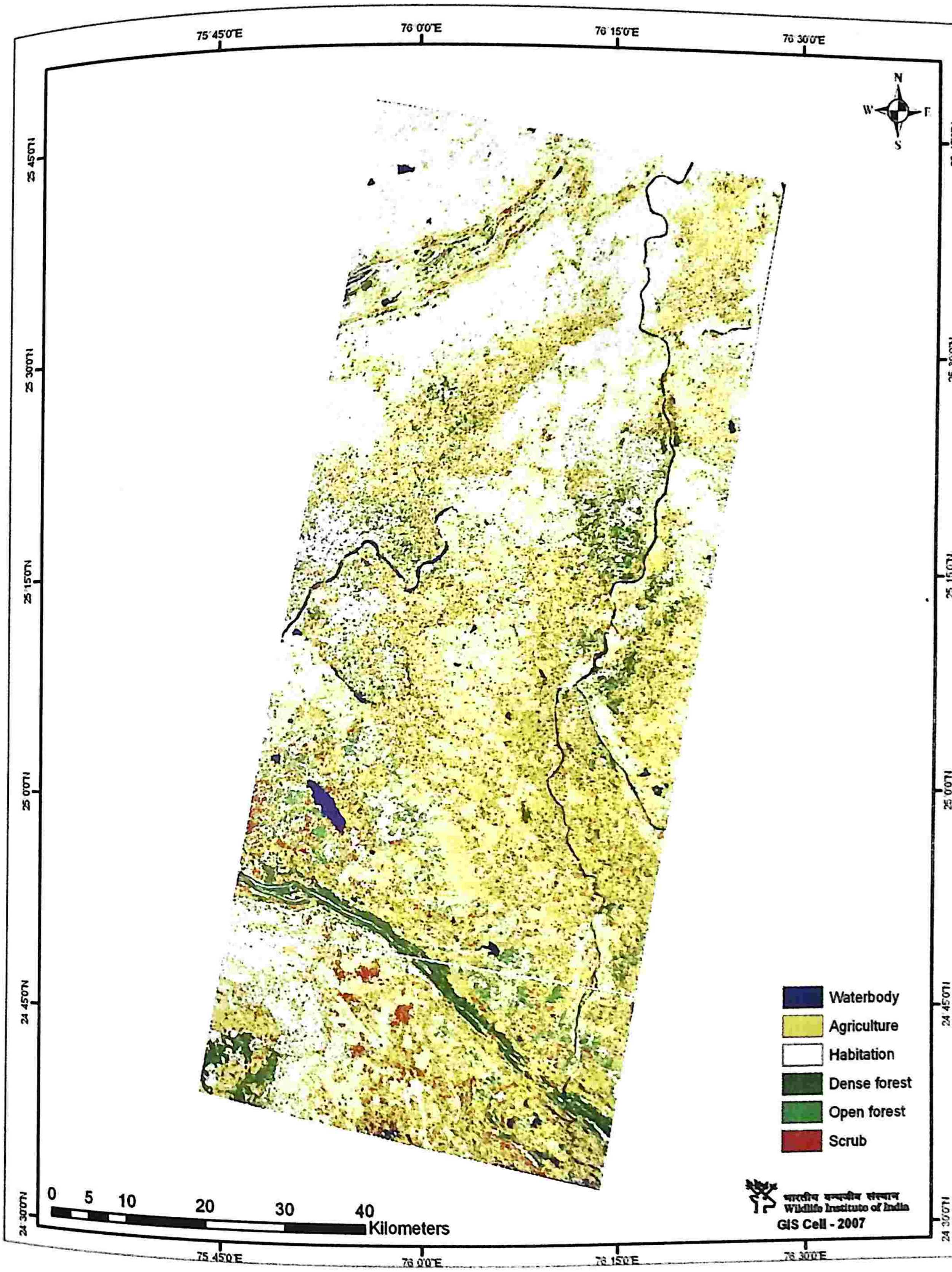
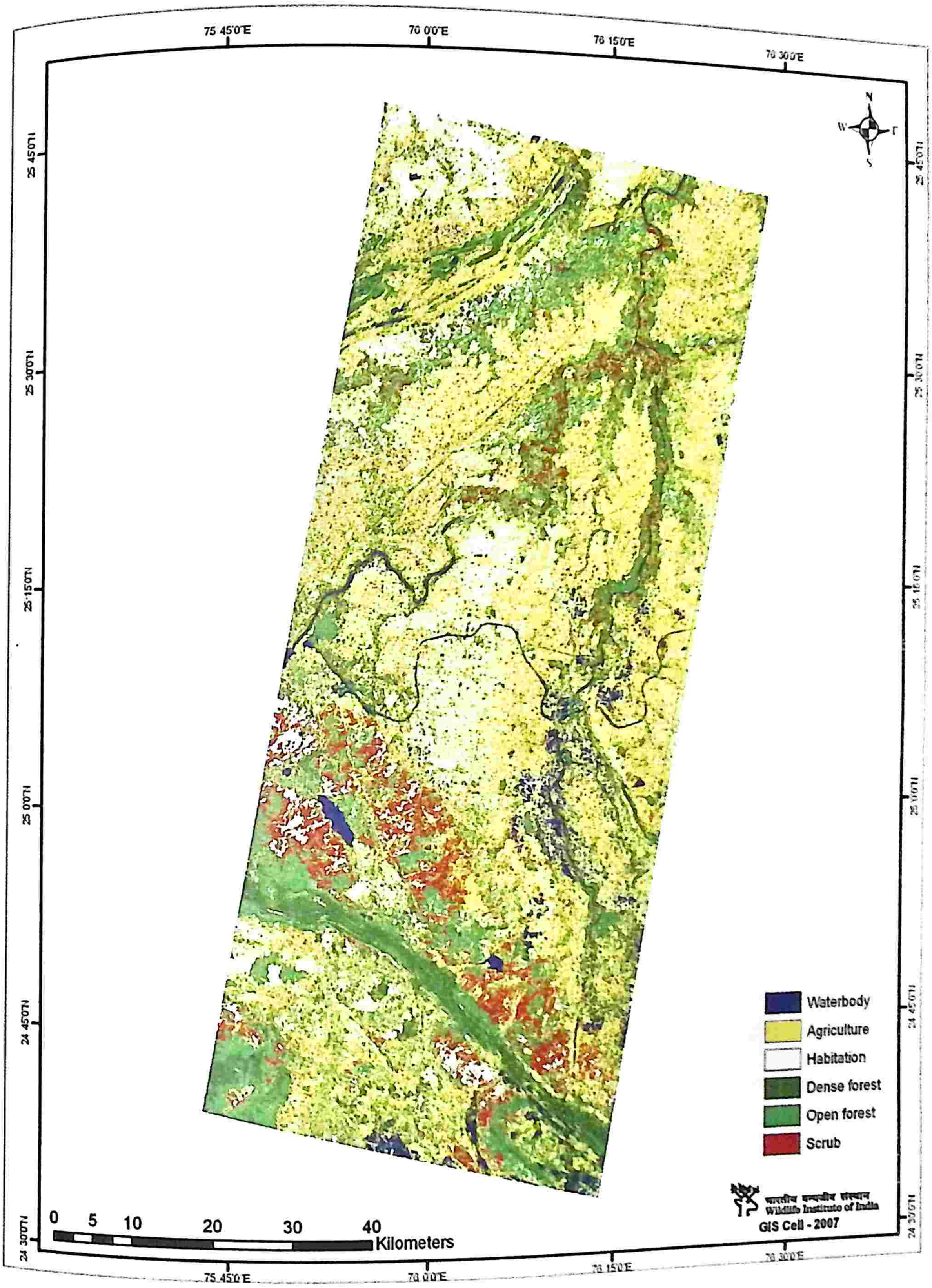


Fig 3 Land cover map of Kota district, Rajasthan (2001)



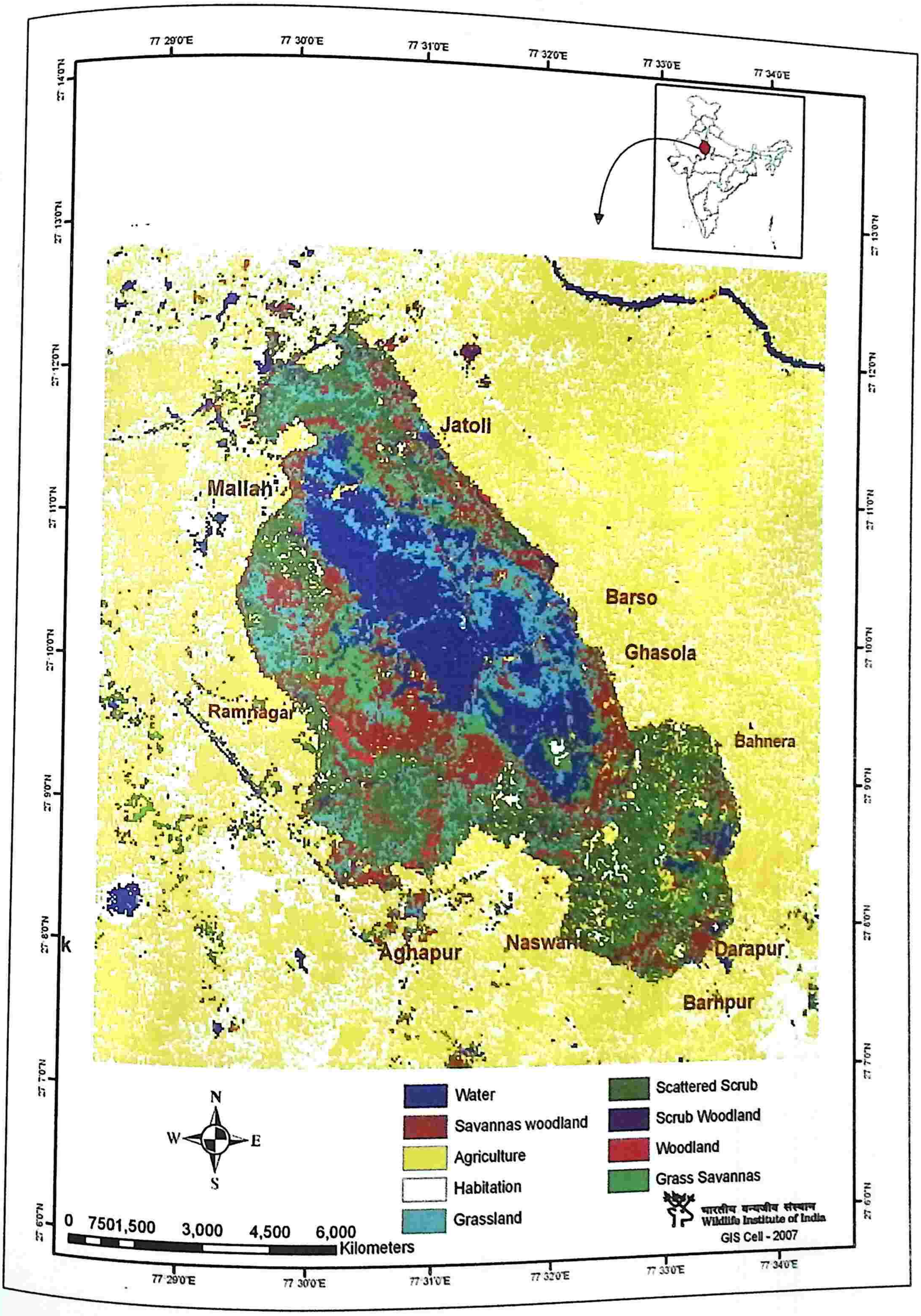
7.3.2 Land Use Characterization of Bharatpur

In the 104 sq.km of study area including Keoladeo Ghana National Park, that was evaluated, there are nine major land cover categories *viz.* (1) Water, (2) Savannas woodland, (3) Agriculture, (4) Habitation, (5) Grassland, (6) Scattered scrub, (7) Scrub woodland, (8) Woodland and (9) Grass savannas (Fig 4). Of these, the agriculture and habitation alone occupy 70% of the landcover (Table 3). The forest is of dry mixed deciduous types (Vijyan 1991). And the park has grassland consisting of perennial species such as *Cynodon dactylon*, *Vetiveria zizaniodes* and *Desmostachya bipinnata* while annual species are rersented by *Dicanthium annulatum*, *Paspalidium punctatum*, *Sporobolus helvolus*, *Echinochloa colonum*, *Panicum antidotale*, *Paspalum species*, *Cyperus rotundus* and *Scirrpus tuberous*.

Table 3 **Area of different Land Cover Categories in Bharatpur study area (based on 1999 landsat image).**

Land Cover Categories	Area (Sq Km)	Percentage (%)
Water	6.89	7
Savannas Woodland	6.32	6
Agriculture	47.24	45
Habitation	26.00	25
Grassland	5.32	5
Scattered Scrub	7.81	8
Scrub Woodland	0.77	1
Woodland	0.58	1
Grass Savannas	3.05	3
Total	103.98	

Fig 4 Land cover map of Keoladeo Ghana National Park, Bharatpur, Rajasthan (1999)



7.3.3 Land Cover Change

The landuse/landcover in 6854 sq km, a part of Kota district has changed to a greater extent from 1989 to 2001. Although there is a significant change shown in the 3 classes, namely water/marsh, habitation/fallow-barren and forest the Kappa value of 0.07% shows that they may be due to random spatial changes between the two time data sets. The water/marsh lands and forest area have increased in area while the habitation / fallow- barren land have decreased randomly. The changes in these land use classes can be attributed to the socio-economic changes brought in the area in the past 2 decades. The increasing pressure on the carrying capacity of area is prominently reflected in the land use and land cover variations. (Table 4, Fig 5).

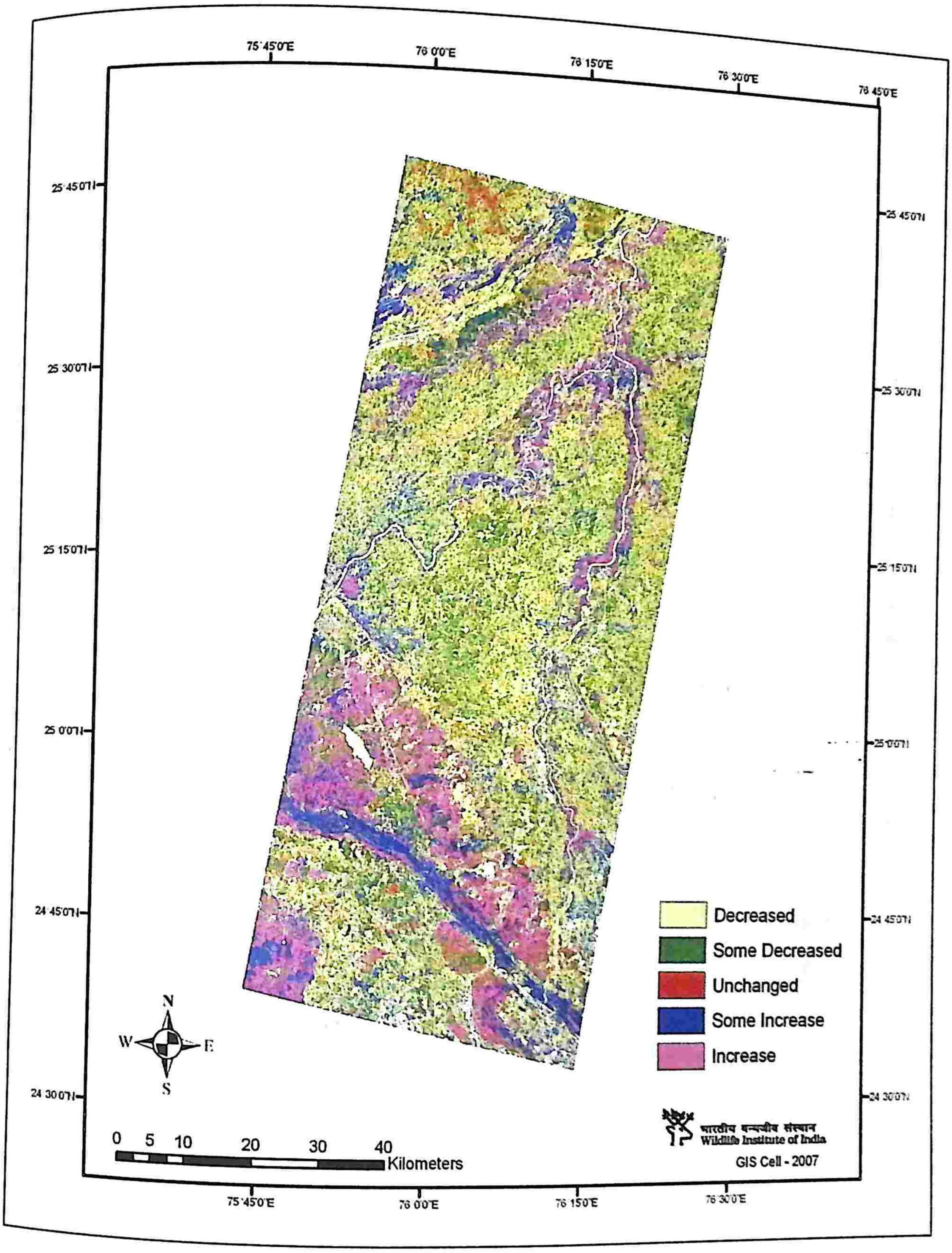
Table 4 Percentage Change (Cross-tabulation) of Kota study area between 1989 and 2001

Landcover categories	Water	Habitation/ Fallow-Barren	Forest	Total	Kappa Index of Agreement
Water/ Marsh	1.95	0.36	0	2.31	0.80
Agriculture	14.87	6.74	0.07	21.68	0.00
Habitation/ Fallow-barren	3.39	11.25	6.13	20.77	0.01
Forest	1.71	6.38	13.8	17.03	0.79
Scrub	0	0.57	4.43	5.01	0.00
Total	21.94	53.62	24.44	100	

Chi square= 19476150.0, df=12, Cramer's V=0.7218

Overall Kappa= 0.0720

Fig 5 Map showing percentage change of Kota study area between 1989 and 2001



7.3.4 Validate

The magnitude image showed threshold to isolate areas of change versus areas of normal variation, while the change direction image may be used to identify the types of change that have occurred. The ratio of changes, in the study area shown in both the images (Fig 6 & Fig 7).

Fig 6 Map showing change in magnitude image of Kota study area during 1989 and 2001

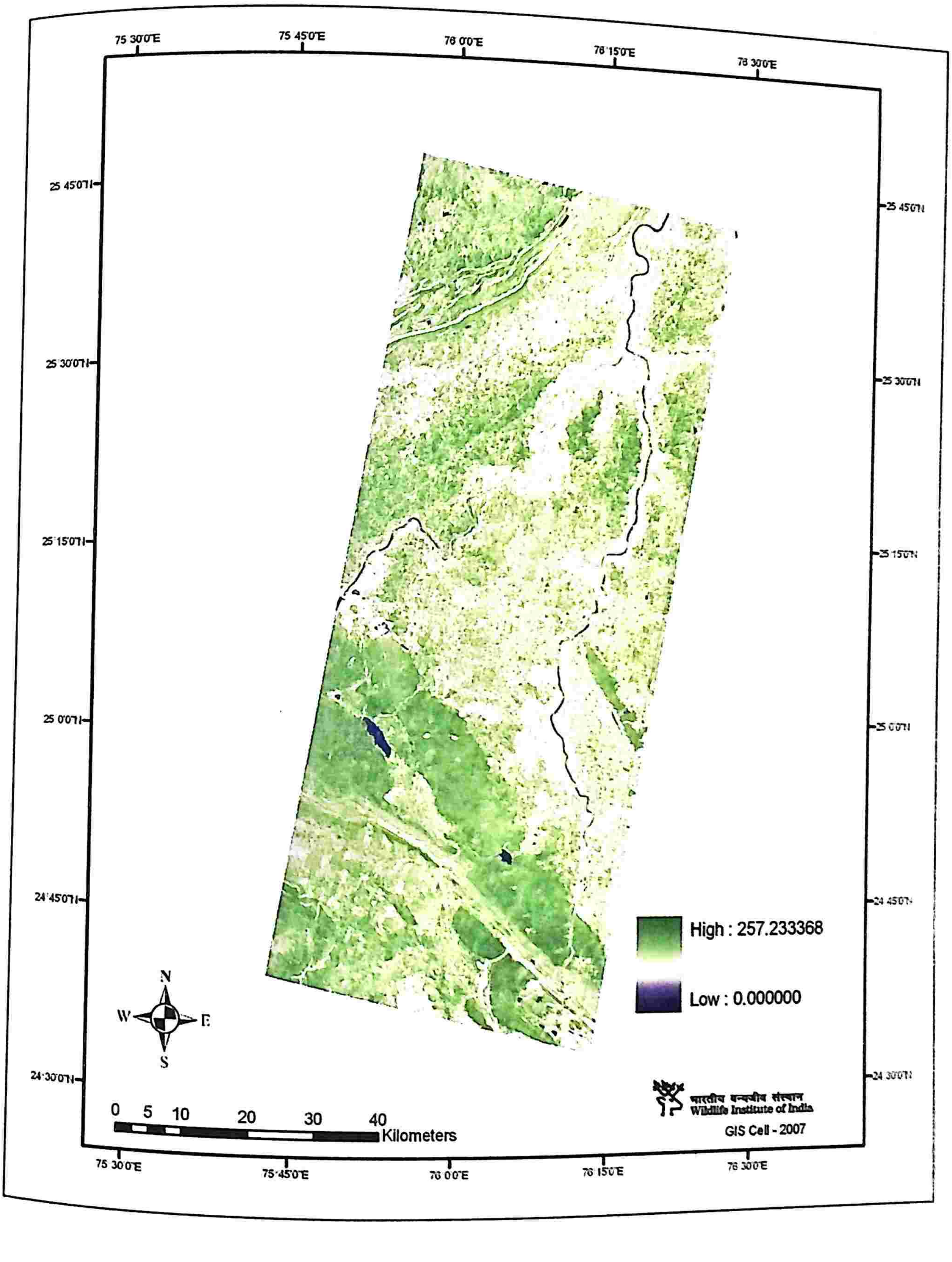
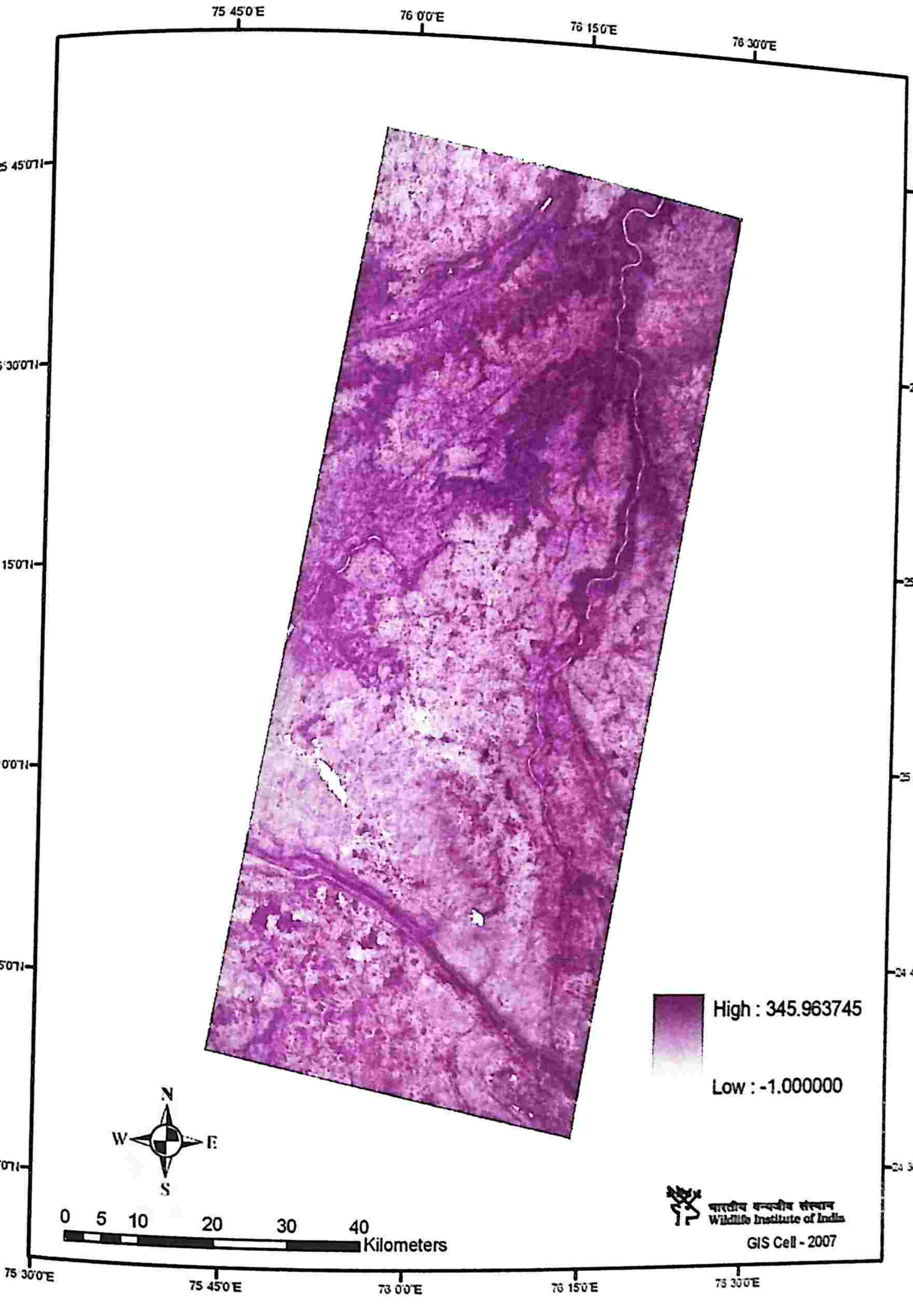


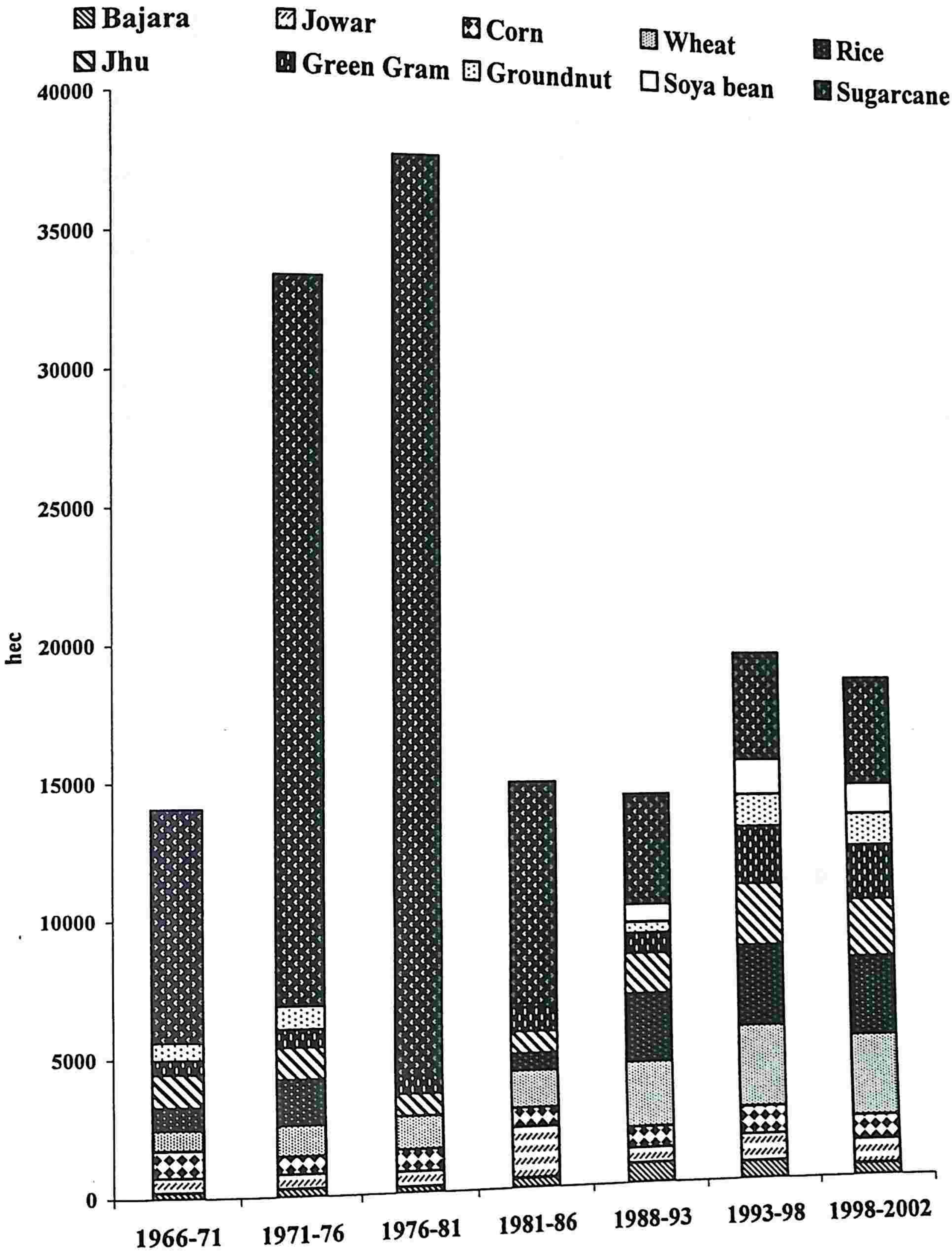
Fig 7 Map showing the direction image of Kota study area during 1989 and 2001



7.3.5 Change in Agriculture Landscape in two Study Area

Secondary data on the agricultural practices and cropping pattern suggest that during earlier years in 1960s, the area under crops such as jowar and wheat were much higher, but decreased over the years, particularly since 1988. The reason is that the area under oilseed crops such as mustard and soyabean were grown substantially in both Rabi and Kharif seasons. Several crops are being replaced in several areas by soyabean, and these fields, are pumped by heavy use of pesticides which kills the fauna leaving little for Sarus Cranes to forage on (Fig 8).

Fig 8 Area under different crops in Kota district (1966-2002)



Results from Bharartpur shows that in 1967-72 area under sugarcane cultivation was more. Rice was grown in lesser area in the district as compared to other crops such as Wheat, Green Gram, Bajara and mustard. There was an increase in the cultivated area under the crop Bajara in the year 1982-89 and Oil seed crops such as mustard showed increasing trend from 1989-96 and 1996-2000 (Fig 9). Region is predominantly cultivated for subsistence agriculture, but cash crops like mustrard are also sown. Major crops in the kharif season around Keoladeo National Park are Jowar, barchi & pulses and during rabi season are wheat and mustard. Although some rice and sugarcane are also grown these are not grown in the immediate vicinity of the park.. Rice was grown in lesser area in the district as compared to other crops such as wheat, green gram, bajara and mustard. Around Keoladeo Ghana National Park wheat and bajra are main rabi crops. Fig 10 shows the general land use and cropping pattern in Bharatpur district.

Fig 9 Area under major crops in Bharatpur (1967-2000)

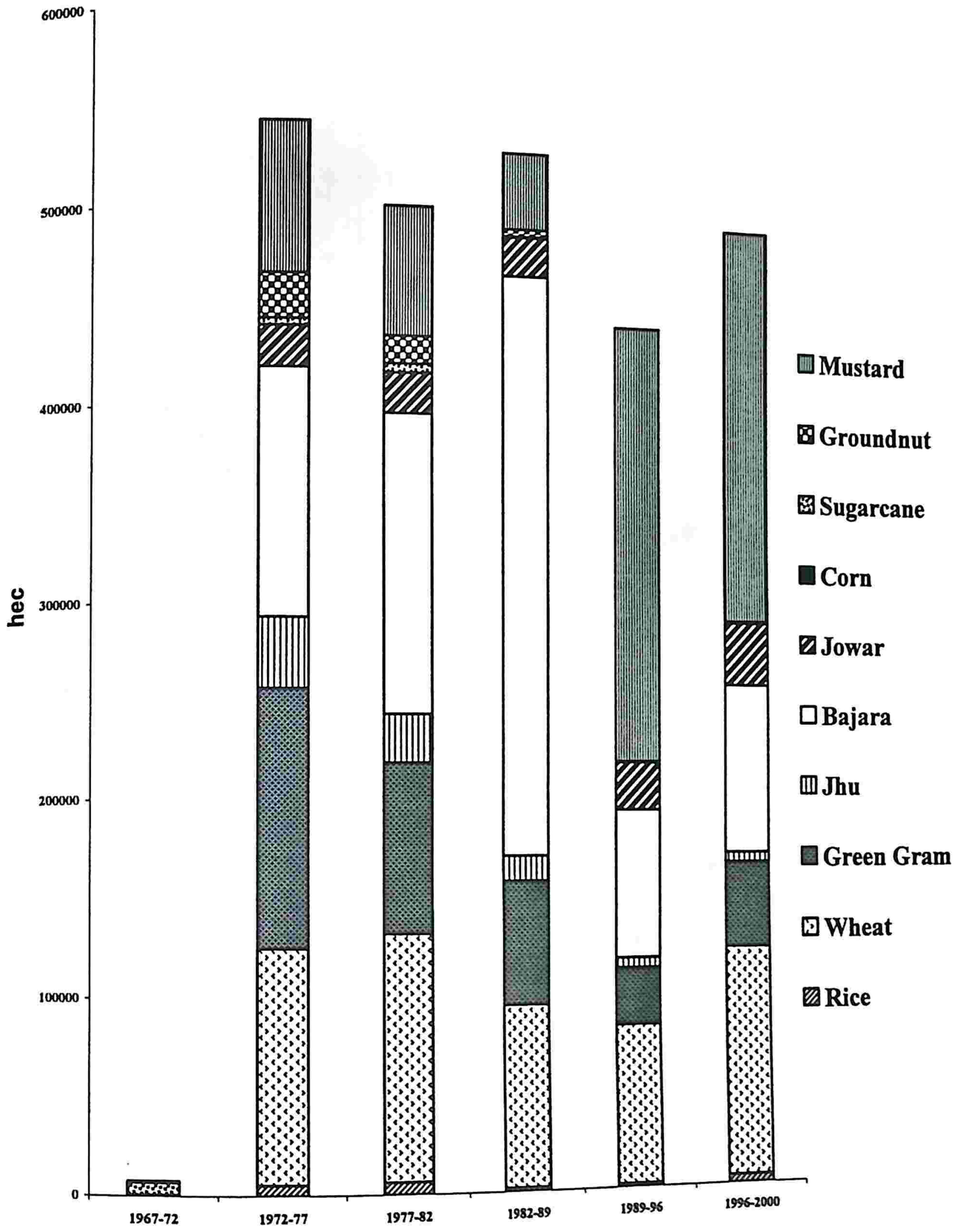
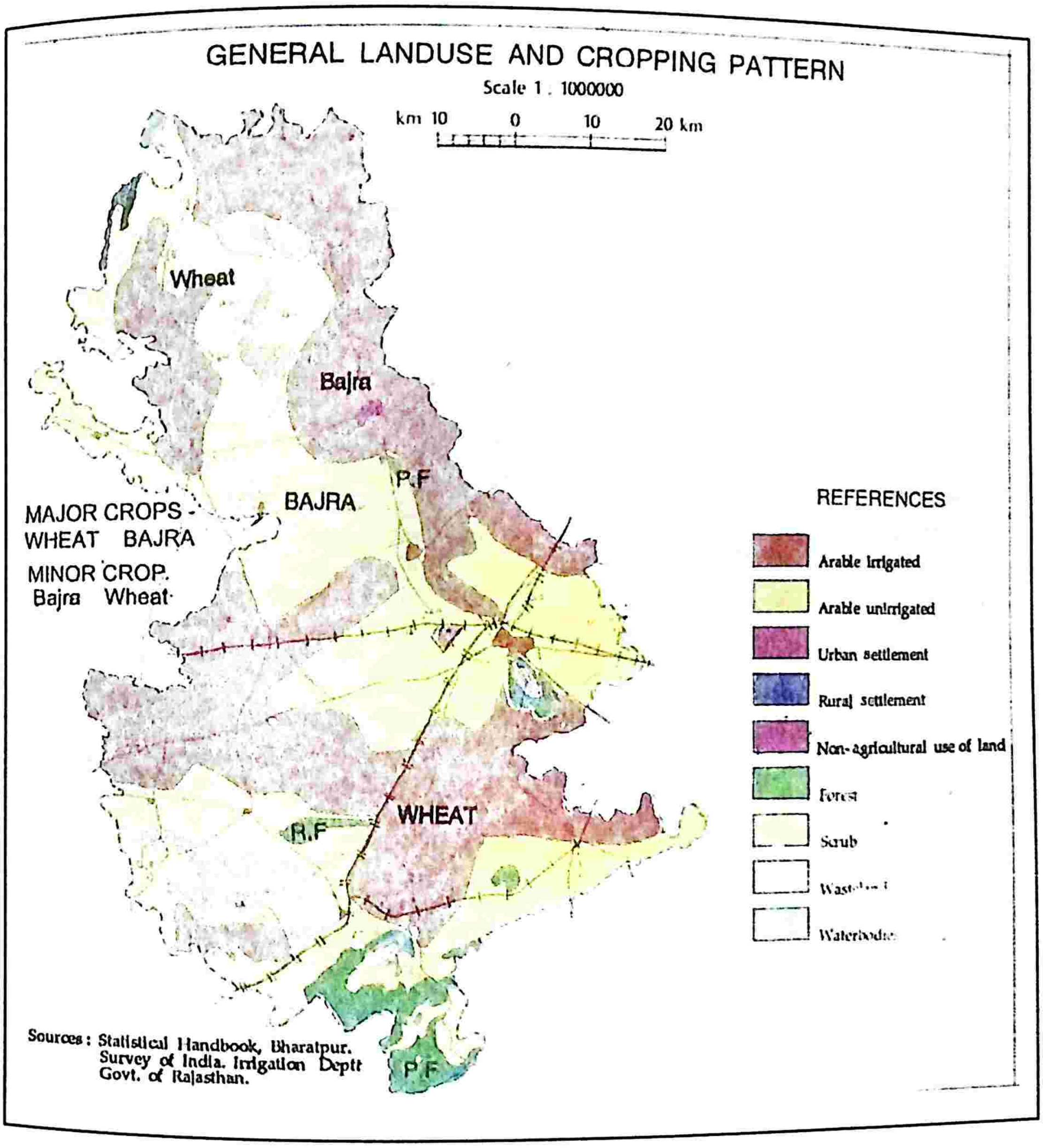


Fig 10 Map showing the general land use and cropping pattern in Bharatpur district.



7.4 Discussion

The Sarus Cranes in the study areas used habitat such as natural marshes with reeds, shallow water bodies, ponds and agriculture areas like rice. These marshes are endangered due to agricultural development. The agricultural areas used by these Cranes have the particular characteristic of being located next to bodies of water. The Indian agriculture scene has witnessed a rapid change in the cropping patterns over the past 30 years and intensification of the agriculture process had led to a decrease in the number of natural wetlands (Choudhury & Rao 1996). Due to development changes in the landscape, however seem to have led the Crane to use more agricultural fields than natural wetlands. Sarus Crane was seen to prefer paddy and wheat fields to other kinds of crop field (Sundar *et al.* 1999). All over the country rice and winter wheat, which were the erstwhile largest grown cash crops, are being replaced in several areas by sugarcane and soybeans. These fields are not ideal for Crane habitat because the sugarcane forms a thick impenetrable barrier to the movement of the Cranes. In the study area with agricultural development is likely to increase and with it will come the associated alteration of wetlands. The preferred crops like paddy and wheat are also decline in the study area. Rapid urbanization and other developmental projects will also lead to reduction in the amount of wetlands. Given such a scenario, Crane-human interaction is definitely going to increase in the years to come. With the data collected and reports available (Sundar *et al.* 1999), it seems that farmers are increasingly becoming intolerant to nesting and foraging by Cranes in their fields. An important reason for changing values can be attributed to the increasing immigration of the ever-growing farming population into Sarus populated areas. The new farmers do not have the same regard for the Cranes and prevent the birds from using their crop fields by either hunting and /or removal of eggs from nesting pairs (See Chapter 6).

The past history of the study area shows that a total of twelve man-made wetlands were created during late 1955-60 and Ummedganj and Kansuva were also part of it. Kansuva, Ummedgang and Dadhdevi was surrounded by dense forest of Koria (*Holarrhena antidysenterica)*, Kher (*Acacia catehu*) and Dhokhda (*Anogessius pendula*), till the right main canal of Chambal was not constructed (Firoz 1983). There were Tiger cages built during the 18th century for hunting tigers; the remains of the cages can be seen still today. The forest of Dadhdevi was famous for its Kewara trees (*Pandanus fascicularis*) which are present today in a small patch of the temple groove (Jagat 1983). Basically this whole area formed the link between Dara Wildlife Sanctuary, Shergarh and Shahbad sanctuary (Mathurala.1939). The Sarus Cranes were seen in the state gardens of that time in this belt. The numbers are not known but it was common to see the Sarus. However, it has been reported by locals that before the canal, Sarus were seen in agriculture fields and in the wetland present. After the construction of the canal, in the 80's the number of Cranes increased along the canal due to the formation of large marshes along it and the pressure of agriculture fields was less compared to today. Another species that had the maximum benefit of the canal were the Purple moorhen whose number increased many folds, earlier it was seen in a few patches (Bharat Singh Pers. Comm.).

Kota district of Hadothi region is a leading producer of soyabean in Rajasthan. It occupies approximately one-third area (33%) of the Kharif, as the black soil favourable for the cultivation of this crop is available in plenty in the district. It covers not only maximum area in Kharif, but at present ranks first in all the crops cultivated in the district (Kalwar 1999). Soyabean is cultivated on 13.2% area of Kharif seasons. The maximum area (+256.63%) increased in Kota district followed by Jhalwar (15.29%), Chittaurgarh (8.56%) and Bundi (7.82%) during the last one decade. It is replacing jowar and maize crops of Kharif seasons (Kalwar 1999). The area under mustard has also increased since 1988 till 1999. Oilseed crops are replacing cereals and gram in the study area. Such a transformations in the landscape and use of synthetic chemicals can be deleterious to the well being of resident fauna and have direct and indirect effect (Rands 1985, Green 1989, Panek 1997, Thomson *et al.* 1997).

Hadothi region which comprises of Kota, Bundi, Baran and Jhalwar district was well known for its dense forests and luxuriant vegetation before 40 to 50 years is now extensively exposed to biotic pressure. The occurrence of denuded forests and barren hillocks in the area has become a regular feature now because tree species are excessively lopped for cattle fodder, fuel, and timber and for some other purposes. The domestic animals such as goats, cows and camels are the worst enemies of the vegetation and during monsoon period the vegetation is heavily damaged by herds of sheep which migrate from Marwar regions. The problem of soil erosion has been seriously aggravated in the area. This has been caused significantly by rain water and floods and partly by high velocity winds. The process of soil erosion has primarily been enhanced because of deforestation and vegetative denudation. As a result of erosion, natural tree vegetation of the area has been replaced by exotic thorny tree species *Prosopis juliflora* and prickly shrub species *Lantana camara* (Sharma 2001). Significant increase has been registered in Kota, and increase in forest cover is mainly due to plantations raised under various project namely Aravalli afforestation project, Indira Gandhi Canal Project. Important plant species of plantation are Acacia spp, *Dalbergia sissoo* and *Azadirachta indica*. Protection to the forest and raising *Prosopis juliflora* along the fences have also contributed to the increase of vegetation cover (Forest Survey of India 1999).

Table 8 Forest cover in the district of Kota and Bharatpur.

District	Year	Geographical Area	Dense Forest	Open Forest	Scrub
Kota	2001	5,443 Km^2	168 Km^2	448 Km^2	151 Km^2
Bharartpur	2001	5.066 Km^2	78 Km^2	171 Km^2	93 Km^2
Kota	1993	12436	254	1305	-

Changes and availability of critical wetland Habitats for Sarus Crane in Bharatpur

The wetland condition of Keoladeo Ghana National Park depends largely upon the amount of water received from the Ajan Bund (about 1 Km from the Park) and on direct precipitation. As soon as enough water accumulates behind the bund (usually mid-July), water is released into the park filling impoundments to a depth of 20-30cm. In late September or October, water is again released from the Ajan Bund raising the water level in the impoundments by one meter or more. The discharge of water from the Ajan Bund is also necessary for irrigation on the northern side of the Park and for making the land behind the bund available for winter cultivation. The water depth and duration in different blocks within the park are also regulated by following a definite sequence of release through sluice gates. Blocks Lw and L are filled first followed by E, F, D,B, K and N. Water is released into blocks in two installments, first to a depth of 20-25cnm and then to 120cm after filling the rest of the blocks. Blocks F, K, E and L are flooded just enough to retain a mix of aquatic and terrestrial habitat as required by the cranes which use them. A depth of about 30cm is maintained in these blocks up to December-January. Depths vary between 90and 120cm in the central deeper parts of LW, L, K, E and D blocks while among periphery depths are much lower (50-60cm). During winter and the following summer, the water drops gradually to its lowest level by the end of June. Standing water remains only in some parts of the blocks but the level depends upon inputs from the post- monsoon (winter) and pre-monsoon (summer) rains.

Brijgopal since (1970) indicate several significant changes in the biodiversity. Some of these concerning the plantation of trees and shrubs. The *Prosopis juliflora* has increased considerably. After the severe drought of 1970, *Typha angustata* invaded the park for the first time. Groundwater was pumped into the Park and its timing coincided with the dispersal of seeds from Typha stands outside the Park. Slow and shallow flooding facilitated germination and quick establishment of Typha. During the past few years, reduced availability of water, prolonged dry periods and several management decisions, accelerated the process of terrestrialization and conversion of several wetland areas into dry scrubland. Vijayan (1991) reported general decline of floating-leaved and submerged macrophytes corresponding with an increase in emergent. The population of Siberian Cranes declined sharply from 200 in 1964-65 to a single pair arrival in 2000 and 2001. The Population of other waterfowl, particularly diving ducks, has gradually declined. Pheasant tailed jacana, Bronze winged jacana, Ring tailed fishing eagle, and Sarus Cranes have also declined (Vijyan 1991). The total count of Sarus Crane inside the park is regularly done every year since 1983 and a total of 657 Sarus Crane were counted during the 1984 and during the study period 61 Sarus Crane were counted, in 2001 8 Sarus Crane and 14 Sarus Crane in year 2002 were counted (Kumar 2004) (See Chapter 3, Table 3.).

The large year to year variability in the total amount of rainfall and its distribution during the year affect the depth, duration and timing of water in different blocks (Chauhan and Malvika 2001) have affected the Sarus Crane population. Extensive water diversion of rivers Gambhir and Banaganga has nearly eliminated flood since 1974. A dam was constructed during the 1980's on the R. Gambhir at Pacchna. The rainy season flow in R. Banganag has declined rapidly during the past 20 years. The park's water problem has therefore been aggravated by declining river flows and multiple demands on the smaller amount of water that is stored behind Ajan Bund. Groundwater is also heavily exploited for agriculture in the villages surrounding the park. Due to the construction of a dam and utilization of water for various other purposes along the course of the river, the quantum of water received by the park has been going down steadily. Water from the Ajan bund is supplied by the Public Works Department to the park and to nearby agricultural fields. It is usually released after being retained in the bund for a few days to facilitate inundation irrigation. Through this process the particulate organic matter settles, which is highly nutritious for the crops and, at same time, reduces salutation in the wetland. Water is supplied in July – August for about a month, but very rarely during August-September. The time of release of water to the park is vital to the growth of aquatic plants, breeding of the heronry species and Sarus Cranes. The quantum of water received is the most important factor in the survival of the wetland, and to some extent that of the upland forests.

The quantum of water let into the park during the seventies and eighties varied strikingly from a minimum of 0.017 million m^3 in 1985. In most years it was above 14 million m^3 in 1985. In most years it was above 14 million m^3 (Vijayan 1991).

Although a minimal quantity was supplied in 1986, the drought was not felt severely in the park during that year because of the availability of surplus water from the previous year's supply. However in 1997-88, the effect of drought was obvious when the wetland dried out completely and dead and dying animals were observed even during the end of the winter season (Chauhan&Gopal 2001). During the early 1990s water supply was adequate due to higher rainfall in 1998, the park received about 14 million m^3 water which flooded areas that had received no water other than the monsoon rain for more than two decades. This was followed by a severe drought in 2000 leaving the impoundments dry again and the groundwater was again pumped into some of the impoundments. The release of water in different blocks during the study period is given in (See chapter 4).

Once the water is let into the Ghana canal within the park, it is taken to different compartment or blocks of the wetland at the desired level through sluice gates. At times, when water is abundantly available, the terrestrial areas are also flooded for a short duration after which, the water is flushed out to the villages. The maximum water spread area was during September-October (Vijayan, 1994). Although water loss through infiltration is minimal, most is lost by evapo-transpiration which is very high during the hot and dry summers, leaving only a few pools in the central, deeper portions of the park (Vijayan, 1991).

7.5 Summary

1. During the present study Land use changes pattern was studied, by mapping the land cover in the study area relevant to Sarus Crane and compared with past years to evaluate the degree of change with respect to the critical terrestrial habitat requirements of Sarus Cranes so that appropriate conservation measures could be directed more efficiently to the critical habitats. The study areas were mapped and various land-cover/land-use types described and compared to detect changes in the Sarus Crane preferred habitat and its effect on Sarus Cranes populations.

2. The changes in land use and its possible impact on Sarus Crane life history parameters were also studied. Sarus Cranes used habitat such as natural marshes with reeds, shallow water bodies, ponds and agriculture fields. These marshes are endangered due to increasing agricultural development. The agricultural areas used by these Cranes have the particular characteristic of being located next to bodies of water. The natural marshes along the wetlands with agriculture fields on the margins appear to be the most preferred habitat for the Sarus Crane but the encroachment of these marshes to convert them into agriculture fields is diminishing their survival chance. Sarus Crane was seen to prefer paddy and wheat fields compared to other crops.

3. The wetland condition of Keoladeo Ghana National Park depends largely upon the amount of water received from the Ajan Bund (about 1 Km from the Park) and on direct precipitation. As soon as enough water accumulates in the Ajan bund, water is released into the park filling impoundments to a depth of 20-30cm. During the past few years, reduced availability of water, prolonged dry

periods and several management decisions, accelerated the process of terrestrialization and conversion of several wetland areas into dry scrubland. The total count of Sarus Crane inside the park has been regularly done every year since 1983 and a total of 657 Sarus Crane were counted during the 1984, and during the study period only 61 Sarus Crane were counted in 2000, 8 Sarus Crane in 2001 and 14 Sarus Crane in year 2002. The year to year variability in the total amount of rainfall and its distribution during the year affect the depth, duration and timing of water in different blocks of the park. The quantum of water received is the most important factor in the survival of the wetland, and to some extent that of the Sarus crane both within and outside the Keoladeo Ghana National Park in Bharatpur.

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Chapter 8

Suggested conservation strategies for enabling long-term survival of Sarus Crane in the semi—arid landscape from the lessons learnt from the present study

1. In semi-arid landscape, where water bodies (wetlands) are the limiting factor due to low precipitation and high evaporation loss, the Sarus Crane seem to have adapted to a second nesting season synchronizing with the creation of man-induced wetlands (See Chapter 5) in the dry season. It is necessary to maintain the periodicity of water, particularly in such wetlands in Kota and Keoladeo Ghana National Park and other semi-arid areas where the post-monsoon provisioning of water to wetlands support the wetland avifauna and the Sarus. If the wetland have an anthropogenic source of water that should be ensured, for seasonality of water to remain for a longer time period, and even those wetland where second nesting is recorded a same strategies be adopted. The large year to year variability in the total amount of rainfall and its distribution during the year affect the depth, duration and timing of water in different blocks in Keoladeo Ghana National Park. The time of release of water to the park is vital to growth of aquatic plants, breeding of the heronry species and the utilization of the protected wetland by Sarus Cranes and their increased chance of survival.

2. All the identified wetlands and the surrounding landscape that support large density of breeding Sarus Crane needs to be identified and such mosaic of habitat to be made disturbance free as next to natural predation, anthropogenic factors contributes the most to the success and failure of breeding success of Sarus Cranes (See Chapter 5).

3. Additional research based information are also required to enhance Sarus Crane conservation protection and management activities in Kota and Bharatpur. Detailed research on local and seasonal movements of Sarus Cranes in both wet and dry season nesting period is required by banding more juveniles and information on their monitoring documented. This will provide information on the kinds of critical habitats to be conserved (See Chapter 4).

4. The information on what kinds of threats are prevalent for chick survival is required in detail in the semi-arid landscape where the situation may be different in different semi-arid condition. Unlike at Kota and Bharatpur, where the water management by anthropogenic agency results in providing the preferred wetland situation for Sarus, in other semi-arid areas where the water regime is probably governed by nature it is important to understand the life history parameter and strategies of Sarus in such landscape, with respect to wetness of their habitat.

5. For the dry season nesting Sarus Cranes to be properly protected in Kota, (which is the only district where second nesting from February to May is recorded), removal of encroachments from wetlands and restoration of the marshes along the wetlands are required by declaring them as "Conservation or Community Reserves" to avoid further encroachments.

6. The protection of the marshes created from the seepage and escapes of the wetland and canals along the agriculture fields are important to be maintained. From the present study it is evident that the cranes use these marshes for most of their important life history parameters such as breeding, maintenance and

feeding. These marshes are also important for the rural landscape where they help in recharging the groundwater of the area and are therefore, useful for the crops and cattle of villagers during the drought period.

7. Maintaining a minimum water level in the larger man-made wetlands or large reservoirs is important too. During the dry summers Cranes utilize these wetlands for feeding and roosting and these areas are also used for nesting during the second breeding season (See Chapter 5&6), thereby helping the Crane population in semi-arid landscape.

8. Sarus being a bird in the habitat matrix outside the forested landscape is often encountered in agricultural fields and hence the people's attitude to Sarus is of significant importance. Destruction of Sarus nests, stealing of eggs, occasional hunting, has been the direct threats to Sarus in Rajasthan (See Chapter 5). All identified wetlands and the surrounding landscape that support large density of breeding Sarus Cranes are required to be identified and such mosaic of habitat to be made disturbance free, either through creation of Protected Areas or through Community involvement.

9. Annual counts of the Sarus population at Keoladeo National Park have been carried out by an NGO since 1983 and has provided the much needed information on what is happening to the Sarus population (See Chapter 3). Inventorization of important wetlands and the surrounding landscape that support Sarus Crane population and annual Sarus counts can be conducted by local NGO's by creating such network, that will have community involvement.

10. Involving the local communities around the breeding sites of Sarus Cranes through education and awareness campaigns on a prolonged basis conducted by government agencies and NGo's to protect and monitor the breeding sites, nests and chicks from predation has helped increase the number of the cranes during the present study. Forming more such "Rural Protection Groups" in other areas by interested youths from the rural village (or breeding area.) may be a strategy that not only will link people to Sarus but also will provide much more incentives to local people for wildlife conservation, particularly outside Protected Areas.

Appendix1 Sketches of Cranes behaviour pattern from Mastomi and T.Kitagawa (1975).

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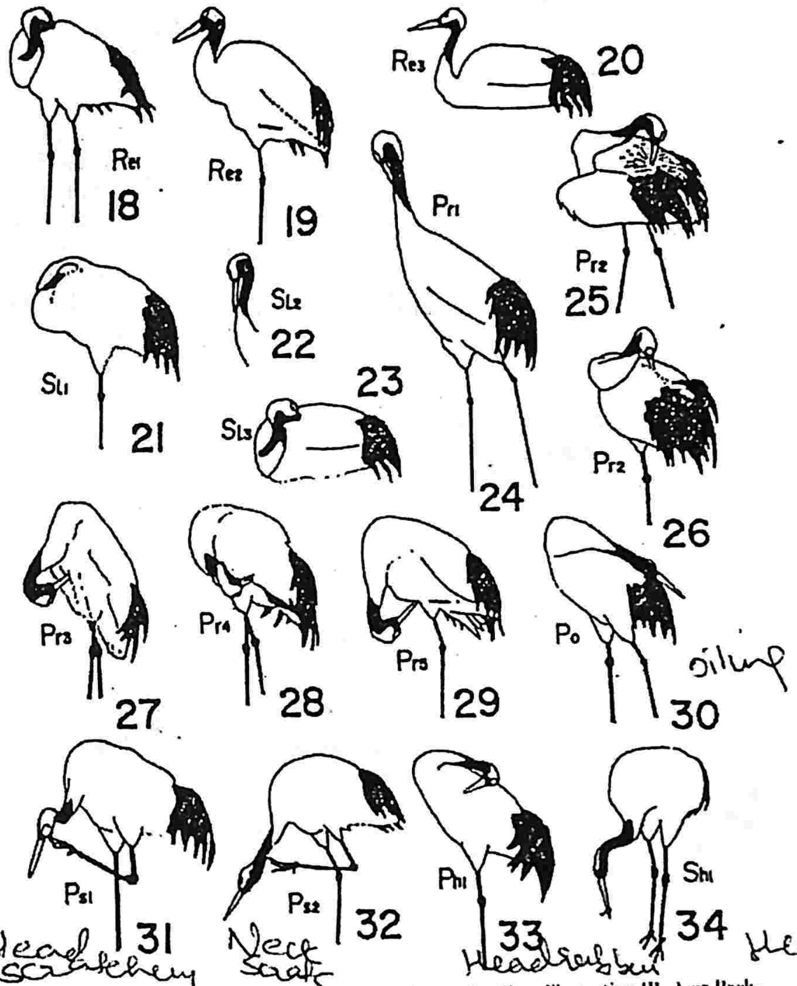

Fig. 18~34. Postures of ~~maintenance~~ behaviour. 18. Sleep-like-resting (R_{e1}) or Back-sleeping (S_{l1}); 19. ~~Neck-shortening-resting (R_{e2})~~; 20. Sitting (R_{e3}); 21. Back-sleeping (S_{l1}); 22. Down-sleeping (S_{l2}); 23. Sit-back-sleeping (S_{l3}); 24. Neck-preening (P_{r1}); 25, 26. Back preening (P_{r2}); 27. Breast-preening (P_{r3}); 28. Wing preening (P_{r4}); 29. Leg-plumage-preening (P_{r5}); 30. Oiling (P_o); 31. Head-scratching (P_{s1}); 32. Neck-scratching (P_{s2}); 33. Ordinary-head rubbing (P_{h1}); 34. Head shaking (S_{h1})

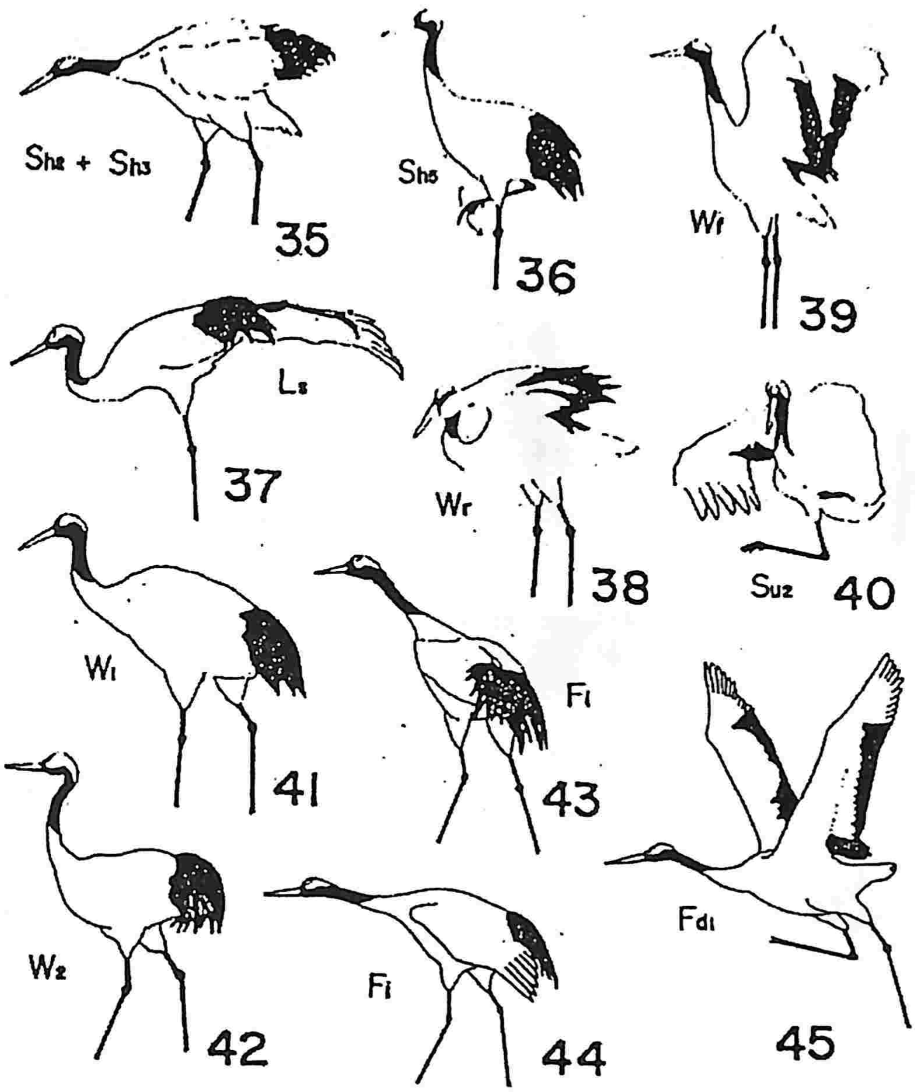

Fig. 35~45. Postures of maintenance behaviour. 35. Compound posture of Head/neck-shaking (S_{h2}) and Body/wing-shaking (S_{h3}); 36. Leg-shaking (S_{h5}); 37. Leg-stretching (L_s); 38. Wing-raising (W_r); 39. Wing-flapping (W_f); 40. Wing-spread-sunning (S_{u2}); 41. Slow-walking (W_1); 42. Rapid-walking (W_2); 43. 44. Intentional postures (F_i); 45. Horizontal-head-dashing (F_{d1}).

lowed by eager preening (P_r. A.III.1.1.). oiling (P_o. A.III.1.2.), wing-shaking (S_{h1}, A.III.2.4.), etc. Observed throughout the year but not frequently.

III.8. *Head/beak-washing* (W_a): *F* normal, *H* lowered, B_d slightly or obliquely

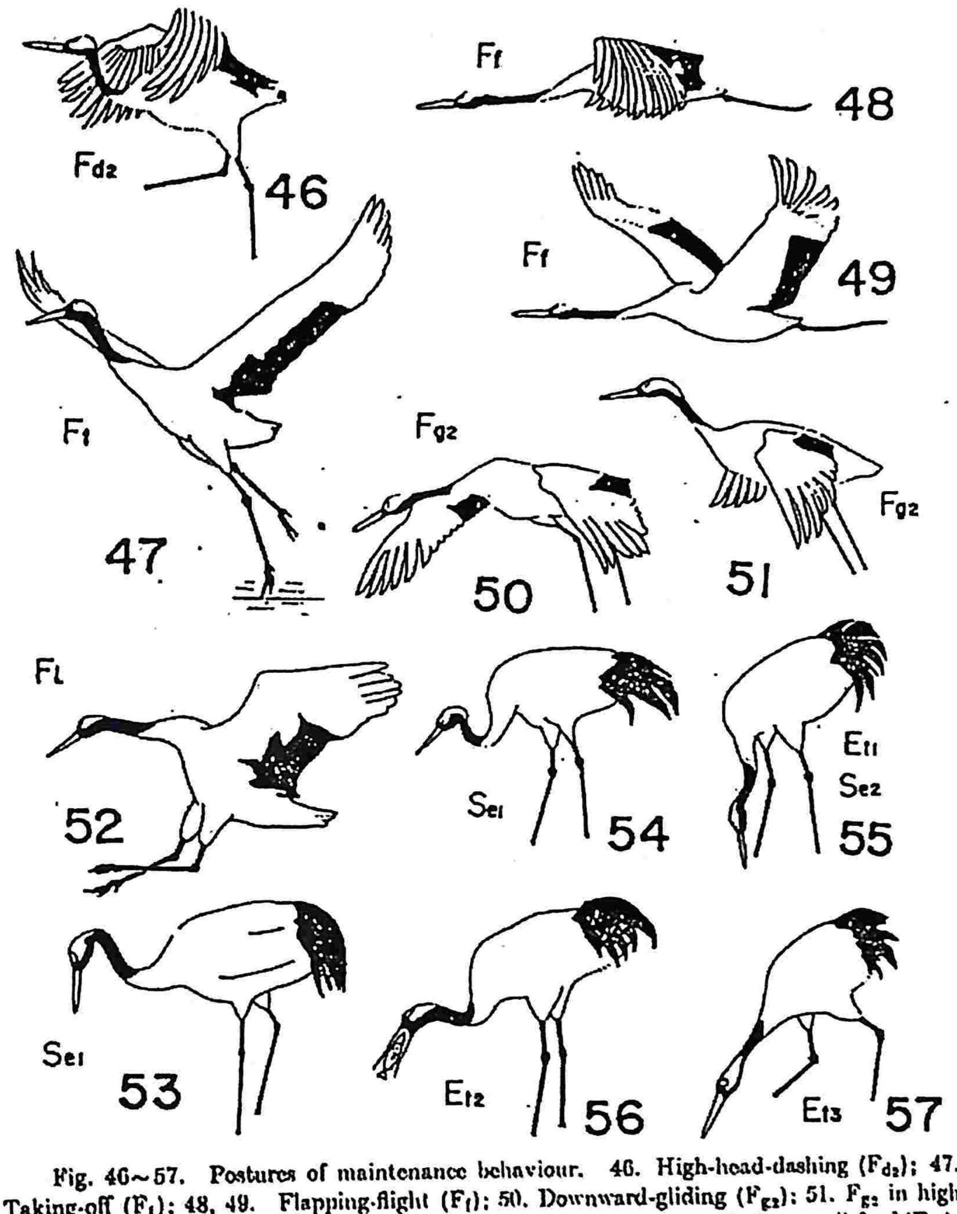

Fig. 46~57. Postures of maintenance behaviour. 46. High-head-dashing (F_{d2}); 47. Taking-off (F_t); 48, 49. Flapping-flight (F_f); 50. Downward-gliding (F_{g2}); 51. F_{g2} in high speed; 52. Landing (F_l); 53, 54. Foraging (S_{e1}); 55. Sticking (S_{e2}) or Eating-small-food (E_{t1}); 56. Swallowing-medium-food (E_{t2}); 57. Eating-moving-animal (E_{t3}).

4.1. *Watching* (F_w, Fig. 92): Identical with alert (A_1, B.1.6.) or neck-curved-gazing (G_3, A.VII.3). Described later.

4.2. *Intentional posture* (F_i, Figs. 43 and 44): *F* sleeked tightly, B_d horizontally

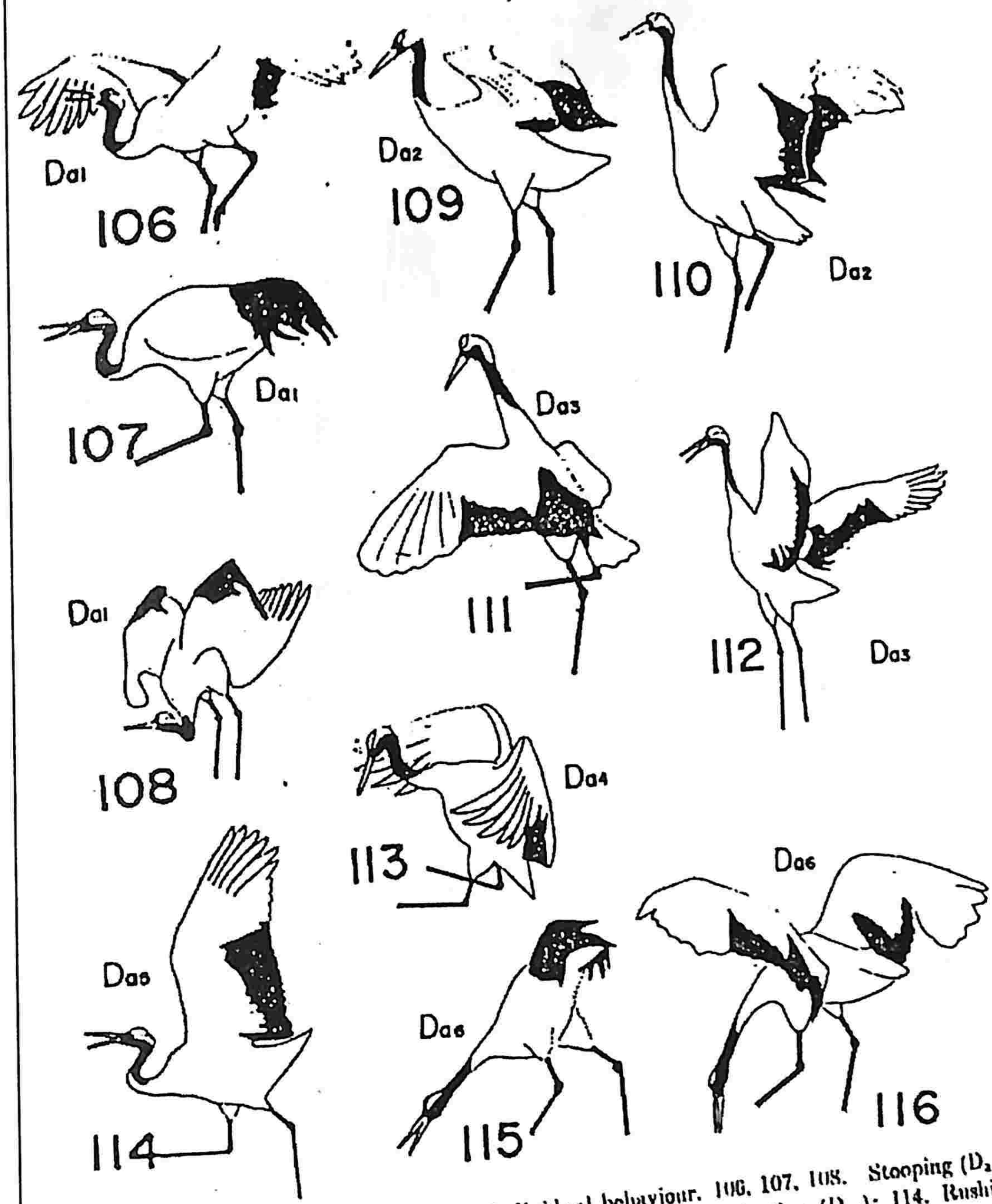

Fig. 106~116. Postures of interindividual behaviour. 106, 107, 108. Stooping (D_{a1}); 109, 110. Pre-leaping (D_{a2}); 111, 112. Leaping (D_{a3}); 113. Floating (D_{a4}); 114. Rushing (D_{a5}); 115, 116. Picking-up (D_{a6}).

(C_2, Fig. 122): Male leaning backwards and laterally (usually left) a little, flapping W' continuously. Male lowering rump, pressing his cloaca to female's by evading her T_d normally to right side. B of female occasionally lowered to be lightly

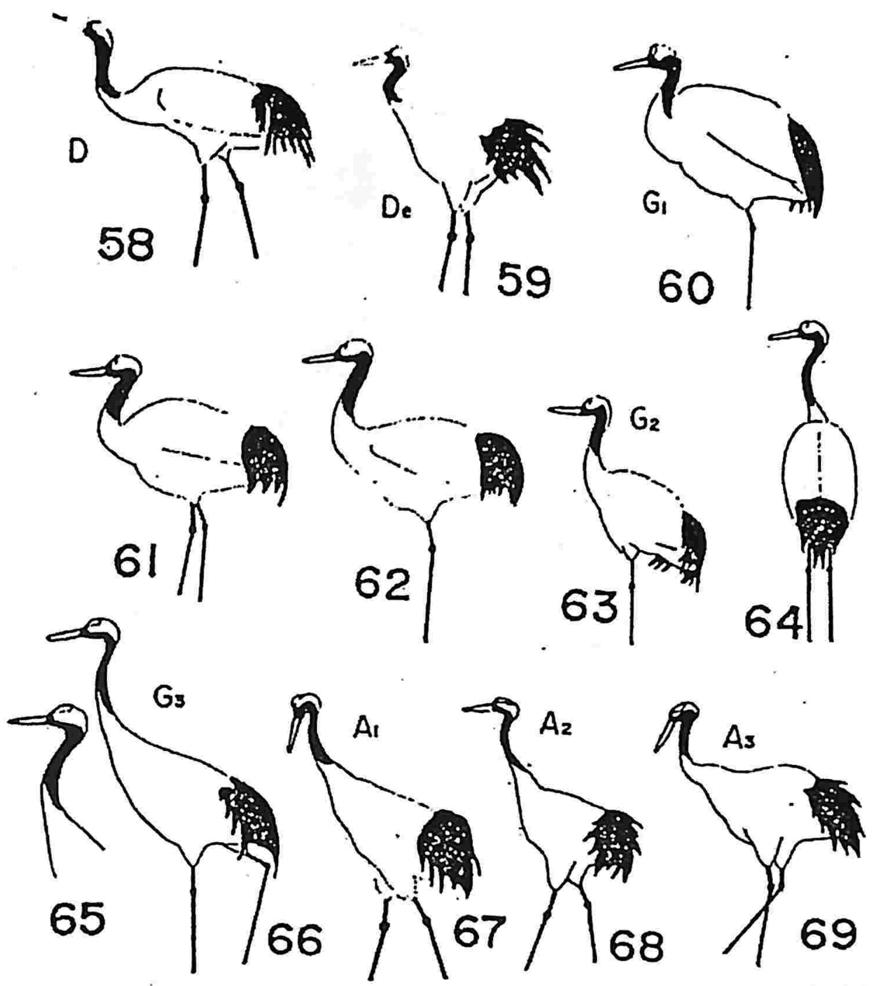

Fig. 58～69. Postures of maintenance behaviour (Fig. 58～66) and interindividual behaviour (Fig. 67～69). 58. Drinking (D); 59. Defecation (D_e); 60. Neck-retracted-gazing (G_1); 61, 62. Transitional postures from G_1 to G_2; 63. Neck-raised-gazing (G_2); 64, 65. Transitional postures from G_2 to G_3; 66. Neck-curved-gazing (G_3); 67. Downward-adornment (A_1); 68. Forward-adornment (A_2); 69. Lowered-adornment (A_3).

VII.3. *Neck-curved-gazing* (G_3, Fig. 66): *F* sleeked much more than G_2, B_z about horizontal and directed to the object, *H* highest, N_r vertically up, N_f curved slightly. *C* expanded partly or completely, T_i obliquely up. Strongest gazing generally performed at caring eggs or other social activities.

VII.4. *Sit-gazing* (G_4, Fig. 20): Similar to sitting (R_{c3}, A.I.3.) or alert (A_1, B.I.6.) made at sitting.

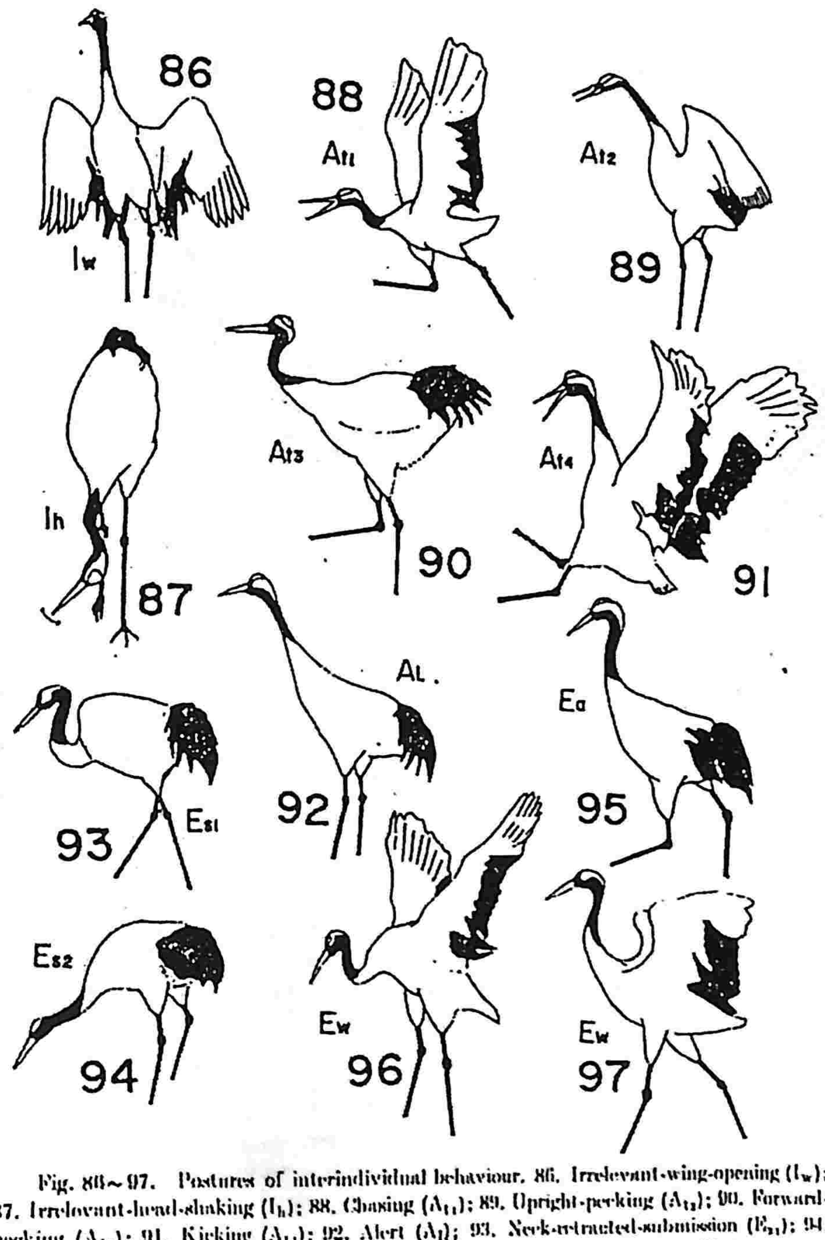

Fig. 86~97. Postures of interindividual behaviour. 86. Irrelevant-wing-opening (I_w); 87. Irrelevant-head-shaking (I_h); 88. Chasing (A_{t1}); 89. Upright-pecking (A_{t2}); 90. Forward-pecking (A_{t3}); 91. Kicking (A_{t4}); 92. Alert (A_l); 93. Neck-retracted-submission (E_{s1}); 94. Head-down-submission (E_{s2}); 95. Avoiding (E_a); 96, 97. Wing-raise-fleeing (E_w).

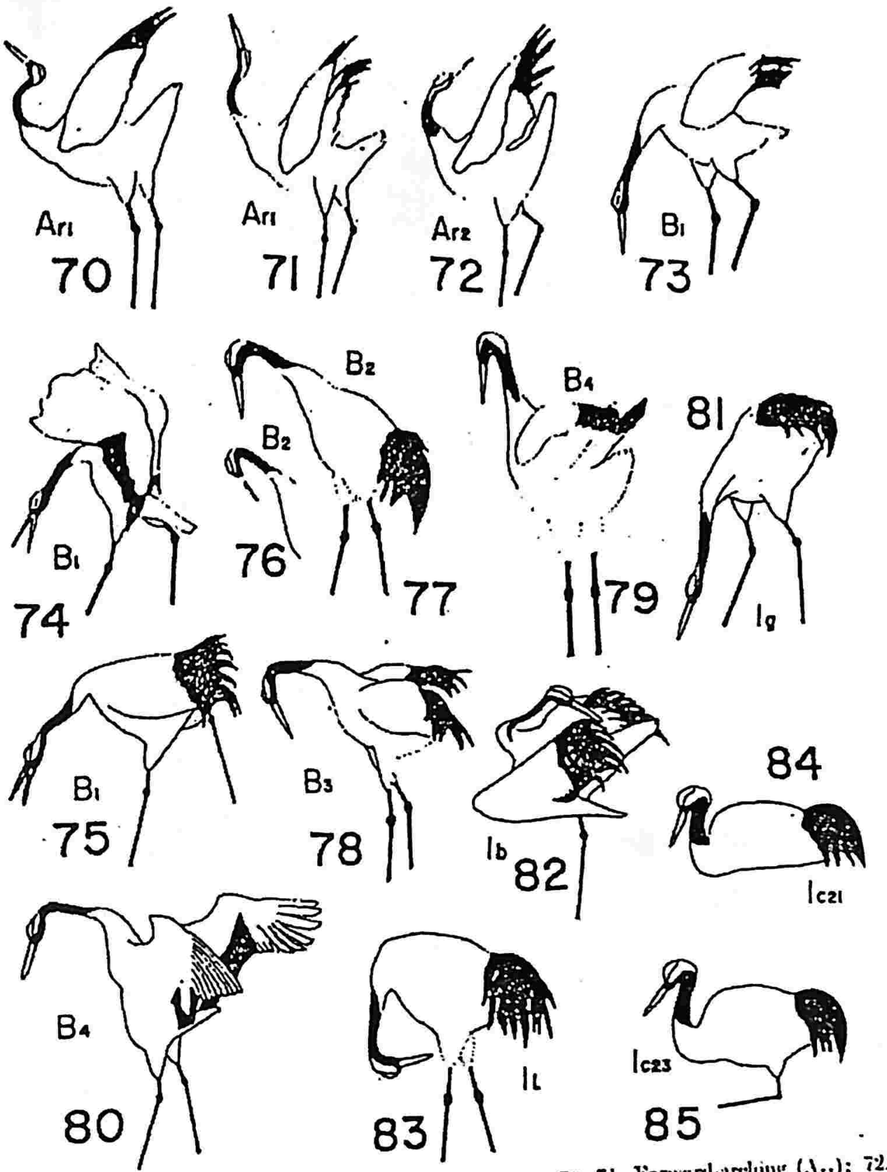

Fig. 70~85. Postures on interindividual behaviour. 70, 71. Forward-arching (A_{r1}); 72. Side-backward-arching (A_{r2}); 73. 74. 75. Low-bowing (B_1); 76, 77. High-bowing (B_2); 78. Wing-shake-bowing (B_3); 79. 80. Wing-raise-bowing (B_4); 81. Irrelevant-ground-sticking (I_g); 82. Irrelevant-back-preening (I_b); 83. Irrelevant-leg-preening (I_l); 84. Irrelevant-crouching (I_{c21}); 85. Irrelevant-crouching (I_{c23}).

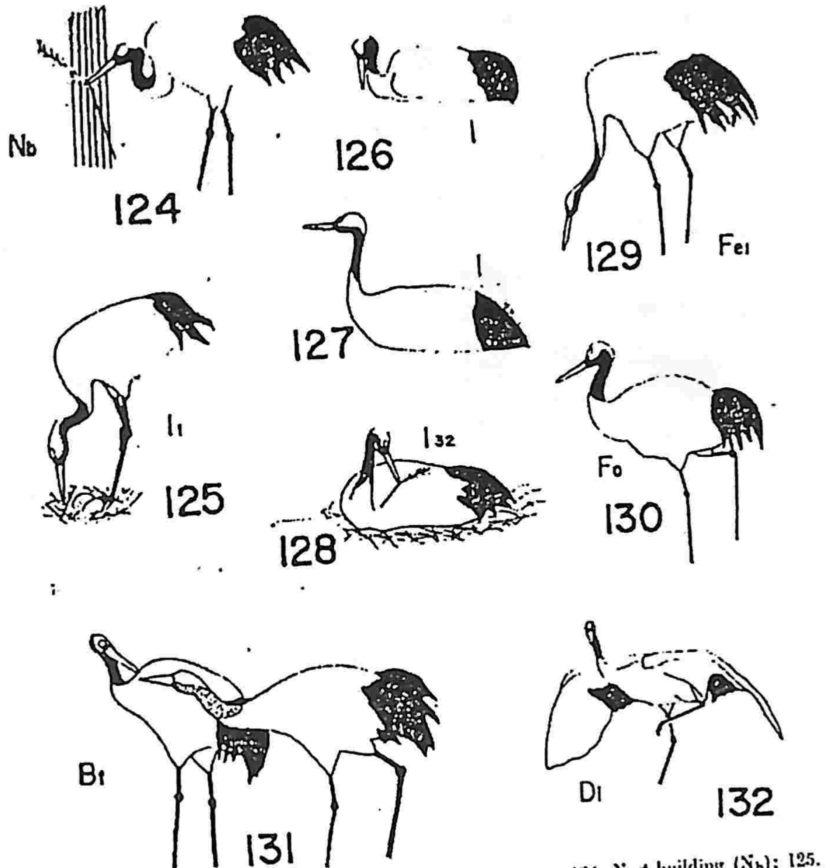

Fig. 124 ~ 132. Postures of interindividual behaviour. 124. Nest-building (N_b); 125. Shifting (I_1); 126, 127. Incubating postures; 128. Nest-mending-in-sitting (I_{32}); 129. Low-feeding (F_{e1}); 130. Following (F_o); 131. Bill-touching (B_t); 132. Diversionary display (D_1).

territory, they come up to the animal with the posture uttering *alert call* (B.I.6.). They follow it with rather hurried steps and usually stand or move around it with alert posture, keeping a certain distance. These behaviour patterns are also released in winter flocks at feeding or roosting places against strange animals passing through there. Any member takes part in the tumult in concert.

ypsoensis (Heude), so far observed as a target approaches the family in the breeding

IV.2. *Diversionary display* (D_1, Fig. 132): *F* sleeked, *H* slightly down, *N*

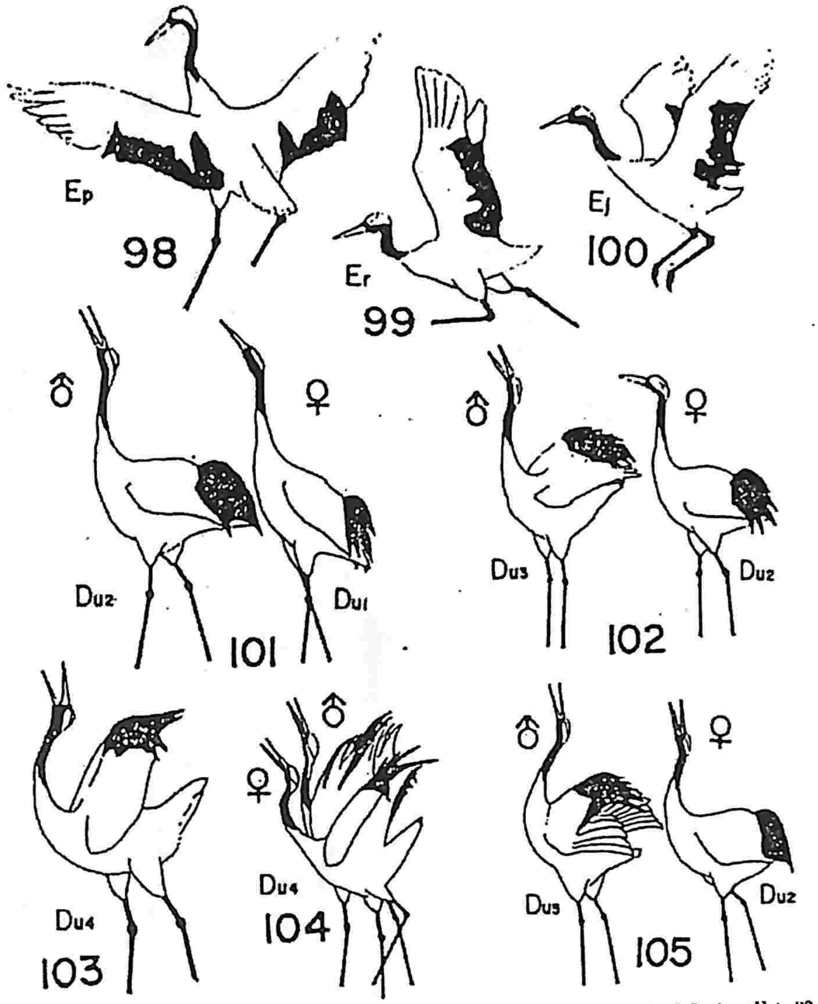

Fig. 98 ~ 105. Postures of interindividual behaviour. 98. Wing-spread-fleeing (E_p): 99. Running-off (E_r): 100. Jumping-up (E_j): 101♂. Semiclosed-wing-duetting (D_{u2}): 101♀. Closed-wing-duetting (D_{u1}): 102♂. Semiraised-wing-duetting (D_{u3}): 102♀. D_{u2}: 103. 104. Obliquely-raised-wing-duetting (D_{u4}): 105♂. Drooped-wing-duetting (D_{u5}): 105♀. D_{u2}.

arch. W folded and raised as much as possible, T_4 raised upwards, T_1 horizontal.
1.5. *Drooped-wing-duetting* (D_{u5}, Fig. 105♂): Similar to D_{u1}, except primaries
held stiffly at T sides, but below as in *Grus antigone antigone* (Linnaeus), *Grus rubicu*