SPATIO – TEMPORAL ANALYSIS OF LAND USE & LAND COVER CHANGE IN INDIRA GANDHI CANAL AREA

Dissertation submitted to Jawaharlal Nehru University

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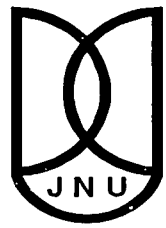
MASTER OF PHILOSOPHY

VIKAS KUMAR



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25 July 2011

CERTIFICATE

This is to certify that the dissertation entitled ***"Spatio - Temporal Analysis of Land Use and Land Cover Change in Indira Gandhi Canal Area"*** submitted in partial fulfilment for the degree of **MASTER OF PHILOSOPHY** is my bonafide work and may be placed before the examiners for evaluation. This Dissertation has not been submitted for any other degree of this University or any other University.

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TO

MY PARENTS

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Spatio – Temporal Analysis of Land Use & Land Cover Change in Indira Gandhi Canal Area

Introduction to the study

1.1 INTRODUCTION: Land is an important natural resource and provides substratum for many other resources as it embodies soil, water and associated flora and fauna involving the total ecosystem (Rao et al., 1991) .Among the resource, agriculture is the backbone of the economy of any agrian country like India. Agriculture contributes about 40 % towards the gross national product & provides livelihood to about 70 % population. Land use and land cover is of dynamics nature and need proper monitoring for the sake of optimum utilization of land resources. Land cover and land use are often assumed to be identical, they are rather quite different. Land cover may be defined as the biophysical earth surface while land use is often shaped by human, socioeconomic and political influences on the land.

The land use & land cover pattern of a region is an outcome of the natural & socio-economic factor and their utilization by man in time & space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use & land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. According to Wilkie and Finn (1996), the collection of remotely sensed data facilitates the synoptic analyses of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity.

Conversion of land to feed and shelter the growing human enterprise has been one of the primary modes for human modification of the global environment. Over the coming decades, expansion and intensification of agriculture, growth of urban areas, and extraction of natural resources will likely accelerate to satisfy demands of increasing numbers of people at higher standards of living. Human transformation of the Earth's land surface has multiple consequences for biophysical systems at all scales, ranging from local urban heat islands (Kalnay and Cai, 2003) and alterations in cropping patterns (Storck et al., 1998; Rose and Peters, 2001)to altered patterns of global atmospheric circulation (Werth and Avissar, 2002) and long-term extinction of species (Pimm and Raven,2000).There is need to understand the consequences of land-use and land cover change processes, and integrating this understanding into the emerging focus on land-change science (Turner et al., 2003),are major needs for the future.

The dependability of India's agriculture on the south-west monsoon & its consequent vulnerability has been recognised from the earliest times. Agriculture has always been the principal occupation of the vast majority of the people & successive rulers from time to time have been directing their energies to improve the lot of the farmer, to give him protection against the failure of rains. Efforts were made to bring the waters to the field irrigation. Early irrigation ventures were mostly concerned with storing rainwater in tanks & with leading canals from the tanks to farmer's field. Although irrigation from the wells in Indus valley started during Mohan-Jo-daro. Harappan period perhaps due to great of ground water, irrigation from well waters did not make much headway in the desert of Rajasthan. Only a few plots in the Sujangarh and Reni in Bikaner district were watered from Kachcha wells in 1897. No irrigation from wells existed in Jaisalmer state as well were too deep. Irrigation from rainwater by constructing kharins or khadeens existed in Jaisalmer district in the 18th century. Kharins are shallow depression into which the rainwater flows. They are basically used to harvest surface runoff from the surrounding area for raising crops during Rabi season. Where soil is harder and the surrounding hilly and rocky surface runoff is diverted to shallow depression.

The Indira Gandhi Canal is one of the biggest canal projects in India. The Indira Gandhi Canal Project was conceived in April, 1948 with the noble aim of improving the living condition of human being and to cater to the minimum needs of cattle populations in the region. It starts from the Harike Barrage at Sultanpur, a few kilometres below the confluence of the Sutlej and Beas rivers in Punjab state. It runs south-southwest in Punjab

and Haryana but mainly in Rajasthan for a total of 650 kilometres and ends near at Ramgarh, near Jaisalmer, in Rajasthan. Its construction started on the 31st March, 1958, inaugurated by then Home Minister Govind Ballabh Pant. It was built with the aim of converting part of the Thar Desert from wasteland to agriculturally productive land. The project area is classified as arid. It is thinly populated and requires large scale effective settlement of people to realise the benefits of transfer irrigable water. The project was planned in two phases for the convenience of planning and construction. It was earlier known as the Rajasthan Canal. The name was changed on the 2nd Nov, 1984. It uses water released from the Pong dam and provides irrigation facilities to the north-western region of Rajasthan, a part of the Thar Desert. It consists of the Rajasthan feeder canal (with the first 167 km in Punjab and Haryana and the remaining 37 km in Rajasthan) and 445 km of the Rajasthan main canal which is entirely within Rajasthan. The IGNP traverses seven districts of Rajasthan: Barmer, Bikaner, Churu, Hanumangarh, Jaisalmer, Jodhpur, and Ganganagar. The Indira Gandhi Canal, a vast manmade river system, is a symbol and tribute to India's engineering skill (Rao, 1992). Broadly speaking, the socioeconomic and biophysical objectives of the irrigation project were to:

1. Halt the process of desertification.
2. Develop agriculture in the command area.
3. Create human settlements in the sparsely populated area.
4. Provide drinking and industrial-use water to the inhabitants of the project area and adjoining regions.

The physiography of the area is characterized by vast stretches of undulating wind-blown sand dunes occasionally rising to about 60 meter with extensive sandy flat area. As the canal enters the Rajasthan territory, the land is fairly flat for about 65 km with scattered sand dunes. The area is not drained by any river. Principle rainfed crops grown in the area in the project period are Bajra, Gaur and some pulses including Moong. It should take care of the aspect like sustained irrigated agriculture, human settlement, pastoral development and stabilisation of sand dunes and overall economic and socio economic development.

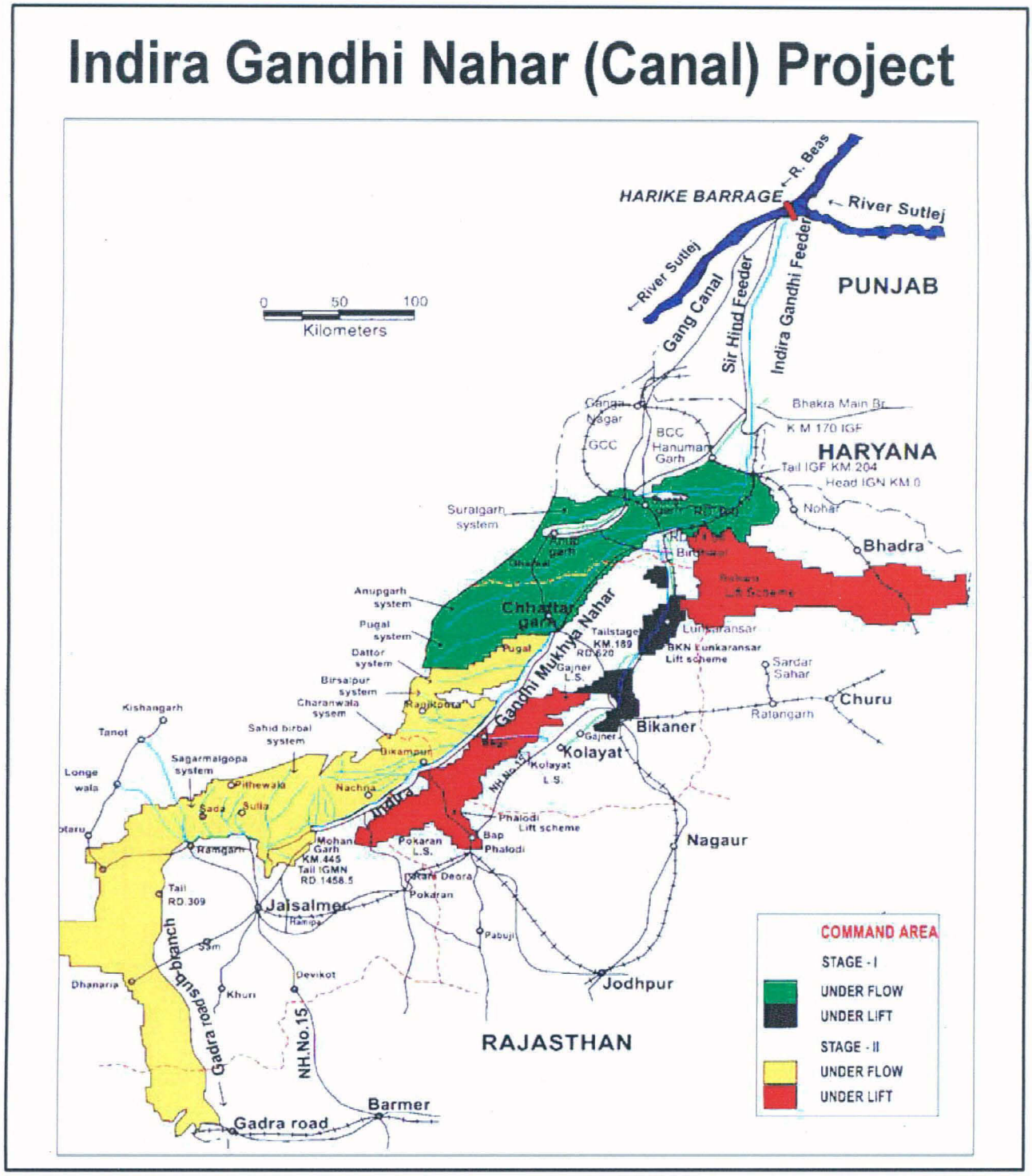
1.2 NEED FOR STUDY: Only few landscapes on the Earth that are still in their natural state. Due to anthropogenic activities, the Earth surface is being significantly altered in some manner and man's presence on the Earth and his use of land has an effect upon the natural environment thus resulting into an observable pattern in the land use & land cover over time. The land use & land cover pattern of a region is an outcome of natural and socio – economic factors and their utilization by man in time and space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Indira Gandhi canal region has witnessed remarkable expansion, growth and developmental activities such as building, road construction, deforestation and many other anthropogenic activities. Presently unplanned changes of land use have become a major problem. Than the main emphasis on the study is the find out changes occur during 1971 to 2008, with the respect of the socio- economic, demographic and spatial location.

1.3 STUDY AREA: The Indira Gandhi Canal Project is a bold irrigation project with the objectives of assured irrigation. Indira Gandhi Nahar (Canal) Project (hereafter IGNP), earlier known as Rajasthan Canal Project, is one of largest irrigation projects in the world. IGNP meets the irrigation requirements of a vast area in the Thar Desert of North-Western India. The mighty Thar Desert has been immortalized in songs and legends as Maroosthali, the land of the unknown-hostile, harsh and merciless (Bhakar, 2007). IGNP was conceived to transform the dreary and desolate Thar into a land of prosperity and plenty. IGNP owes its existence to the 'Indus Water Treaty' of 1958 between India and Pakistan, which allocated the water of three western rivers of Indus System Ravi, Beas, and Sutlej to India (Gulati, 1973). The transformation brought about by the project in poverty alleviation, improving agricultural productivity, providing livelihood, settling people, and providing drinking water, etc. has been remarkable (Kavadia and Hooja, 1994).). IG Canal is a gravity canal and runs at a distance of 40-50 km from the India-Pakistan border. The area on the west of the canal and between the canal and international border is the served by 'flow system'. The areas to the east of the main canal are too high to be commanded by gravity flow from the canal. These areas will be served by seven 'lift irrigation schemes'. Due to its extensive size the Project has been divided into two stages-

- Stage-I: It comprises of 204 km long Feeder from Harike Barrage in Punjab to Masitawali in Hanumangarh district in Rajasthan, and 189 km long main canal from Masitawali to

Chattergarh in Bikaner district. It has 3454 km long distribution system to serve a CCA of 0.553 Mha; it has one 'lift canal'- Lunkaransar lift scheme.

• Stage-II: It comprises of 256 km long main canal from Chattergarh to Mohangarh in Jaisalmer district, and has 5606 km long distribution system to serve a CCA of 1.41 Mha. It has six 'lift canals'- Sahwa lift scheme, Gajner lift scheme, Kolyat lift scheme lift, Bangarser lift scheme Phalodi scheme lift scheme, and Pokaran lift scheme (Gupta.A.K. et al., 2002)



Source: Gupta A.K. et. al. (2002)

Figure 1.1 Index Map of Indira Gandhi Nahar Project

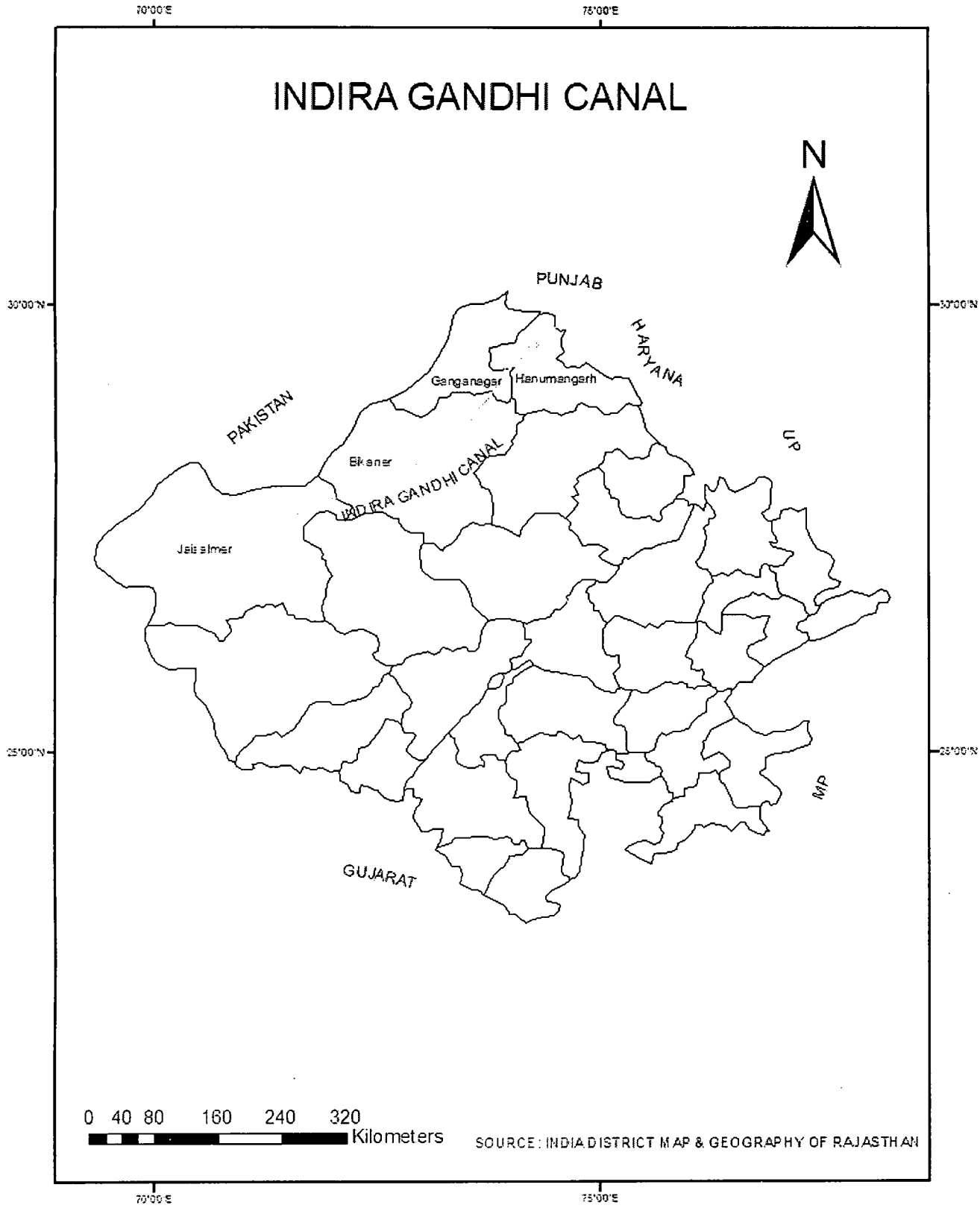


Figure 1.2 Indira Gandhi canal (in Rajasthan)

1.4 GEOLOGY:

1.4.1 SOILS: As the soils in the command area are porous and the rate of infiltration is high, it is expected that about 40 % of the water applied for irrigation may be lost as deep percolation and of the about 25 % to 30 % would replenish the ground water system. The experience of stage 1 of the project indicates that the average annual rise in water table of that area is approximately 0.3 m to 0.5 m even though the water table before the introduction of canal irrigation was very deep and the hydrological barrier was not reported to be present at shallow depth. Of course the effect of Ghaggar floods and the storage of flood waters in natural depressions in stage 1 areas have to be reckoned.

In stage 2 command area, these features are not there to influence the rate of rise of the water table but the presence of hydrological barrier at shallow depth (within 10 m) in about one third of the area may lead to perched water table and consequent water logging depending upon the thickness of the barrier layer and aquifer characteristics of layer below hard pan. As all above factors were not fully known as an interim measure, suggestion was to reduce water application and impress on efficient water management for stalling the chances of water logging.

1.4.2 REGIONAL GEOLOGY: The desert region has scanty rocky outcrops, which generally provide data for conception of geological formations. The interpretative geology of desert region has been drawn by Geological Survey of India by gradually pooling the data from the dug wells, logs of bore holes drilled by various agencies like ONGC, UNDP, central Ground Water Board and Rajasthan Ground Water Department. The western desert is considered as a shelf together with the Indus plain in Pakistan, bounded on the east by Aravali range, on the west by Indus geo syncline and dissected by the basement ridges on the south and Delhi- Lahore ridge on the north. The interference drawn from a number of bore holes and drilling data is that a part of stage 1 area and particularly entire area of stage 2 of the project is covered by a blanket of windblown sand with older alluvium underneath.

In the flow command area, Quaternary formation resting beneath the sand cover from the phreatic aquifer. East of the above zone, are encountered the Palana sand stones, Nagaur sand stone and tertiary horizons that form the top aquifers. Around Ramgarh and further south east the Baleser, Khuliala and Jaisalmer formation are encountered. In part of the area, just

beneath the upper sandy soils, there exists the impervious bed of sticky clays and hard kankar pans at varying depths. Examination of litho logos of exploratory holes reveals that the surface soil is normally sandy with varying amounts of clay; at places clay and kankar are also observed at surface. Shale/clay, hard compact friable carbonate nodules and lime coated gravel with clay are present at varying depth having poor infiltration rate and behaving as impervious barrier.

Examination of the bore hole data shows that most of the command area has the alluvial cover of more than 20 m and can be a potential source of ground water depending upon the aquifers characteristics and the quality of recharged water. Along the course of buried drainage channels and younger alluvial plain the formation comprises shallow aquifers where depth of water table varies from 10 m to 20 m and quality of water is good but this area is very limited. Among the deep aquifers, the most potential aquifers have developed under limestone and sandstone strata due to well defined joints, fractures and cavities.

1.4.3 GROUD WATER: The command area can be divided into 6 zones on the basis of common geological and hydro-geological condition, hydraulic characteristics, ground water potential and drainage of the subsurface. The zones are arranged in order of the geological age and stratigraphic position of the rock formation as under:

Zone	Geological Formation	% of CCA (approx)
1.	Quaternary formation	47.0
2.	Tertiary formation	47.0
3.	Lathi formation	1.5
4.	Jaisalmer formation	1.3
5.	Marwar super group	
(a)	Nagaur group	1.9
(b)	Bilara group	0.3
(c)	Jodhpur group	nil

(d) Bap boulder beds		negligible
6.	Parihar formation	1.0

1. Quaternary Formation: Quaternary formation consists of a superficial layer of Aeolian (wind blown) deposits followed by fluvial deposits. It occur in 50 to 100 km wide belts along the international border and occupies the greater part of the flow command. Its thickness ranges from a featheredge to over 200 m increasing towards the international border. The deposits comprises moistly fine to medium grained, well sorted , loose to poorly cemented, rounded to sub rounded sand, silt and clay.

Although the thickness of saturated zone exceeds 150 m near Khara in eastern part and close to the international border the thickness of useable aquifers is limited to a thin lens of a few meters at the top. The formation of Jaisalmer and Barmer districts contains water that is highly mineralised but many places useable for livestock.

2. Tertiary Formation: The tertiary rock extend from Sam in the south west to Bikaner in north east in an arc type belt. They underlined a thin veneer of blown sand and alluvium. The Indira Gandhi canal traverses through the tertiary rocks for greater part of its length. Considerably part of the flow command and the greater part of Phalodi and Kolayat lift irrigation scheme areas and the whole of Gajner lift irrigation scheme area is underlain by tertiary rocks at shallow depths.

In Bikaner district the tertiary formation is represented by Palana series comprising essentially sandstone and shale and clays with subordinate limestone, fuller's earth and lignite.

Ground water in the formation occurs under the water table, in confined and unconfined conditions. It occurs in the pore spaces, joints and fissures. The thickness of unconfined aquifers in Palana range from 10 m to 80 m, increasing northwards. The main water table lies at depths ranging from 75 m to 100 m in the western part of Jaisalmer district, decreasing towards Nachana where it is about 20 m, and again increasing to 50 m or more toward Bikaner. In some places perched water bodies are found at comparatively shallower depth ranging from 5 m to 27 m.

3. Lathi Formation: The quality of ground water varies widely in this formation. It is best in central part of Lathi basin. The ground water becomes more mineralised in the direction of flow, deteriorating rapidly close to its contact with younger formation. The comparatively better quality of ground water in perched zones indicates that the materials in vadose zone are well leached.

4. Jaisalmer Formation: Quality of ground water is generally poor in Jaisalmer formation. Water of comparatively better quality occurs in isolated pockets and in perched aquifers.

5. Marwar Formation: The quality of ground water in phreatic aquifers zone tapped by dug wells in mostly brackish to saline in greater part of area occupied by Nagaur group in the Kolayat and Phalodi lift irrigation scheme. The highest salinity of ground water is in the area around a Rann like depression.

6. Parihar Formation: The water on evaporation leaves saline residue in the bed of Rann which are leached into ground water. Thus the ground water not only in these formations but also in the sandstone aquifers in the Parihars, which are on the down gradient side, is saline.

1.5 SCOPE OF STUDY: The last quarter of Nineteenth and much of Twentieth century witnessed the initiation of major irrigation projects in deserts of USA, former USSR, Egypt, Pakistan, India and Middle East. Arid and semi-arid lands were looked upon as last land frontier/empty land-banks and the Irrigation Projects as the harbingers of development, which brought these arid lands under the fold of agriculture, leading to rise in their economic potential by increasing the productivity manifold. This was also perceived as an answer to the ever-growing food and settlement needs of rapidly increasing world population. While the techno-engineering challenge of damming rivers and large scale inter-basin transfer of water for blooming deserts with irrigation was successfully addressed, sustaining economically viable irrigated agriculture has proved to be much more difficult. Than main emphasis of study find changes in land use & land cover in Indira Gandhi canal area over time period. Various article elaborate shift in agriculture pattern in Indira Gandhi canal area. Than main focus of study is find out changes in this agriculture pattern & land use & land cover categories. Water logging and salinisation affect nearly all-major irrigation schemes situated in desert environments. For example, lower Colorado River lands in American West,

northern Mexico, Punjab and Indus Valley Irrigation systems in Indian subcontinent, The Euphrates and Tigris basins of Syria are plagued by salinity hazard (Worster, 1992).

1.6 RESEARCH QUESTION:

1. What is the trend of land use changes from 1971 to 2008 in the study area?
2. What is trend in agriculture pattern in study area over time period?
3. Does salinity & water logging affect cultivable land in the region?

1.7 OBJECTIVES:

1. To analyze changes in agricultural or cultivable areas of various crops in Kharif & Rabi season during time period of 1971 to 2008 in Indira Gandhi Canal Area and to find out impact of Indira Gandhi Canal on agricultural yield of major crops at district level and to look at the changes in cropping pattern in the Indira Gandhi Canal Area over this time period.
2. To find out changes in the land use & land cover over this time period at tahsil level and to examine shift of area from one category to another category.
3. To analyse the impact of canal on changes in land use & land cover and to look at land degradation due to water logging and salinity in Indira Gandhi Canal Area. Analysis of land use & land cover during 1977 to 2008 with using GIS & RS.

1.8 DATA BASE OF STUDY:

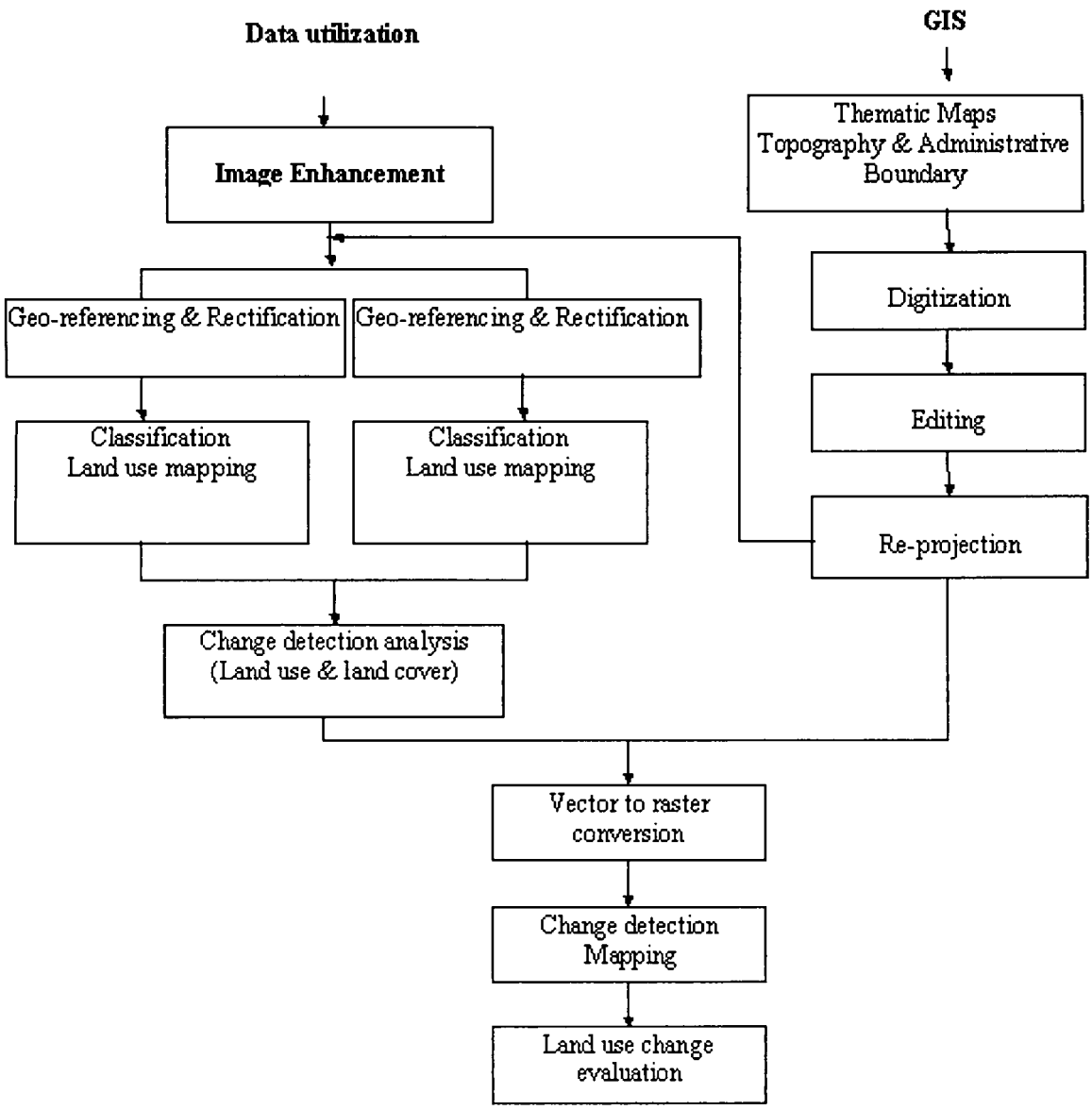
1. Topographical sheets of Ganganagar, Hanumangarh & Bikaner districts.
2. Multitemporal Remote Sensing data of the region (MSS, TM, ETM+)(ESDI,GLCF)
3. District census handbook (Ganganagar, Hanumangarh & Bikaner).
4. LAND USE LAND COVER PROJECT REPORT MANUAL, National Remote Sensing Centre
5. RAJASTHAN AGRICULTURE STATISTICS AT A GLANCE (1970 TO 2009), Commissionerate of Agriculture, Rajasthan, Jaipur.
6. Published maps from various sources (NATMO, GSI, etc.)

7. Google earth map
8. History of IGNP handbook

1.9 METHDOLOGY: Agriculture area & yield is show changes from present time period to previous time period. Use of secondary data of Agricultural crops in three district of Indira Gandhi Canal area during 1970 to 2008. This secondary data of agriculture crop for Ganganagar, Hanumangarh & Bikaner is divided into two main seasons: 1. Kharif 2. Rabi season. Than this two seasons categorized on the basis of crop grown in these area.

Land use & land cover changes at tahsil show by using secondary data sources. Land use records are maintained by land revenue department. The land use categories add up to reporting area, which is somewhat different from the geographical area. The survey of India is responsible for measuring geographical area of administrative units in India. There are mainly nine category under land use & land cover namely Forests, Land put to non agricultural uses, Barren & wasteland, Area under permanent pasture and grazing lands, Area under miscellaneous tree crops and groves (not included in net sown area), Culturable waste land, Current fallow, Fallow other than current fallow & Net sown area. Than changes in land use & land cover at tahsil level found from 1979 to 2006.

For the change in land use and land cover the main methodology is the change detection. Remote sensing technique has been widely used in the field of change detection. Change detection for GIS is a process that measures how the attributes of a particular area have changed between two or more time periods. Change detection often involves comparing aerial photographs or satellite imagery of the area taken at different times. They can broadly group into four categories: visual interpretation approaches, pixel-level change detection (PLCD), feature-level change detection (FLCD) and object-level change detection (OLCD) .The temporal change in the region is shown by the using of the satellite image in the year of 1977, 1989, 1999 2001 and 2008 2010. There is using the sensor of MSS, TM & ETM, which collected the different images, this is helpful for the classification purpose. These images cover the whole area of the Ganganagar district. Than the different image overlap by the procedure of the change detection method, with the using of the ARC-GIS & ERDAS. The flowing chart is showing the major step of the research.



Source: "Ahadnejad, Mohsen (2004)"

Fig 1.3 Flow chart showing the major steps of research

1.10 Literature Review:

For first objective i.e. to analyze changes in agricultural or cultivable areas of various crops in Kharif & Rabi season during time period of 1971 to 2008 in Indira Gandhi Canal my hypothesis pertains to look at whether the increasing pattern in agriculture area for major crops is same or not. Area variation in the agricultural area can be well observed in the canal area. Authors like Sharma argue that there has been greening of the Thar Desert. Sand dunes have become green, cattle rearing have been replaced by intensive farming, sound water harvesting practices have disappeared, and eucalyptus plantations have supplanted the native desert plants (Sharma, 2004). Changes in agricultural areas which made non-cultivable parts of Rajasthan cultivable had a direct correlation on the agricultural yield thus to find out impact of Indira Gandhi Canal on agricultural yield of major crops at district level and to look at the changes in cropping pattern in the Indira Gandhi Canal Area over this time period it can be said there has been variation in the agricultural yield.

According to Ram and Chauhan introduction of canal irrigation brought drastic changes in the cropping pattern from rainfed pearl millet and guar to irrigated cotton and wheat cropping system. (Ram and Chauhan, 2002). They support their statement with is temporal analysis in Kharif & Rabi in Hanumangarh district. Author discussed about change in cropping pattern during the canal period. There is temporal analysis in Kharif & Rabi in Hanumangarh district. Introduction of canal irrigation brought drastic changes in the cropping pattern from rainfed pearl millet and guar to irrigated cotton and wheat cropping system. During the last 41 years from 1956-57 to 1997-98 the acreage under Bajra, Jowar, maize, barley and Kharif pulses has declined by 58.18%, 96.11%, 90.77%, 58.57% and 24.77% respectively. . Use of multi-date IRS LISS-III data in conjunction with the topo maps and field surveys, significant changes in land use as influenced by canal irrigation, have been identified and mapped.

Other authors like Ansari and Rehman argue that Indira Gandhi Canal Project (IGCP) has transformed the desert waste land into agriculturally productive area as well as maintaining the eco system of the region. The IGCP is not only an irrigation project in the normal sense, it is anti desertification, a rehabilitation and desert reclamation project. The desert landscape has been physically and economically transformed into a productive region with the implementation of IGCP (Rehman and Ansari, 2002). The authors examine the cropping pattern for various crops and change in area in percentage as temporal analysis, and

conclude that there are changes in both Kharif and Rabi season for selected crops. The desert landscape has been physically and economically transformed into a productive region with the implementation of IGCP. The soil of study area is Aeolian in origin consisting of sandy plain, interdunal flat and dunes. . In this article yield level of selected Kharif and Rabi crop also show the impact of the IGCP in the study area. The changing scenario cropping pattern of the study area involves many factors like availability of Himalayan water at thirsty land of western Rajasthan. The IGCP brought drastic change in western Rajasthan. Farmers shifted from traditional dry farming to commercial and food crops. Another important factor which should be taken as primary consideration that is increase of population in study area which has created demand of food and commercial crops in order to improve the living condition of the local people. The decrease area under Bajra, Jowar and maize are only due to availability of irrigation in desert area which provide farmers to grow those crops which fulfil their food problems and gives maximum returns.

Kumar (1997) evaluates the impact of the construction of field channel on the cropping pattern, intensity, proportion of irrigated area, farm, income, farm input, output and labour in the command area of Hirakumd canal system. It has comparative analysis between the villages with or without irrigation. Verma (1995) examine the policy issue about water use in the command area of IGCP. The author advocates for the policy for acquiring high irrigation technology and intensive in order to maximise the profit and production per unit of water and land.

Impact of Indira Gandhi canal over time period on crop pattern discussed by scholar. Kaswan (2010) presented a paper on eco profile of crop production in IGNP command area. In this author describe about impact on crop due to the Indira Gandhi Canal. Farmers of the command have harvested good yields of crops for long time. After two decades of the introduction of canal irrigation, the problem of water logging and soil Salinisation started in the IGNP command. The twin problem not only adversely affected crop production in canal command but also created ecological problems. Water scarcity due to adoption of high water requiring crops was noted in the command. Attempt has been made to assess the problem of land and water management on the one hand and high production of quality crops on the other. The growth rates of area, production and productivity of major crops have been computed using exponential function to the data for the point of time and area under study. Khetawali distributory (KWD) of Indira Gandhi Canal Project (IGCP) command was selected as the study area.

For the second objective i.e. to find out changes in the land use & land cover over this time period at tahsil level and to examine of shift of area from one category to another category. Changes are evident in this as well. According to Imam earlier the cultivation of crops was regulated by rains, therefore, only summer (Kharif) crops were possible, but with the introduction project, winter (Rabi) started growing. Further Imam through surveys conducted in the areas argues that economic change is inherent to development of irrigation project has brought changes in occupation and employment, income generation, asset building, expenditure pattern, saving, etc. That has changed pre- project condition the society which was partially nomad or semi-nomad to agricultural settlers with introduction of irrigation with the project that has resulted in rapid growth and stabilisation of agriculture as a major occupation (Imam, 2006).

Scholars like Gahlot demonstrate the impact of the IGNP on livestock health management. He further adds that IGNP would provide half of the geographical area of the largest state of India with water for drinking, irrigation, installation of industries and for plantation of new trees in the command area and along the canals. 'This has transformed northern part of Arid Rajasthan into Green and Granary. Sand dunes have become green and wildlife makes there inhabit in this region. Availability of feed and fodder resources in the command area has tremendously increased leading to intensive animal husbandry and wild life activities. The ecological developments have also led to rise in wildlife fauna population'. (Gahlot, 2005).

Changes in land use & land cover also reflected by change in settlement pattern. Prior to introduction of Indira Gandhi canal there clustered pattern of settlement. After introduction of canal concentration of urban built up area increase. Chaudhary (1996) examine the settlement development in Indira Gandhi canal command area in Thar Desert. It was expected that the canal irrigation would put the economy of desert area on new footing by enabling intensive cultivation. A three tier system of human settlement was planned on the basis of size, function, distance, similar communities, economy, social life and defence strategy. The main study area is Pugal branch service area. The impact of IGNP has, therefore been assessed at three levels: 1. Area level 2. Community level and 3. Household level. Author described the low utilisation of irrigation potential; the land has been allotted to persons who do not any experience of irrigated cultivation. An analysis of impact at community level by compact organisation of society both economically and socially. Community participation in maintenance of assets created. The command area development authority with the objective

of increasing utilisation of irrigation potential has recognised the problem of low rates of settlement as the major impediment in realisation of objectives. Author recommended holistic integrated area development approach with due focus on other development aspects rather than emphasis on irrigation and farm distribution should be initiated. Land use policy calling for not only irrigated agriculture development but also comprehensive development of other resources, leading to diversification of activities needs to be introduced. Introduction of participative management structure having more people's voice is desirable.

Scholars like Srivastava and Rathor demonstrates the impact of world's longest irrigation project in Rajasthan on the environment and on the local inhabitants drawing attention to the accountability of the state to the people, the possible solutions to some of the problems like settlement, and how people may be mobilised for effective management of the canal.(Srivastava and Rathor ,1992).

Dandikar (1993) also examine the policy issue of irrigation development in arid zone with special reference to the command area of Rajasthan canal. The author argues that the policy of providing intensive irrigation may be economically mare profitable but it definitely leads to uneven distribution of resources in the space and society. It may also lead to the problems of soil salinity. He advocates for providing extensive irrigation & development of pasture to boost up the traditional livestock economy of the region.

Livelihood pattern of small farmer adjacent to Indira Gandhi canal area changed over time period. Scholar like Rathor (1991) evaluates irrigation project impact on small farmers. In the Punjab situation is an indicator, it will not be long before most of these small farmers who do not have enough capital of their own are expropriated. It has been noticed in the Punjab that there has been an increase in all categories of farm holdings except in small farmers. It has been observed that many allot-tees of the command area of Indira Gandhi Canal Project have already disposed of their land to rich farmers or well to do people of this area. Some have mortgaged their plots to the landlords, moneylenders or 'arhatiyas' because they have borrowed so heavily that it is almost impossible for them to repay the borrowed amount from the earnings of their small pieces of land while some others have become tenants on their own plots of land. The land legally belongs to them but they have mortgaged their land to the rich and now they have to pay a heavy packet to cultivate their own land.

For the third objective i.e. to analyse the impact of canal on surrounding land and to look at land degradation due to water logging and salinity in Indira Gandhi Canal Area, the

impact can be said to be of multi variation. .Authors like Sharma argues that thought the project promised to green the desert but has in course also waterlogged vast tracts of land and more stands in danger of being turned saline through this process. A number of factors viz. large percolation losses from the irrigation water applied to farmers' fields, seepage losses from channels, overuse of escape channels from the canal systems, relatively low levels of groundwater development, restriction to regional groundwater flow due to subsurface barriers and absence of natural drainage, are responsible for water logging, salinisation and disturbance of natural groundwater balance in the region (Sharma, 2001).

Scholars like Rao questions the pitfalls of the Indira Gandhi Canal viz a viz. the problem of water logging and salinity (Rao, 1992). The recent discovery of a layer of gypsum right under part of the canal could explain why the water is prevented from seeping into the canal bed. Obviously, the application of irrigation water in such area would lead to accumulation of water and ultimately of saline material. The prevailing winds may transport the loosened sand eastward to engulf the more fertile lands on the fringe of the desert, thereby contributing to further desertification.

Multi-purpose river valley projects'(MRVPs) like Indira Gandhi canal project demonstrates the glaring and complete dichotomy between pre-construction projections and post-construction realities. Water logging, salinity, sedimentation and health hazards have a high possibility of occurrence. Even flood control, irrigation and power generation are not effective as envisaged. The absence of post-construction reviews severely hampers assessments of MRVPs' actual performance vis-a-vis its claims. (D'Souza, Mukhopadhyay, Kothari, 1998).

Baijal, Singh (2000) main issue on the Large Dams: Can We Do without Them? Dams and particularly large dams are required to meet the increasing demand for water, food grains, and flood control, supply of power, particularly peaking power, and supply of carbon-free energy. However, there are apprehensions about the effects of hydel projects, especially large dams on ecology and society, and displacement of people. We need to balance current needs with long-term sustainable development. This article analyses the various options on the basis of data available. Proper drafting and implementation of rehabilitation and resettlement plan (R and R plan) can compensate for displacement of people and assuage their miseries; the effects of these dams on ecology require serious discussion. However

social problems caused by such projects would need to be addressed by implementing a generous, detailed and well monitored R and R plan.

Arora also examine the water logging problem in IGCP area specially command area (Arora, 2003). In this article author tell about the different water logging situation in command area. There use of FCC LISS 3 image use for find out the water logging problem. Pre and post monsoon images of IRS IC LISS III were used to generate waterlogged area and land use &land cover maps of the study area. Land use & land cover maps were also developed on the basis of unsupervised classification, which were then improved on the basis of ground truth. Various collateral data with respect to land use and waterlogged areas and other information were collected from various IGNP departments, research farms and farmers. Author show different land use & land cover with help of remote sensing & GIS technology.

Dhawan (1994) study on reclamation of degraded lands within canal commands. In this article the main emphasis on degradation problems in canal commands area. One may accept without much serious reservation the MOW group's three-fold, assessment that (1) the incidence of water logging, salinity and alkalinity is confined to 5.75 million hectares out of 29 million hectares of canal commanded area in India, (2) some of this degraded area is of pre-canal period, and (3) the whole of this affected area is not totally unproductive and that partially affected lands do yield some positive crop output.

Other scholars like Roy examine the impact of irrigation via the canal on socio, economic, environment condition (Roy, 1996). This study based on primary data collected from a sample of 820 household belongs to 68 villages of the command area of IGCP. The impact of irrigation mainly based on the comparison of the household with or without irrigation

An author like Gupta evaluates the irrigation induced environmental degradation (water logging & salinity) and has suggested certain measures for its amelioration (Gupta, 1997). These measures help in reducing further deterioration of the degraded land in IGCP area. Others like Bithu evaluate the introduction of the intensive irrigation in arid areas by the canal overlooking their fragile environment condition which has led to environmental deterioration (Bithu, 1999). Dhir (1983) points out that the soil characteristics and environmental condition in the lower part of the command area of stage 1 and proposed command area of stage 2 are different from that in the upper parts of stage 1. Hence these

areas require a different policy of irrigation development and technology than that adopted for command area of stage 1.

1.11 CHAPTERISATION SCHEME:

CHAPTER 1 Introduction to the study

A brief Introduction of the study with stating its relative importance and need based on a comprehensive literature review. Aims and Objectives of the study determined after reviewing the literature. Information about the source of data procurement is given under the head of Data base. A detailed presentation of the methods and applications used in the study, given under the sub-head of Methodology.

CHAPER 2 Temporal Analyses of Agricultural Area & Yield in Bikaner, Ganganagar & Hanumangarh Districts (1970-2008)

1. Shift in cropping pattern: There is show of change in different agricultural crop from time period 1970 to 2008. This is showing in the form of preconstruction cropping pattern & consequent stages of canal construction at district level.
2. To find out change in agriculture yield in time period at district level.

CHAPTER 3 Changes in Land Use & Land Cover in Time Period 1979 to 2006: A Tahsil Wise Analysis: In this analysis there is find out the change in land use categories at tahsil level & find out impact of canal in land use changes. This is mainly based on tahsil wise analysis of Bikaner, Ganganagar & Hanumangarh districts.

CHATER 4 Application of GIS & Remote Sensing in Land Use & Land Cover Detection in Study Area: In this chapter main aim is find out the change in land use & land cover using GIS & RS. There is also finding out impact of IGNP on the surrounding land on the basis of salinity & water logging.

CHAPTER 5 Summary and Conclusion: A concise summary of the study with concluding remarks, stating major findings of the study is incorporated in this chapter.

Chapter Two

Temporal Analysis of Agricultural Area & Yield in Bikaner, Ganganagar & Hanumangarh Districts (1970-2008)

2.1 Introduction

Agriculture pattern is an important phenomenon to find out the land use & land cover. It is employed in Indira Gandhi Canal Region for showing various crops during time period from 1970 to 2008. The main district in the region of Indira Gandhi Canal includes: Ganganagar, Hanumangarh, and Bikaner. Therefore, in order to evolve a sustained land use pattern for a projected area a multidisciplinary approach is required. The parameters related to characteristics of soil, drainage requirement; and food and fodder requirement of the inhabitants while projecting a cropping pattern and irrigation intensity is very relevant to the canal system, along with availability of water. The dependability of India's agriculture on the south-west monsoon & its consequent vulnerability has been recognised from the earliest times. Agriculture has always been the principal occupation of the vast majority of the people & successive rulers from time to time have been directing their energies to improve the lot of the farmer, to give him protection against the failure of rains. Efforts were made to bring the waters to the field irrigation. Early irrigation ventures were mostly concerned with storing rainwater in tanks & with leading canals from the tanks to farmer's field. Although irrigation from the wells in Indus valley started during Mohan-Jo-daro. Harappan period perhaps due to great of ground water, irrigation from well waters did not make much headway in the desert of Rajasthan. Only a few plots in the Sujangarh and Reni in Bikaner district were watered from Kachcha wells in 1897. No irrigation from wells existed in Jaisalmer state as well were too deep. Irrigation from rainwater by constructing kharins or khadeens existed in Jaisalmer district in the 18th century. Kharins are shallow depression into which the rainwater flows. They are basically used to harvest surface runoff from the surrounding area for raising crops during Rabi season. Where soil is harder and the surrounding hilly and rocky surface runoff is diverted to shallow depression.

2.2 Methodology:

Use of secondary data of Agricultural crops in three district of Indira Gandhi Canal area during 1970 to 2008. This secondary data of agriculture crop for Ganganagar, Hanumangarh & Bikaner is divided into two main seasons:

1. Kharif season
2. Rabi season

The cropping pattern in the virgin IGNP command areas will experience gradual shift. The soils in the command area are presently deficient in nutrients and have low water holding capacity. During the initial period of about five years, the cultivators may raise traditional crops. Gradually with the improvement in water holding capacity and fertility of soil, microclimatic condition and effort of agriculture extensive services, the cropping pattern will change. This has happened in all the irrigated commands, keeping with the changes in agro – economic conditions.

In study area there is various crops grown in both season of Kharif & Rabi. There is shown of crop area & crop yield in the both season in all district. In Kharif season there various crop is grown, these are categorized as:

1. Cereals Crops: Rice, Jowar, Bajra is main cereals crop; while in category of other cereals crop is Maize & Small millets.
2. Pulses Crops: Arhar, Moong, Urad, Moth & Kharif pulses is the main part of the pulses crop.
3. Oilseed Crops: Sesamum (Til) & Groundnut is the main oil seed crop, while Castor, Soyabeen is other oil seed crops.
4. Other Crops: In this category there is various crop grown in the Kharif season. Cotton & Gaur is using as the main other crop. There is another crop is Sugarcane, Chillies, Deshi cotton, Mesta, Sumheamp, Melvin cotton, Vegetables, Raj American & Punjab American cotton.

Rabi season also categorized into above four category, these are

1. Cereals Crops: Wheat, Barley is the main cereals crops.
2. Pulses Crops: Gram is the main pulse crop, while in the other pulses crop is Pea, Musur, Cowpea and Rabi pulses.

3. Oilseed Crop: Rape & Mustard is main oil seed crop. Other oil seed crop is Taramira, linseed and Sunflower.
4. Other Crop: In Rabi season there is various crop is grown. These are mainly Coriander, Cumin, Methi, Ajwain, Isabgol, Potato, Tobacco, Garlic, Sonf, Onion, Mehandi, Rabi Maize, Sweet Potato, Ginger, Turmeric, Fruits, Fodder crops, other species and other vegetables.

2.3 Agriculture Area: Agriculture area is an important part for determination of the impact of Indira Gandhi Canal in study area. Temporal analysis of agricultural area in between 1970 to 2008 of the study area is main feature of this research. This analysis is helpful for finding out the increase or decrease in agricultural area of the study area during time period.

2.3.1 Kharif Crop: In Kharif crop there are very low changes in agriculture area from 1970 to 1980. In Bikaner there is canal reach around seventies of twentieth century. But water allocation for agriculture started around 1980 decades (Dhir, 1983). Before canal irrigation traditionally crop grown on this area. The main agricultural crop of the area was Bajra & pulses. This cropping pattern continues till 1980, after canal introduction there are changes in agriculture crop combination (Ansari, 2000). In Ganganagar & Hanumangarh district canal irrigation impact was also seen in early years of eighties. There are also changes in crop combination in Hanumangarh district (Ram, 2002). Changes in agriculture area in all three districts mainly shown by crop wise. Before 1994 there Ganganagar & Hanumangarh was a single district. After 1994 there for agriculture area for both district added for various crop.

Rice: Rice is the seed of the monocot plants Oryza sativa or Oryza glaberrima. Rice cultivation is well-suited to countries and regions with low labour costs and high rainfall, as it is labour-intensive to cultivate and requires ample water. This is not suitable for desert area of western Rajasthan. After introduction of Indira Gandhi Canal there is also increase in area of rice. Temporal analysis 1970 to 2008 of Bikaner, Ganganagar & Hanumangarh show mainly help by the graph. In graph there is clearly indicates in Bikaner there is area under rice increase from 1980 to 1990, but this is very small increase area compare to Ganganagar & Hanumangarh. In Ganganagar & Hanumangarh there area under rice continuously increases

after 1980. After introduction of canal in this area show significant changes in area under rice from 13 hectare in 1970 to 43589 hectare in year 2000. This indicates area suitable for cultivation of water intensive crop like rice. While in Bikaner there sandy soil is not suitable for rice cultivation.

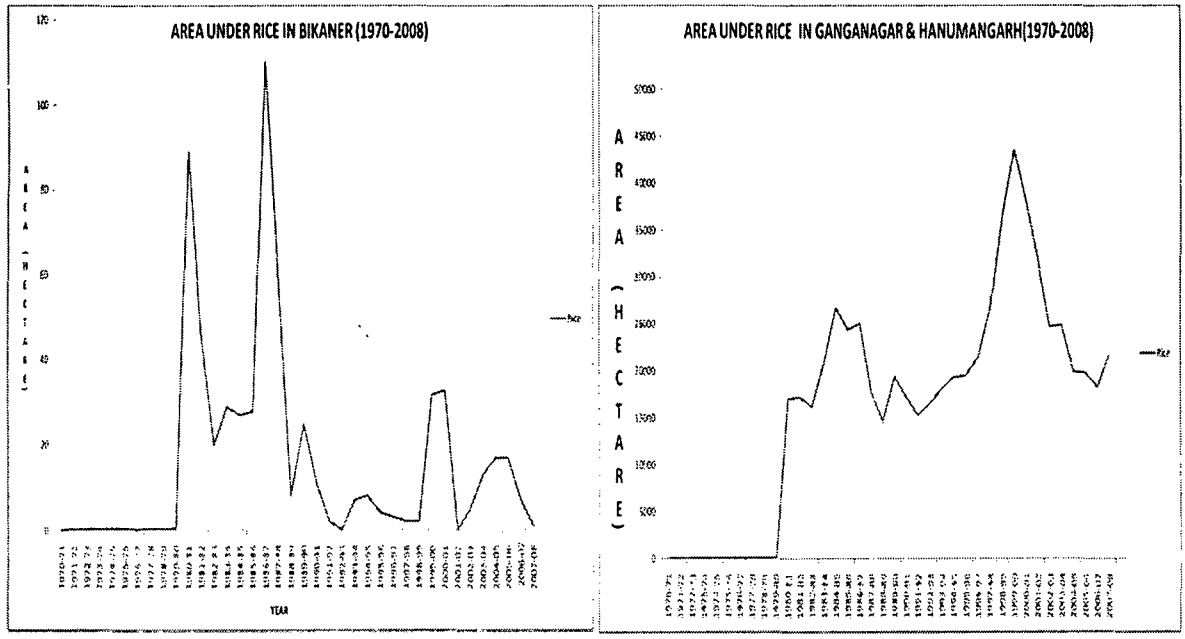


Figure: 2.1 Area under Rice in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Jowar: Jowar or Sorghum is a genus of numerous species of grasses, one of which is raised for grain and many of which are used as fodder plants either cultivated or as part of pasture. The plants are cultivated in warmer climates worldwide. In Bikaner there is increase in area only for few years; afterward there is decline of drought resistant crop. While in Ganganagar & Hanumangarh not show much any significant changes in area under this crop. Particularly this crop area reduced in both districts.

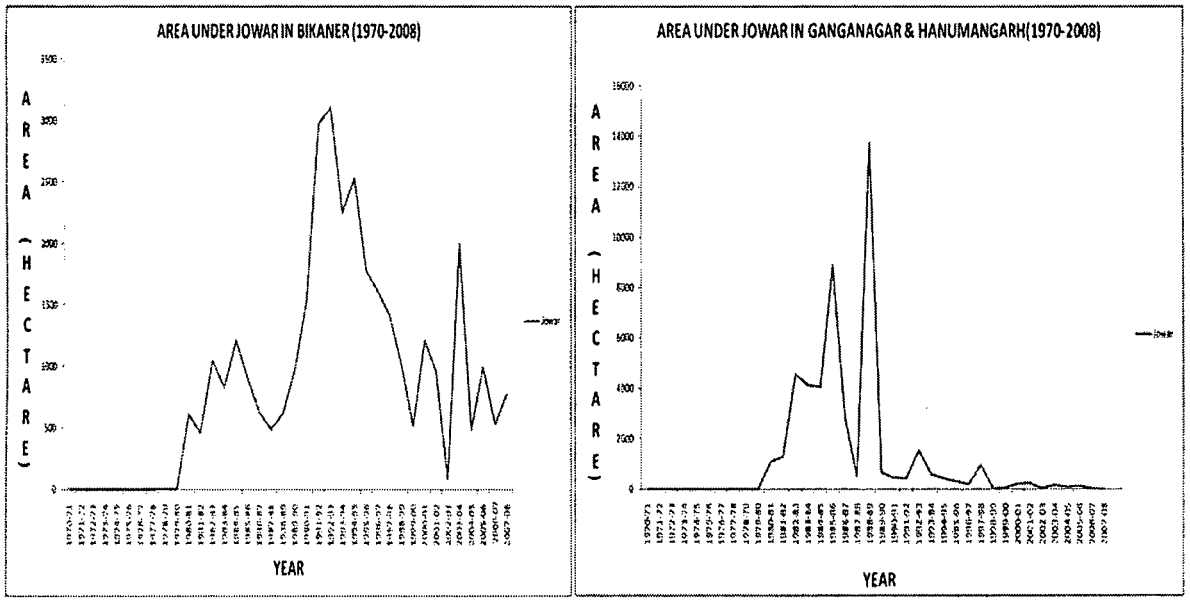


Figure: 2.2 Area under Jowar in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Bajra: Bajra or Pearl millet (Pennisetum glaucum) is the most widely grown type of millet. Pearl millet is well adapted to growing areas characterized by drought, low soil fertility, and high temperature. It performs well in soils with high salinity or low pH. Because of its tolerance to difficult growing conditions, it can be grown in areas where other cereal crops, such as maize or wheat, would not survive. Bajra is truly water deficient crop, where water availability of water is low. Bikaner is major producer of Bajra in Rajasthan. There is increase in area afterward, but in year 2002-03 there is sudden fall in area due to drought condition prevails in western Rajasthan. While in Ganganagar & Hanumangarh there is continues increase of area, but compare to Bikaner this is low.

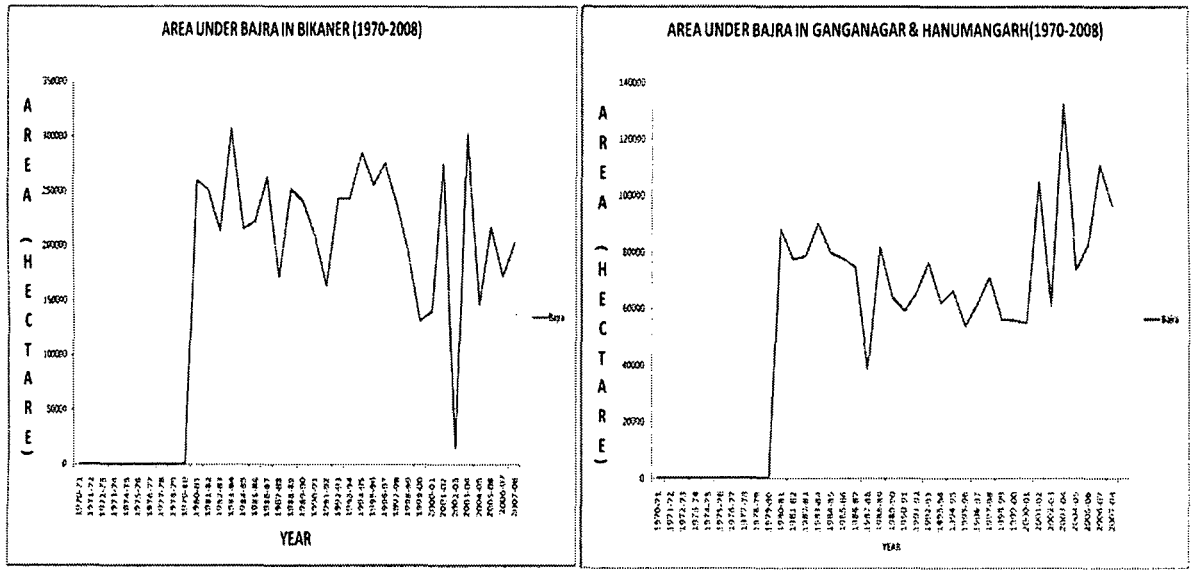


Figure: 2.3 Area under Bajra in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Other Cereals: In other cereals there is mainly include of maize & small millets. Bikaner, Ganganagar & Hanumangarh districts show decline in crop area under this category. Area under this category is very low.

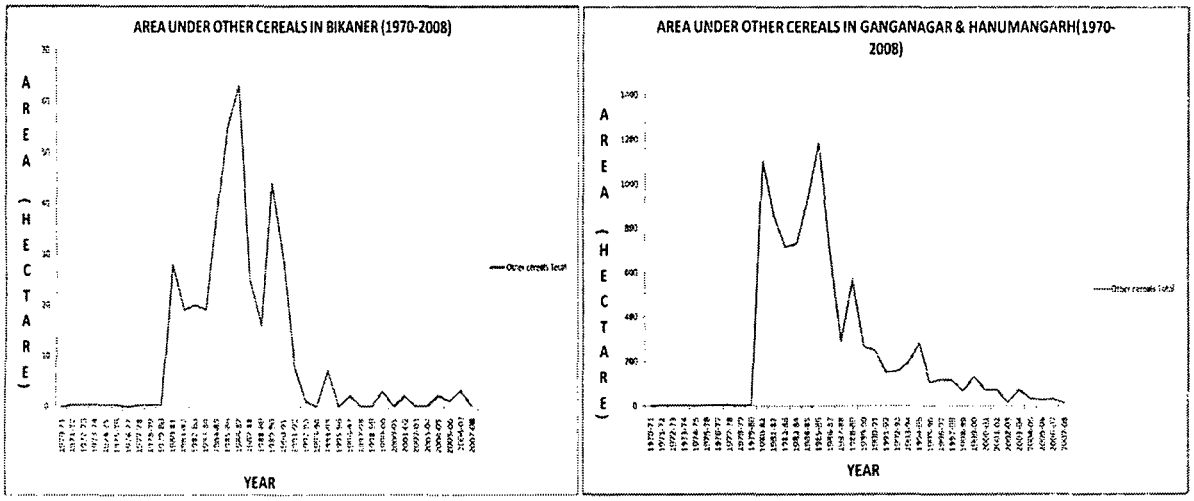


Figure: 2.4 Area under Other cereals in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Pulses: Arhar, Moong, Urad, Moth & Kharif pulses are main category under pulses. Bikaner show remarkable changes area under pulses. There is main crop of Bikaner & this increase trend continues till year 2000, but there is fall under this crop afterward. But proportion under

this crop is still high in Bikaner district. In Ganganagar & Hanumangarh there area continues increase, but area under this crop is low than Bikaner.

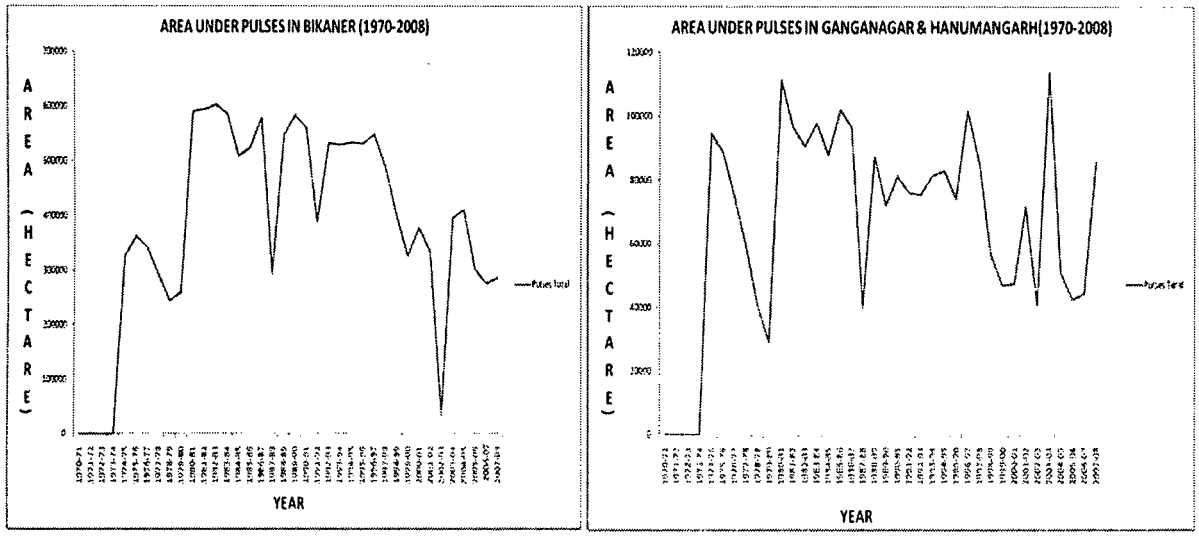


Figure: 2.5 Area under Pulses in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Sesamum (Til): Sesame (Sesamum indicum) is a flowering plant in the genus Sesamum. It is widely naturalized in tropical regions around the world and is cultivated for its edible seeds, which grow in pods. The flowers of the sesame seed plant are yellow, though they can vary in colour with some being blue or purple. Bikaner district show same trend in agriculture area for Sesamum as above crops. There is a very little increase & further reduction in area. While in Ganganagar & Hanumangarh is not much show good result for this crop.

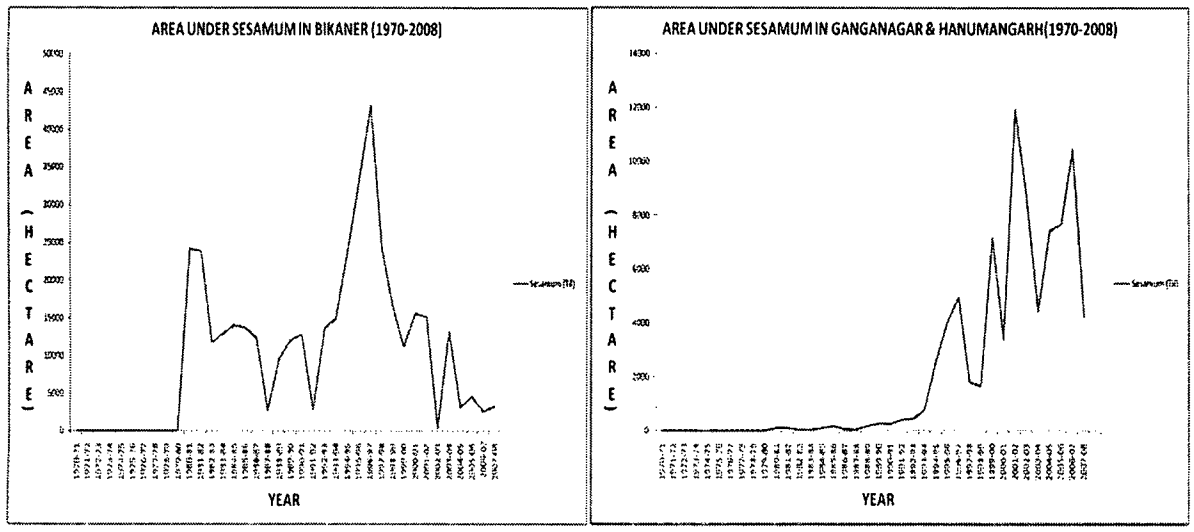


Figure: 2.6 Area under Sesamum in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Ground Nut: Ground Nut seeds that ripen underground, of the following plants, all in the Faboideae subfamily of the legumes. There is contradiction in both districts in area under Groundnut. There is continuous increase in area of oil seed in Bikaner district, while in Ganganagar & Hanumangarh there is reduced in area even below 5000 hectare after year 2000.

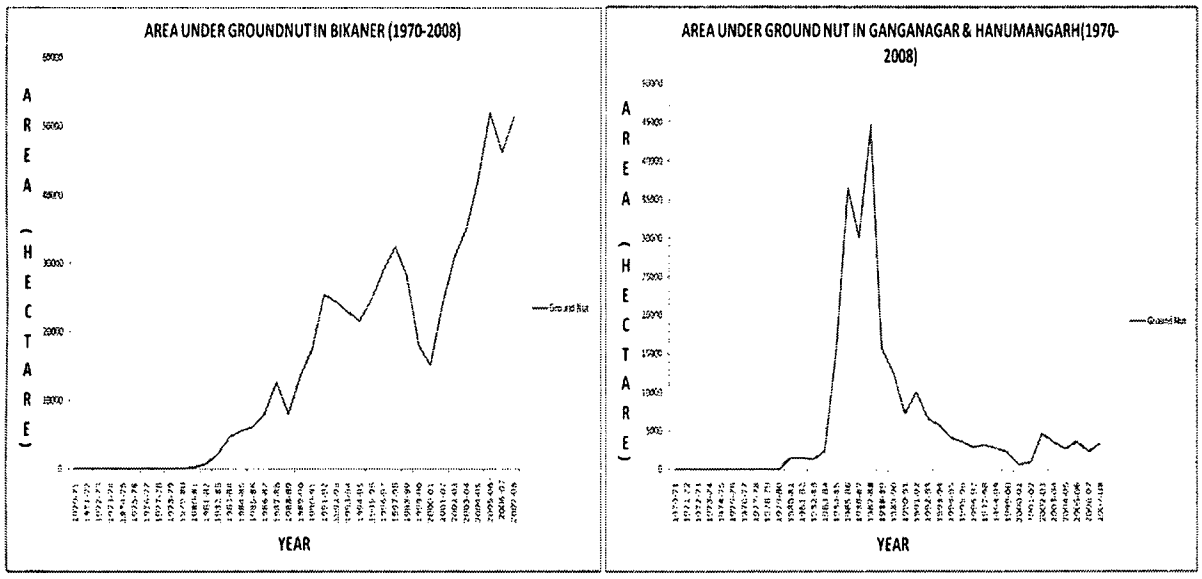


Figure: 2.7 Area under Groundnut in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Other Oil Seeds: Castor, Soyabeen is categorised as other oil seed. In Bikaner there is increase of other oil seed only after 2000, but this change in area is not much high compare to the other crops. This same trend is for another two districts.

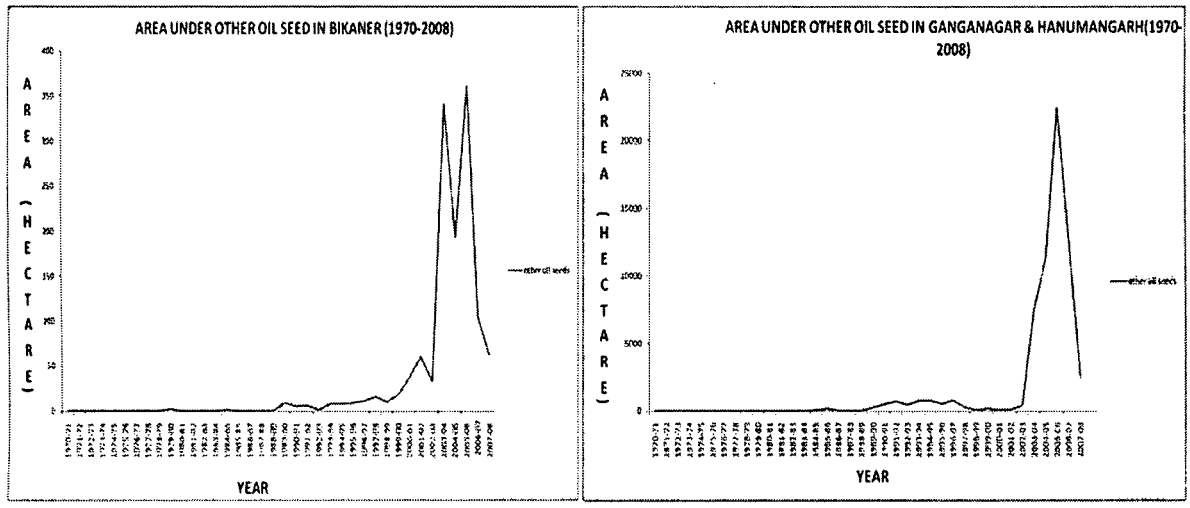


Figure: 2.8 Area under Other oil seed in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Cotton: Cotton is a soft, fluffy staple fibre that grows in a boll, or protective capsule, around the seeds of cotton plants of the genus Gossypium. Cotton is mainly grown where water is available. This clearly indicates area under this crop in Bikaner gain in area after 1989, which is show the allocation of water for agriculture crop. This trend continues till 2002-03, but afterward there is decrease in area under this crop significantly. Cotton is main crop for Ganganagar & Hanumangarh. There is increase in area under this crop afterward 1980. This is show the increase area of cotton growing area.

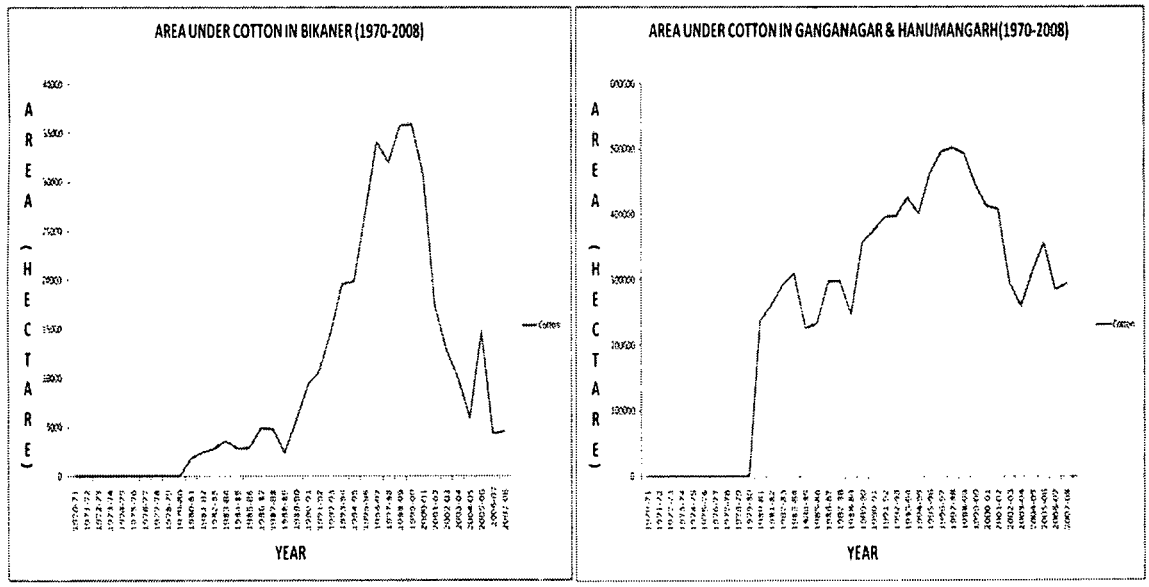


Figure: 2.9 Area under Cotton in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Guar: The guar bean or cluster bean (Cyamopsis tetragonolobus) is an annual legume and the source of guar gum. It grows best under conditions with frequent rainfall, but tolerates arid conditions well. In Bikaner is increase in area of this fodder crop after 2003. In another two districts show a good proportion under this crop. There is increase area under this crop afterward 1980.

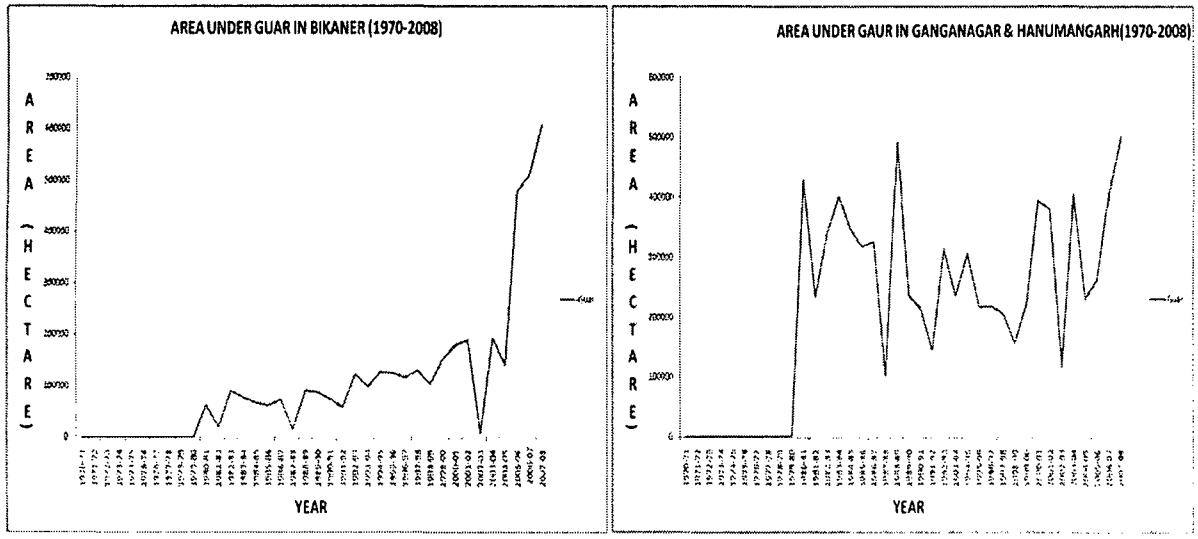


Figure: 2.10 Area under Guar in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Other Crops: Sugarcane, Chillies, Mesta, Sumheamp, Vegetables. Bikaner shows very little contribution in other crop area, while some area under this crop in Ganganagar & Hanumangarh.

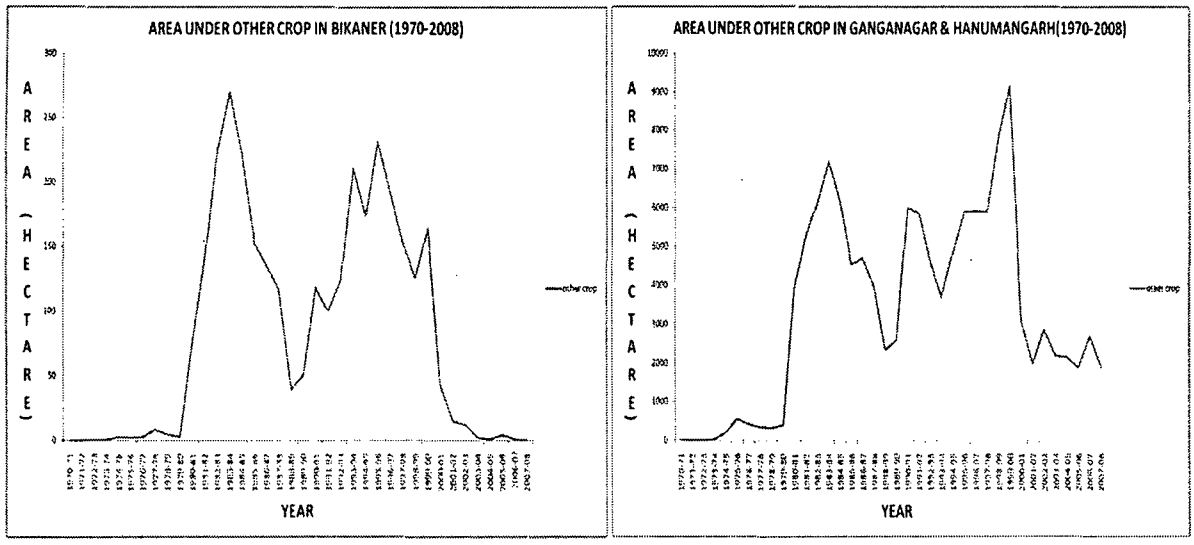


Figure: 2.11 Area under Other crop in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Gross Total Area: This show the overall picture of agriculture area under all crops. In Bikaner there is increase in gross total area after 1980. This is show increase not sharp compare to Ganganagar & Hanumangarh, where there is sharp increase after introduction of canal. Bikaner show stead increase in agricultural area, while other show remarkable changes in area under different crop. Indira Gandhi Canal irrigation benefits taken by mostly of northern districts of Rajasthan, namely Ganganagar & Hanumangarh. There is show some drought condition in al district, but there significant change in area in year 2002-03, where Bikaner show remarkable reduce in area in this year. But the other two district show less changes in area, mainly reach out canal in most out part of the area.

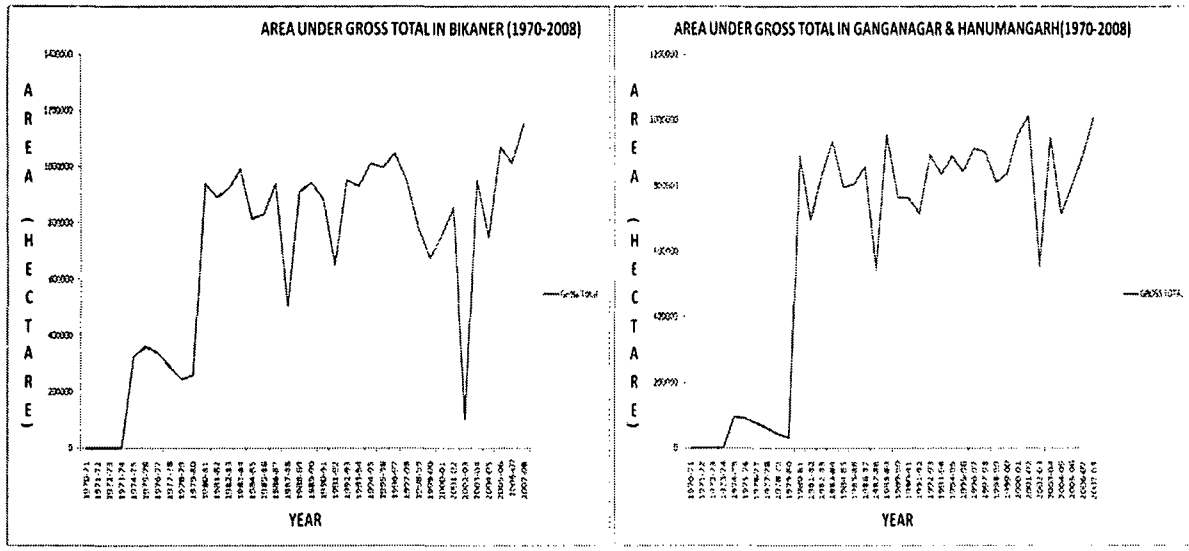


Figure: 2.12 Area under Gross total in Bikaner, Ganganagar & Hanumangarh (1970-2008)

2.3.2 Rabi Crop: In western part of Rajasthan cultivation of crops was regulated by rains, therefore, only summer (Kharif) crops were possible, but with the introduction project, winter (Rabi) started growing (Imam, 2006). Earlier introduction of canal there is limited area under crop; where traditional irrigation facility is available (Rosin, 1993). There are changes in area under various crops in all three districts.

Wheat: Wheat (Tritium spp.) is a grass, originally from the Fertile Crescent region. Wheat grain is a staple food used to make flour for leavened, flat and steamed breads, biscuits, cookies, cakes, breakfast cereal, pasta, noodles, and for fermentation to make beer, other alcoholic beverages or bio fuel. Ganganagar & Hanumangarh is main growing area of wheat. There is increase in the area afterward 1980. This is show this area added as grain house of

Rajasthan. While in Bikaner there is increase in area under this crop, but compare to other two districts is very low. But this area changes is also very high in condition of arid area of western Rajasthan.

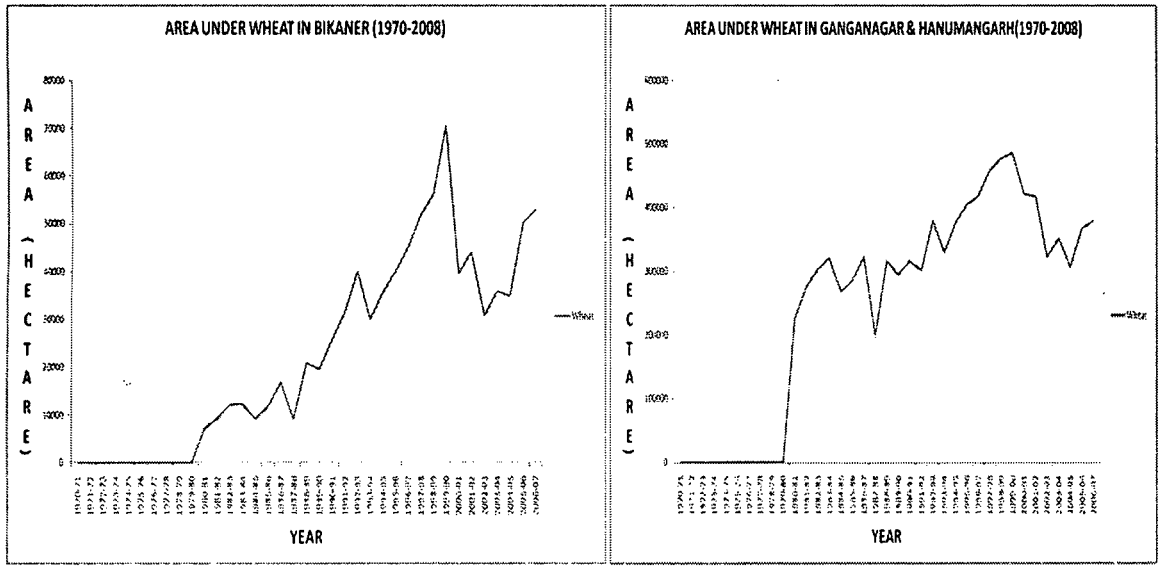


Figure: 2.13 Area under Wheat in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Barley: Barley is a cereal grain derived from the annual grass Hordeum vulgare. Barley has many uses. It serves as a major animal fodder, as base malt for beer and certain distilled beverages, and as a component of various health foods. Under barley there is increase in only in Ganganagar & Hanumangarh. In Bikaner there is very low proportion under this crop. This crop fluctuates in both districts, which show uncertain trend about this crop in this area.

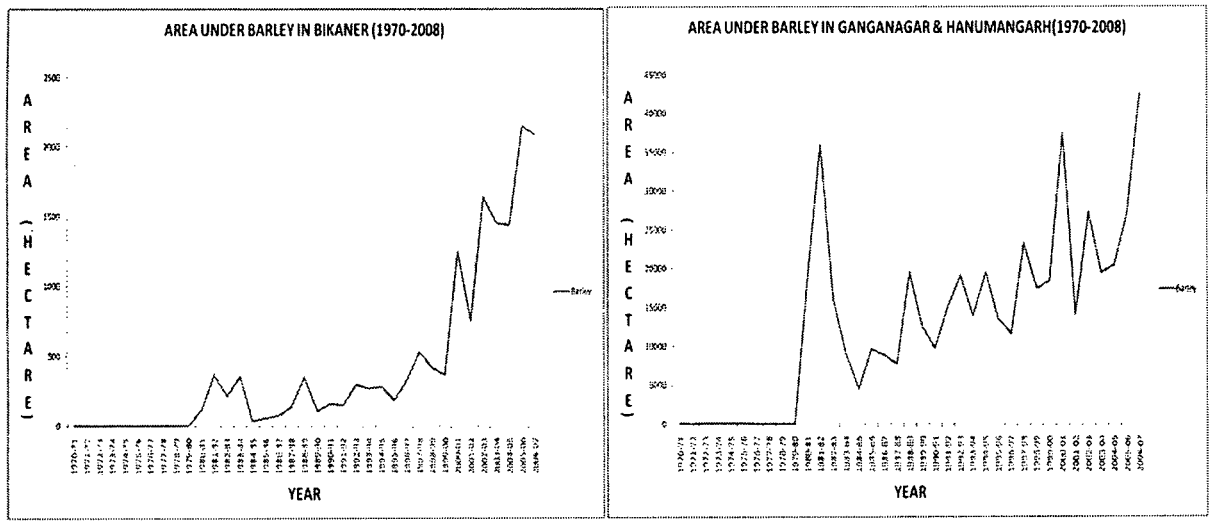


Figure: 2.14 Area under Barley in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Gram: Gram is the main crop of Ganganagar & Hanumangarh, where it is show sudden increase in area of under this crop after1980. There is increase area until 2000, than decrease in area considerably. While in Bikaner there is show good proportion of this crop in Rabi season. There is increase in area continuously under this crop.

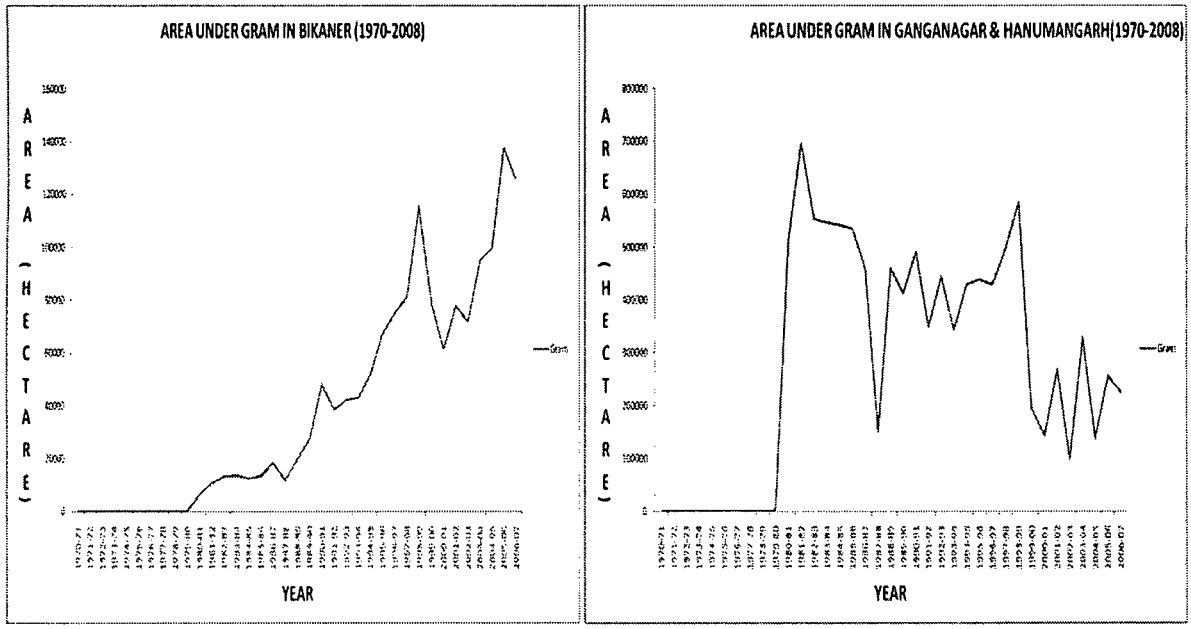


Figure: 2.15. Area under Gram in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Other Pulses Total: Linseed and Sunflower is categorised other leguminous crop. Bikaner shows a very little proportion under this crop. No remarkable sign for increase comes from Ganganagar & Hanumangarh district.

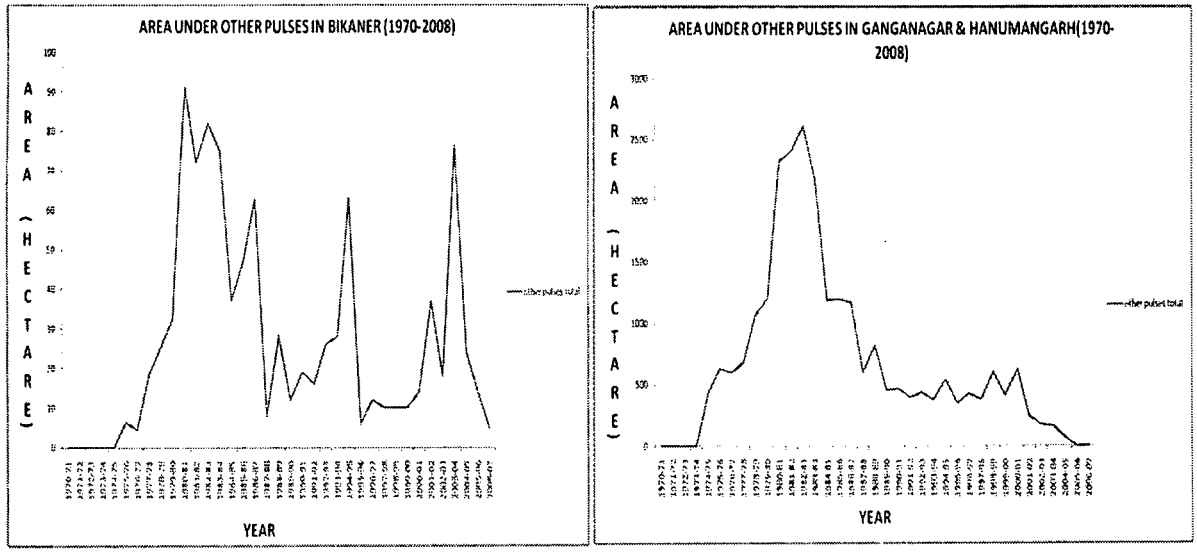


Figure: 2.16 Area under Other pluses in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Rape & Mustard: Mustard is a condiment made from the seeds of a mustard plant (white or yellow mustard, Sinapis hirta; brown or Indian mustard, Brassica juncea; or black mustard, Brassica nigra). Mustard is the main Rabi crop for Ganganagar & Hanumangarh, where is increase this crop afterward 1980. There is some reduction in area in 2001-02, where drought conditions prevailed. While Bikaner is also show a good proportion under this crop, but this is not high much as other two districts.

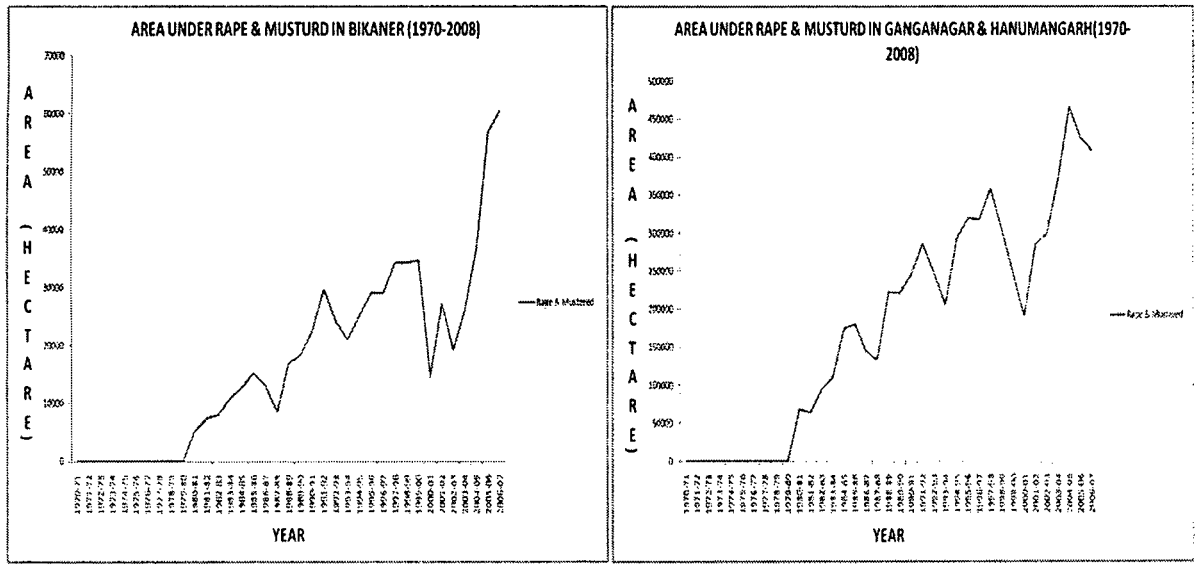


Figure: 2.17 Area under Rape & Mustard in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Taramira: Taramira is another oilseed crop in this area. But this is show increase in particulars year for different region. There is not good trend for this crop. There is sudden increase in Bikaner in year 1995 to 2000, while in other two districts show increase in area in after 2000.

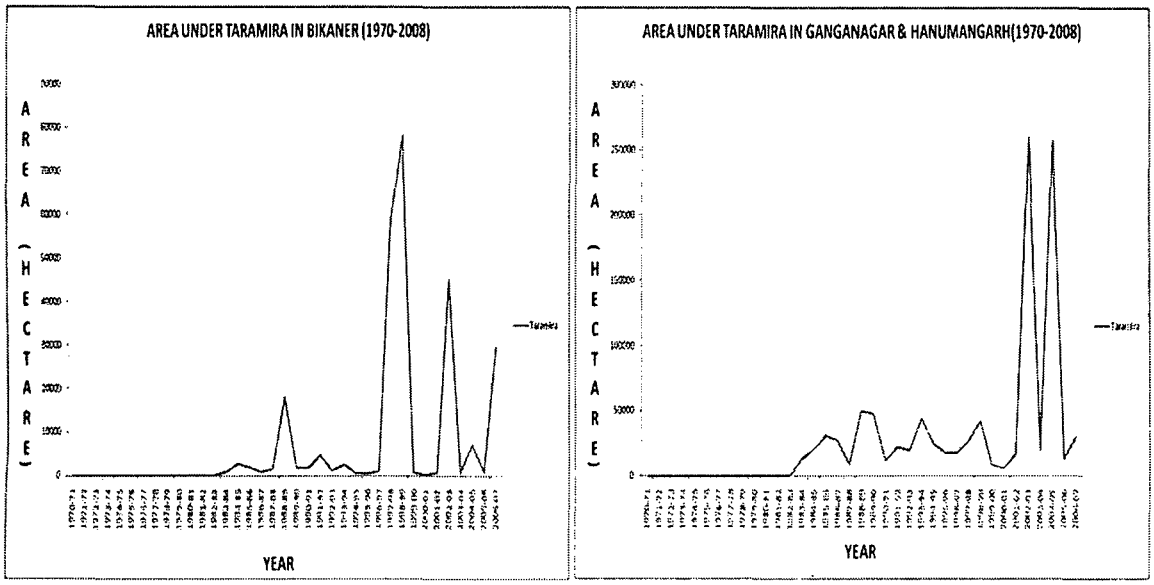


Figure: 2.18 Area under Taramira in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Other Oil-Seeds Total: This category consists of remaining oil seeds. In Bikaner very low proportion IS under this crop & Ganganagar & Hanumangarh also show the same trend.

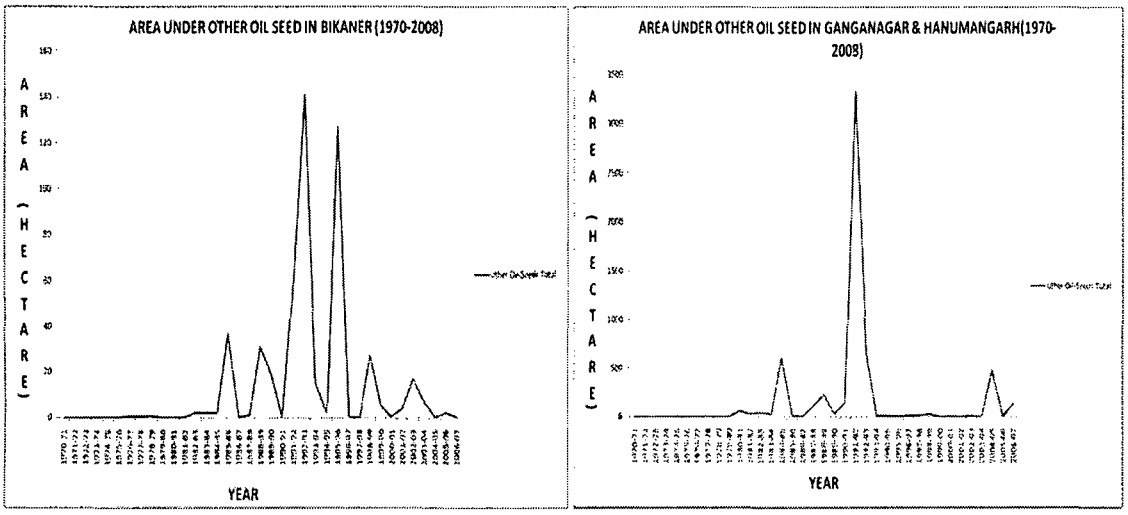


Figure: 2.19 Area under Other oil seed in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Others Crops Total: In Rabi season various crop are grown. These are mainly Coriander, Cumin, Methi, Ajwain, Isabgol, Potato, Tobacco, Garlic, Sonf, Onion, Mehandi, Rabi Maize, Sweet Potato, Ginger, Turmeric, Fruits, Fodder crops, other species and other vegetables. After 2000 there is increase in area under other crop in Bikaner, but this area is not so much compare to other crops. In Ganganagar & Hanumangarh also show same trend, but some increase starts back from year 1973, when canal irrigation takes place.

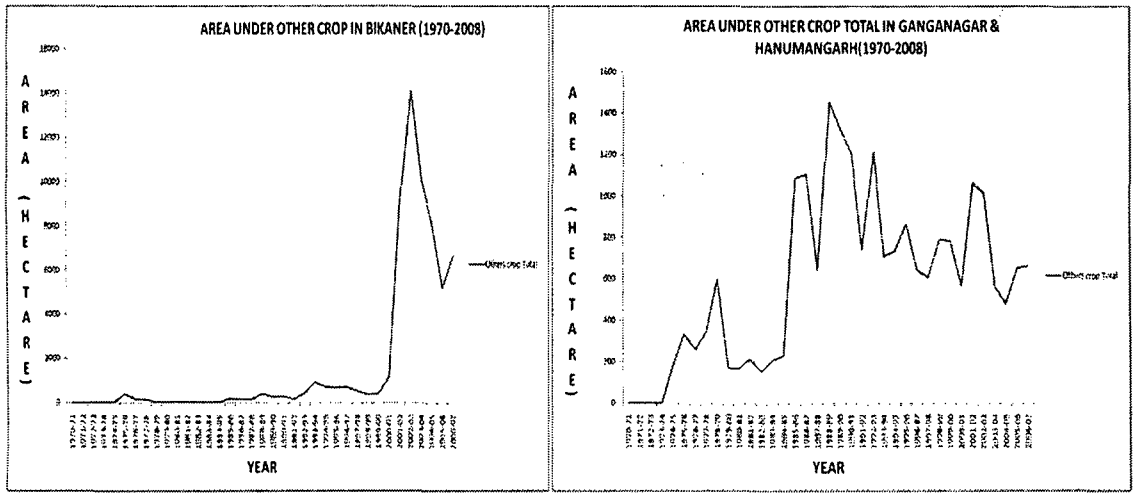


Figure: 2.20 Area under Other crop in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Gross Total: It clearly depicts the condition of crop in Rabi season. In Bikaner under Rabi season three is change in area stars from 1980, where increase area until 2000, than sudden fall in area, but there increase in area afterward 2003. In Ganganagar & Hanumangarh there is sudden increase in Rabi season area after 1980. This trend continues till, having some drought years in this area. This increase in area show remarkable changes in Rabi season in both districts.

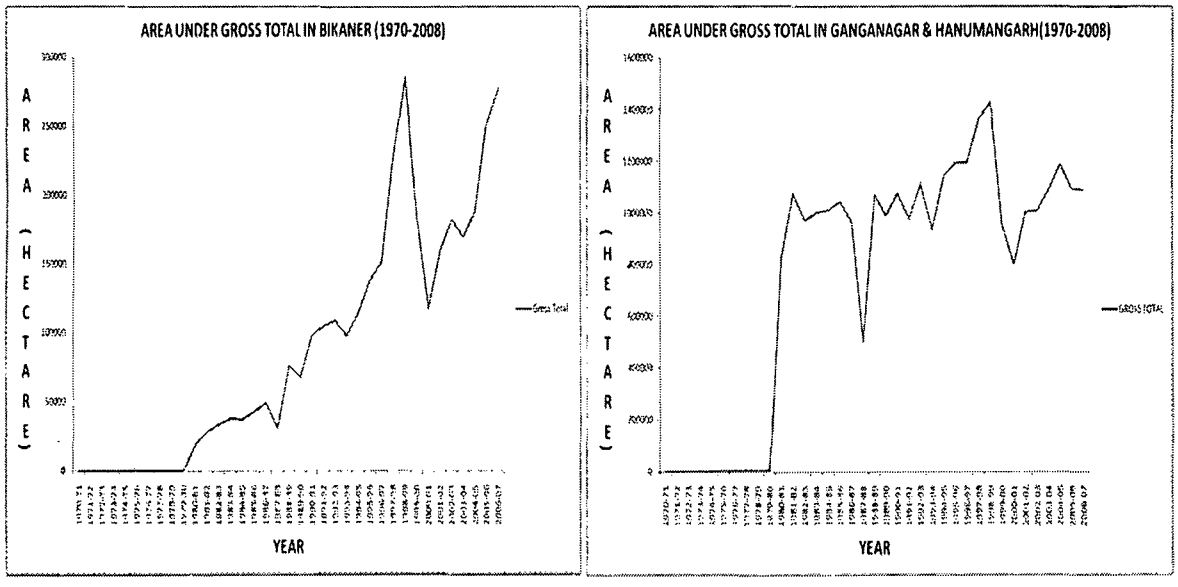


Figure: 2.21 Area under Gross total in Bikaner, Ganganagar & Hanumangarh (1970-2008)

2.4 Agriculture Yield: In agriculture, crop yield (also known as "agricultural output") is a measure of the yield of crop per unit area of land under cultivation. Agriculture yield measures mainly in kg per hectare in all three districts.

2.4.1 Kharif Crop:

Rice: Rice is the main crop of Ganganagar & Hanumangarh district. There is yield around 2000 kg / hectare. There is an uprising trend in yield in both two districts. In Bikaner there is very agriculture yield in earlier decades. But there is increase in yield after introduction of canal in this area.

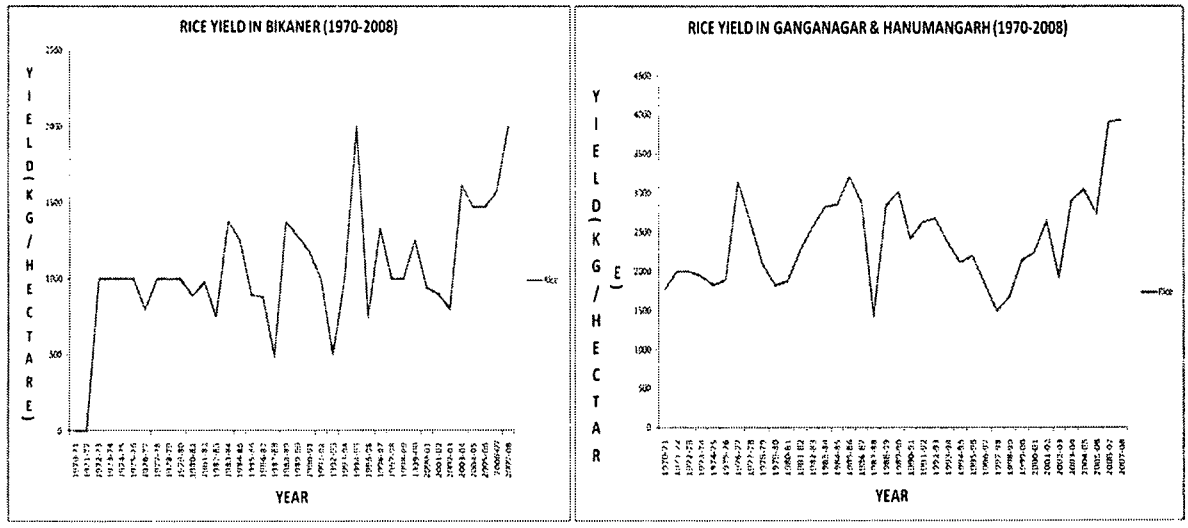


Figure: 2.22 Yield under Rice in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Jowar: Jowar shows a decline trend in yield in Bikaner district, where in Ganganagar & Hanumangarh show more or less same trend of agriculture yield.

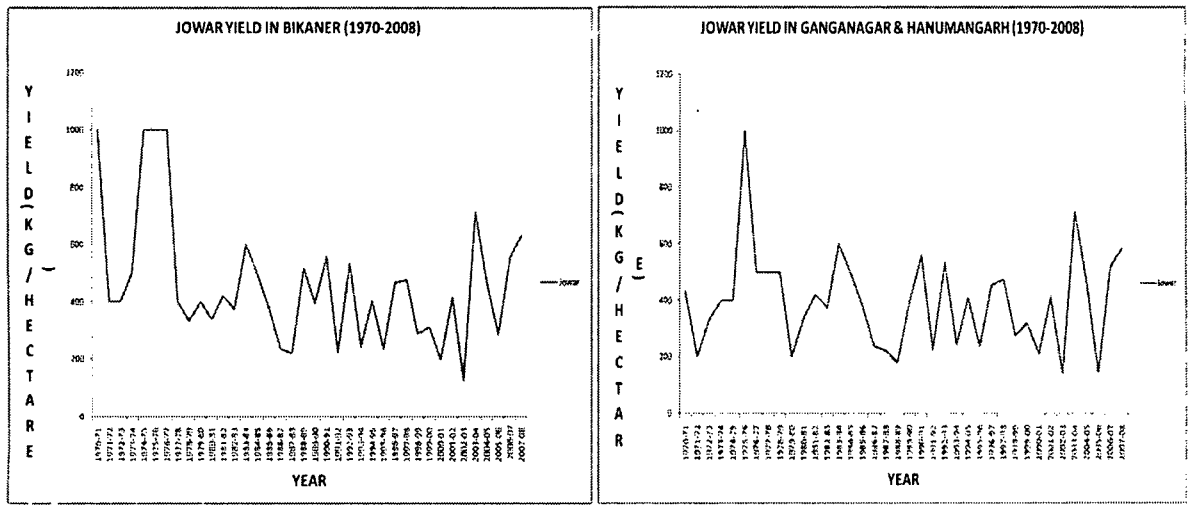


Figure: 2.23 Yield under Jowar in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Bajra: Bajra is the main crop in Bikaner district. There yield is very low in Bikaner up to 1990, then increase in yield. In Ganganagar & Hanumangarh after introduction of canal, there yield remain low, but in recent it signs in upward direction.

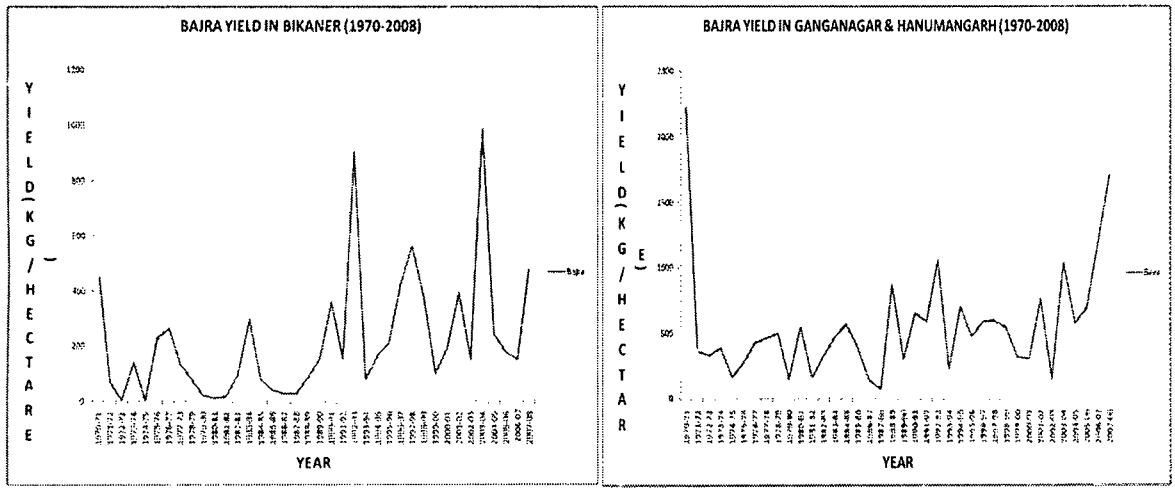


Figure: 2.24 Yield under Bajra in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Pulses Total: In Bikaner pulses yield is also very low expect for some years. While in another two district show an uprising trend in pulses & it reach from below 200 kg per hectare to 1000 kg per hectare.

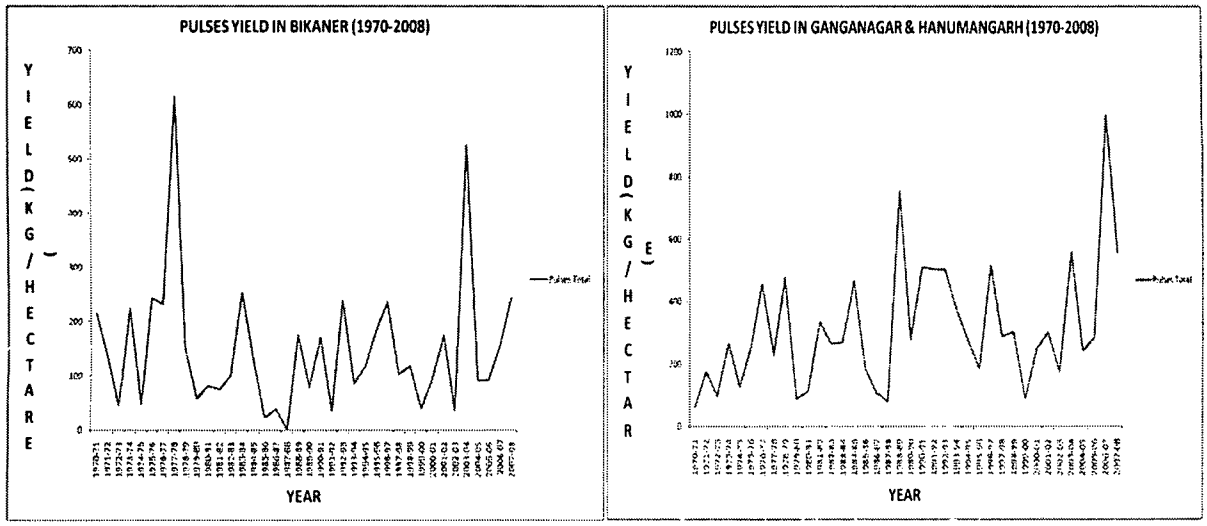


Figure: 2.25 Yield under Pulses in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Sesamum (Til): Sesamum show a reversal trend if compare in two districts. In Bikaner there in earlier low yield, afterward there is increase in yield. While in case of Ganganagar & Hanumangarh there is just opposite trend.

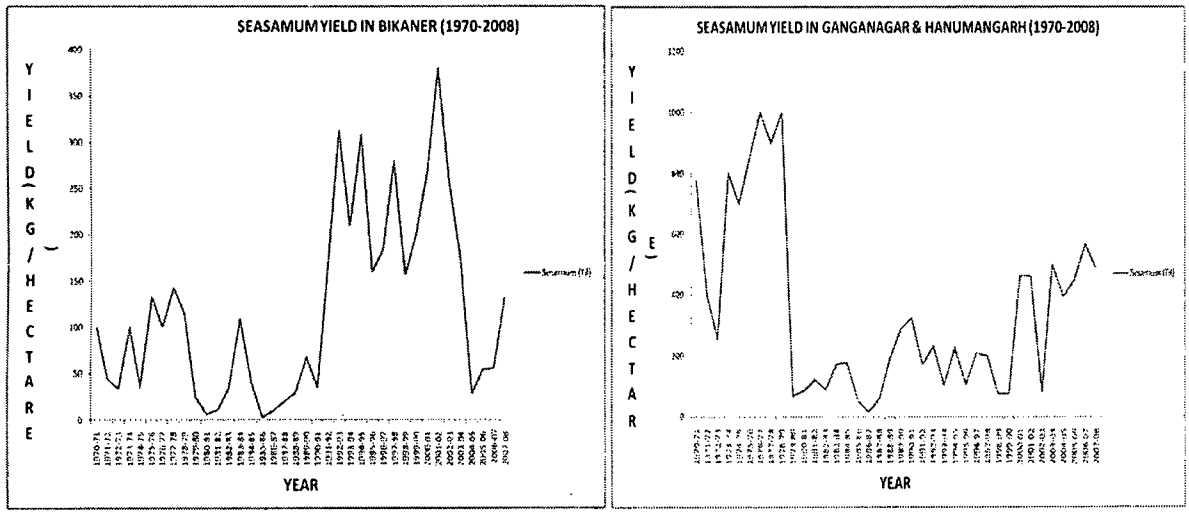


Figure: 2.26 Yield under Sesamum in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Ground Nut: In Bikaner there changes in yield show is very remarkable. There is increase in production per hectare is increase is very high compare to another crops. While same trend is shown by Ganganagar & Hanumangarh, but the is increase is low compare to Bikaner.

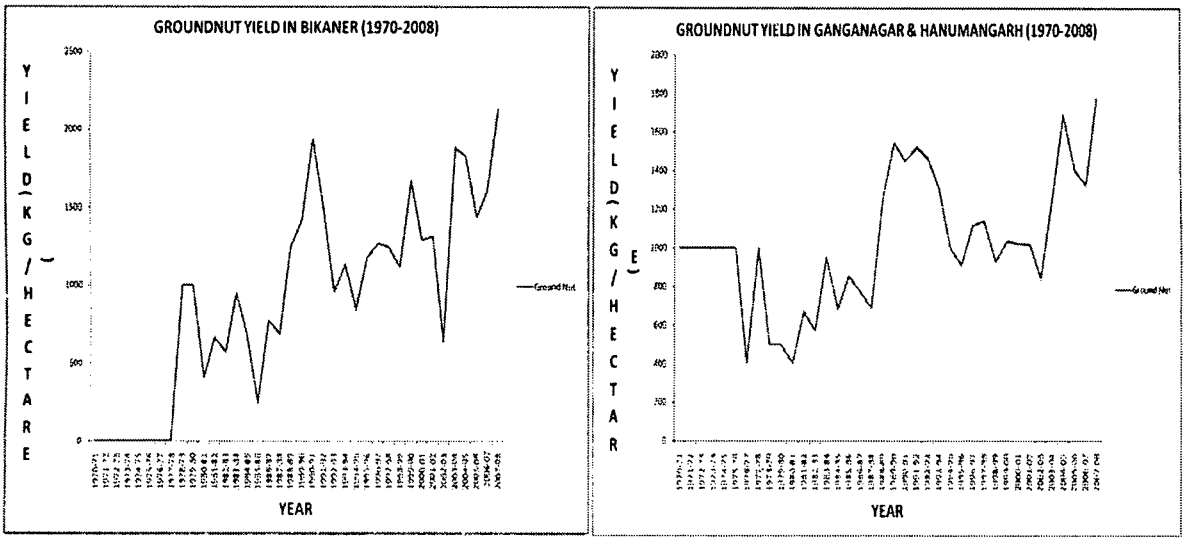


Figure: 2.27 Yield under Groundnut in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Cotton: Cotton is main crop for Ganganagar & Hanumangarh. There yield is more or less same for all year, but there is decline in the year 2002-03 due to drought condition. In Bikaner there is show very fluctuating trend in this crop due to uncertainty of rainfall. There is canal irrigation impact also in the above two district as compared to Bikaner.

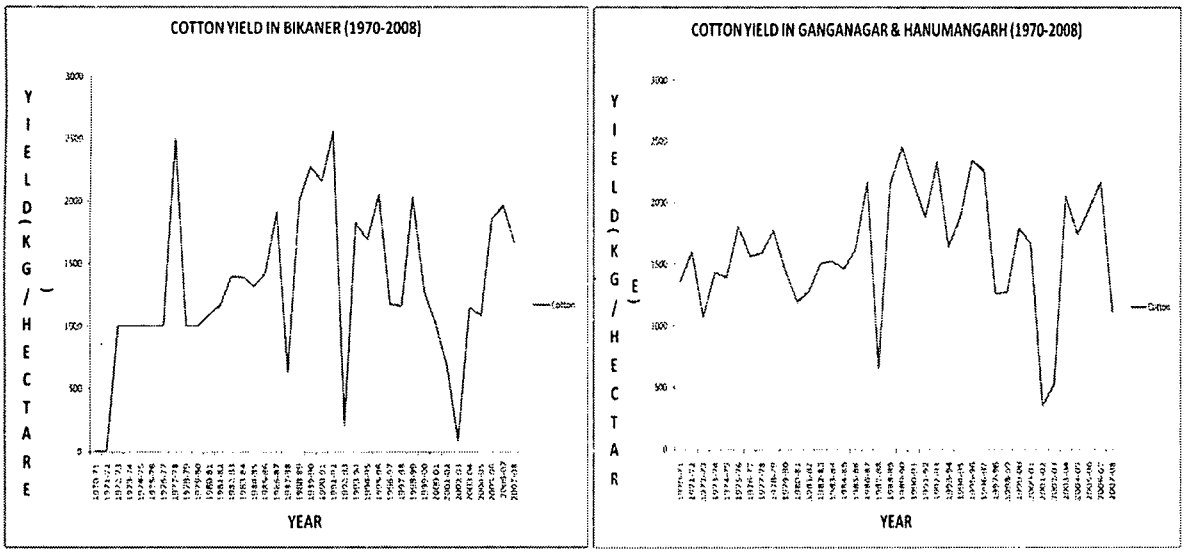


Figure: 2.28 Yield under Cotton in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Guar: Guar is mainly used as a fodder crop in these districts. But in all three districts not so much increase in production. There is more much fluctuation in production in these area.

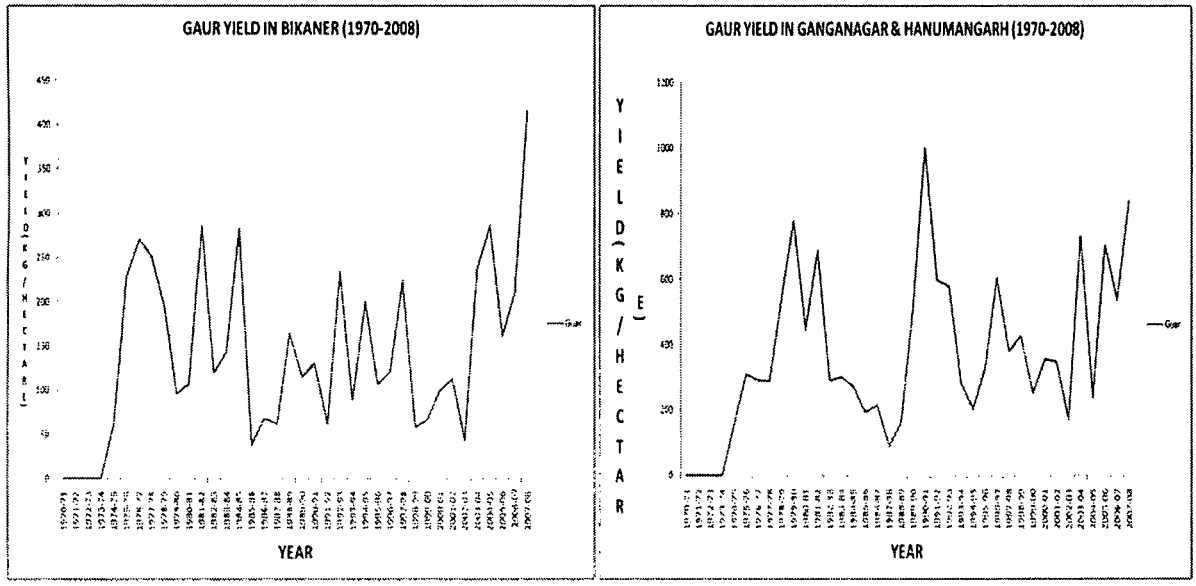


Figure: 2.29 Yield under Gaur in Bikaner, Ganganagar & Hanumangarh (1970-2008)

2.4.2 Rabi Crop:

Wheat: Wheat is an important Rabi crop in this area. In Bikaner there is increase in yield after introduction of canal then decrease in production. From year 1992 there is increase in yield in wheat in Bikaner. While in Ganganagar & Hanumangarh is main wheat producing area of Rajasthan. There is continuous increase in yield in wheat, which match yield to Punjab & Haryana. This is show significant change in wheat production in this area.

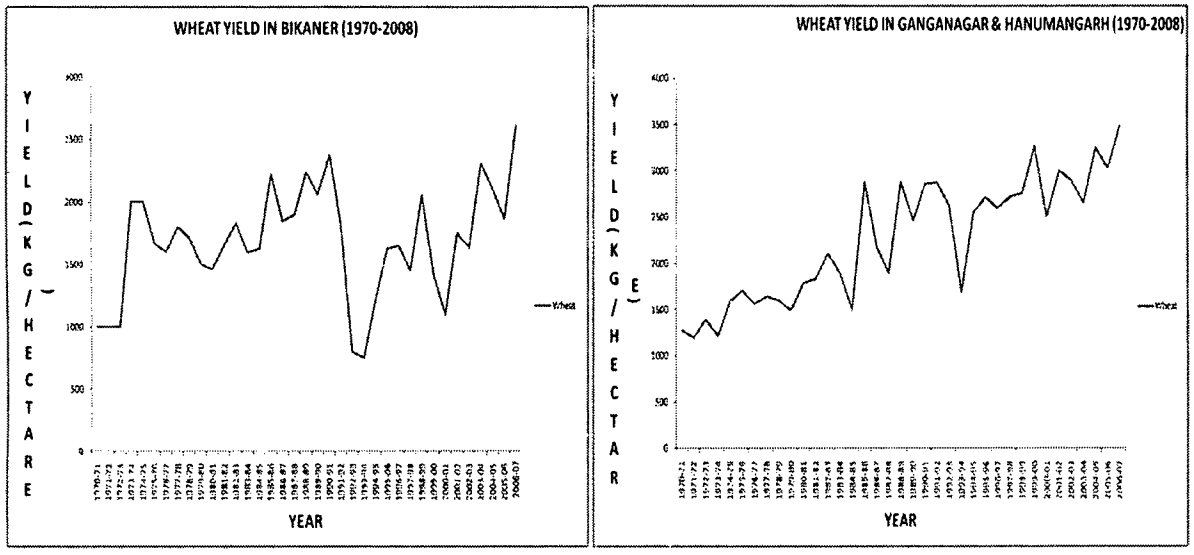


Figure: 2.30 Yield under Wheat in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Barley: Barley is another important crop of both regions. There is increase in yield after introduction of canal in all the three districts. In Ganganagar & Hanumangarh show a significant increase in production.

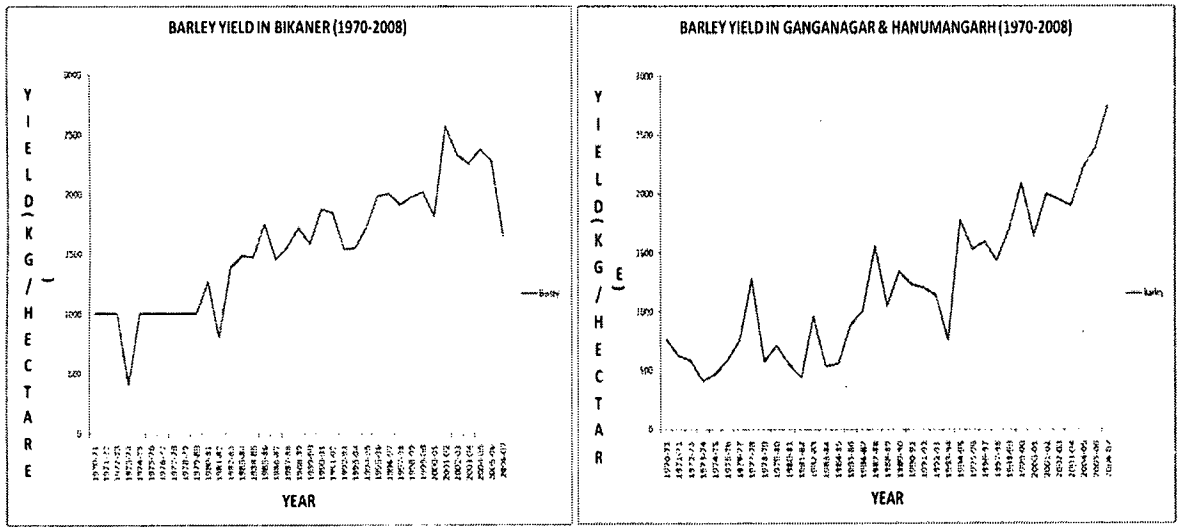


Figure: 2.31 Yield under Barley in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Gram: Gram is the only Rabi crop in all three districts which show a decline trend. There are last decades in Bikaner; Ganganagar & Hanumangarh show a significant fall in this crop production. While in recent years there is some increase in yield.

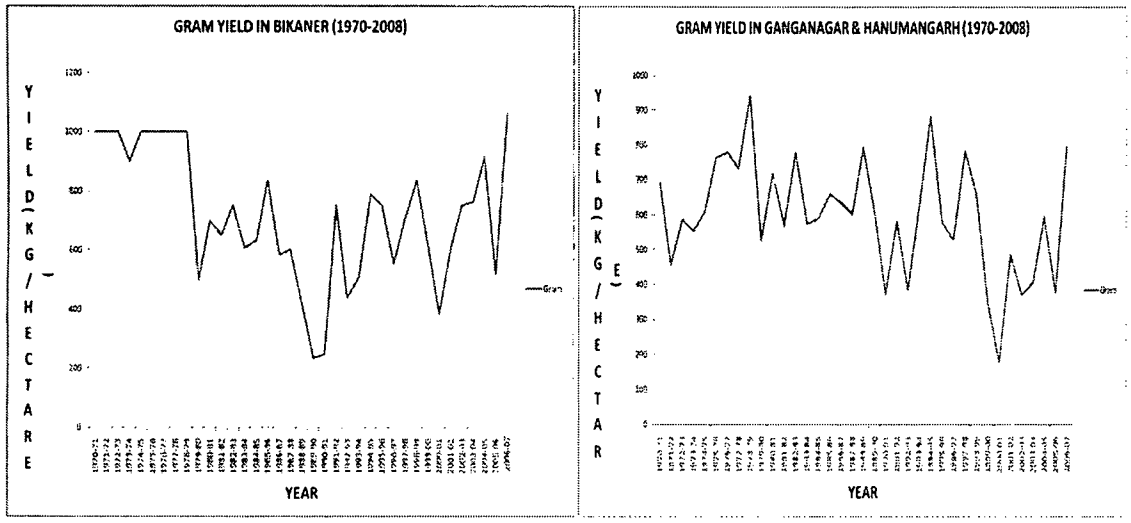


Figure: 2.32 Yield under Gram in Bikaner, Ganganagar & Hanumangarh (1970-2008)

Rape & Mustered: In Rape & Mustard there is increase in yield in all three districts. In Ganganagar & Hanumangarh there is increase in yield continuously; while in Bikaner there is decline in yield during late eighties. Then after upward trend in yield in Bikaner district except drought year of 2002-03.

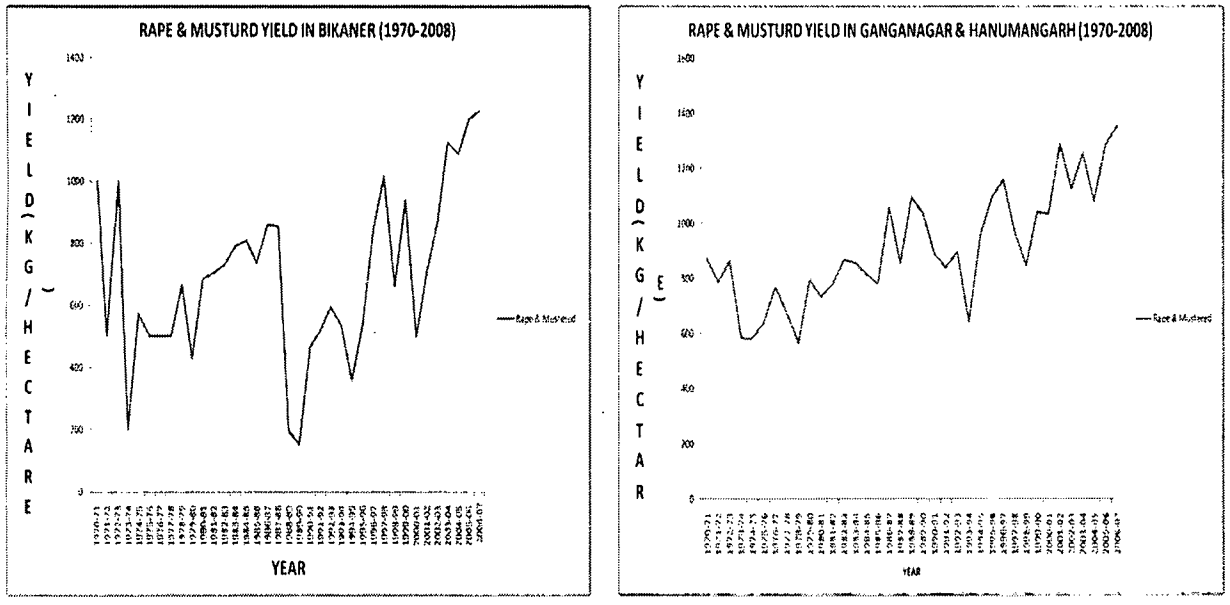


Figure: 2.33 Yield under Rape & mustard in Bikaner, Ganganagar & Hanumangarh (1970-2008)

2.5 Conclusion: From 1970 to 2008 there are agriculture area changes in all three districts. After introduction of Indira Gandhi canal Ganganagar & Hanumangarh show maximum changes in agriculture area. Rice show maximum changes in Ganganagar & Hanumangarh district. This is mainly due to introduction of canal in interior part of both districts through branches. Rice is mainly water intensive crop which require abundance water. In Bikaner there is very low area under rice, it is show sandy soil of Bikaner is not suitable for cultivation for this crop. Jowar show increase only during 1980 to 1990 in Ganganagar & Hanumangarh, than afterward it reduced. While Bikaner show considerable area under this crop. This increase in during mid time period, than it reduced. Bajra is main crop of Bikaner, which also show increase after introduction of canal, while Ganganagar & Hanumangarh show also increase in area, but compare to Bikaner it is low. Pulses are also main crop for Bikaner district, this show increase in Bikaner district. While Ganganagar & Hanumangarh also show increase area in pulses, but it is low than Bikaner district. Ground nut increase in Bikaner after 1990, but other two district show negative changes in area. Cotton is main Kharif crop in Ganganagar & Hanumangarh district, which show increase in area after 1980's, but Bikaner show decline in area afterward 2000.

In western part of Rajasthan cultivation of crops was regulated by rains, therefore, only summer (Kharif) crops were possible, but with the introduction project, winter (Rabi) started growing (Imam, 2006). Wheat is main Rabi crop in all three districts. Ganganagar & Hanumangarh show a prominent change in wheat producing area. Prior to introduction of canal there is very low area under this crop, but t increase over time period. While Bikaner show upward trend after 1995 in this crop. Barley is also main crop for two northern districts, this increase in time period, while Bikaner show very low increase compare to other two districts. Under gram there is increase after 1980 than it reduced in area in Ganganagar & Hanumangarh district. Bikaner has low area under this crop & increase is also very low compare to another two districts. Rape & mustard is main crop of Ganganagar & Hanumangarh district, which show upward trend during time period. While Bikaner show very little change in this area. This all show the impact of Indira Gandhi canal in Ganganagar & Hanumangarh. There water intensive crops increase in area during time period. There prior introduction of canal agriculture area is very low, after than it get boost in area in many major crops, than it reduced in area. This is show problems associated with canal are mainly water logging & salinity problems. Sam & hard pan problem is increased in this area. While in Bikaner canal reach in late eighties. Prior to Indira Gandhi canal there is Great Sandy Desert

in western part of Bikaner. After canal introduction in Bikaner there agriculture area increases over time period. Earlier there is very low growth in agriculture but after 1995 there sandy soil shows a tremendous change in area in various crops. Crops which requires low water there area increase over time period. This is show there utilisation of soil is requires better water management system. But in Bikaner there is also problem of hard pan associated with soil. Water associated problems like water logging; salinity may be arising in recent future. So a better technique is required for sustainable development of area.

Chapter Three

Changes in Land Use & Land Cover in Time Period 1979 to 2006: A Tahsil Wise Analysis

3.1 Introduction: Land use & land cover is mainly shows the geographical phenomena of the area. Land use and land cover is of dynamics nature and need proper monitoring for the sake of optimum utilization of land resources. Land cover and land use are often assumed to be identical, they are rather quite different. Land cover may be defined as the biophysical earth surface while land use is often shaped by human, socioeconomic and political influences on the land (Sharma, 2008). The land use & land cover pattern of a region is an outcome of the natural & socio-economic factor and their utilization by man in time & space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use & land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population.

Land is an important natural resource and provides substratum for many other resources as it embodies soil, water and associated flora and fauna involving the total ecosystem (Rao et al., 1991) .Among the resource, agriculture is the backbone of the economy of any agrian country like India. Agriculture contributes about 40 % towards the gross national product & provides livelihood to about 70 % population. Land use and land cover is of dynamics nature and need proper monitoring for the sake of optimum utilization of land resources. Land cover and land use are often assumed to be identical, they are rather quite different. Land cover may be defined as the biophysical earth surface while land use is often shaped by human, socioeconomic and political influences on the land.

Conversion of land to feed and shelter the growing human enterprise has been one of the primary modes for human modification of the global environment. Over the coming decades, expansion and intensification of agriculture, growth of urban areas, and extraction of natural resources will likely accelerate to satisfy demands of increasing numbers of people at higher standards of living. Human transformation of the Earth's land surface has multiple consequences for biophysical systems at all scales, ranging from local urban heat islands (Kalnay and Cai, 2003) and alterations in cropping patterns (Storck et al., 1998; Rose and

Peters, 2001)to altered patterns of global atmospheric circulation (Werth and Avissar, 2002) and long-term extinction of species (Pimm and Raven,2000).There is need to understand the consequences of land-use and land cover change processes, and integrating this understanding into the emerging focus on land-change science (Turner et al., 2003),are major needs for the future.

***3.2 LAND USE CATEGORIES*:** Land use records are maintained by land revenue department. The land use categories add up to reporting area, which is somewhat different from the geographical area. The survey of India is responsible for measuring geographical area of administrative units in India.

1. *Forests*: It is important to note that area under actual forest cover is different from area classified as forest. Forests can be classified in different ways and to different degrees of specificity. It may be reserved, protected, classified or many type as open, dense etc.
2. *Land put to non agricultural uses:* Land under settlements (rural and urban), infrastructure (roads, canal, etc.), industries, shops, etc. are included in this category. An expansion in the secondary and tertiary activities would lead to an increase in this category of land use.
3. *Barren & wasteland:* the land which may be classified as the wasteland such as barren hilly terrains, desert lands, ravines, etc. normally cannot bring cultivation with available technology.
4. *Area under permanent pasture and grazing lands:* Most of this type land is owned by the village panchayat or the government. Only a small proportion of this land is privately owned. The land owned by the village panchayat comes under Common Property Resources.
5. *Area under miscellaneous tree crops and groves (not included in net sown area):* The land under orchards and fruit trees is included in this category. Much of this land is privately owned.
6. *Culturable waste land:* Any land which is left fallow (uncultivated) for more than five years is included in this category. It can be brought under cultivation after improving it through reclamation practices.

7. *Current fallow:* This is the land which is left without cultivation for one or less than one agriculture year. Fallowing is a cultural practice adopted for giving the land rest. The land recoups the lost fertility through natural processes.
8. *Fallow other than current fallow:* This is also a cultivable land which is left uncultivated for more than a year but less than five years. If the land is left uncultivated for more than five years, it would be categorised as Culturable wasteland.
9. *Net sown area:* the physical extent of land on which crops are sown and harvested is known as net sown area.

3.3 CHANGES IN LAND USE & LAND COVER IN BIKANER DISTRICT: In Bikaner there change in land use & land cover changes in four stages. These are:

1. 1979-80 to 1981-82
2. 1985-86 to 1987-88
3. 1995-96 to 1997-98
4. 2003-04 to 2005-06

In year 1979-80 there is four tahsil in Bikaner district, these are Bikaner, Lunkaransar, Nokha & Kolayat. In year 1985-86 to 1987-88 there is also 4 tahsil in Bikaner district, but in the next time period there is increase no of tahsil. Pugal & Khajuwala is two new tahsil in Bikaner district. These two tahsil carved out from Bikaner & Lunkaransar tahsil. While next time period there is increase 2 tahsil namely Chattergarh & Sridungergarh. These Chattergarh tahsil carved out from Pugal & Khajuwala tahsil. While Sridungergarh tahsil carved out from two district namely Bikaner & Churu.

Then in period of 2003-04 to 2005-06 there is namely 8 tahsil in Bikaner district, but for comparison to previous time period there is clubbed together the tahsils. These 8 tahsil clubbed together into 4 tahsil for changes in land use & land cover. These changes mainly show the change in land use & land cover in Bikaner district over time period.

3.3.1 Change in land use land cover during 1979-82 to 1985-88: In Bikaner district there is changes in various tahsils show a distinct trend. Lunkaransar tahsil which is situated in northern direction show maximum change in forest area in percentage (around 256 %). Bikaner tahsil, which is situated in north east direction, showed also significant change in forest area. Compare to Lunkaransar tahsil the total area increase in Bikaner is more than Lunkaransar. This shows the impact of Indira Gandhi Canal in earlier phase. While in western tahsil Kolayat, where canal is not reached in the area show less change in area of forest cover. While in southern tahsil Nokha, there very low influence of IGNP shows negative change in forest cover. In second category there is land put to non agricultural uses. In this category there is mainly urban built up area, construction, road & other man made structure. During this time period there is maximum negative change in this category Kolayat tahsil, where it changes as much as 32%.There is scarcity of water in western part of the Bikaner. Lunkaransar & Bikaner also show negative changes during this time period, but compare to previous it is low. While Nokha tahsil show slightly increases in this area.

Barren & wasteland category consist the desert, hilly area & ravine area where cultivation is not possible. During this time period there is all tahsil except Nokha show increasing trend. This is show the increase in desert area over time period. Area under permanent pasture show increase in percent very high, but compare to absolute area it is very low. In Bikaner district there no area under miscellaneous tree, crops & groves. While in the category of Culturable wasteland which fallow more than five year shows a decrease in area. It is mainly due to increase of reclamation processes over time period. But current fallow, in which fallow land less than one year & other than current fallow land which have fallow land more than one year but less than five year show increase trend over time period. Only Lunkaransar & Nokha show a negative change in other than current fallow. Net sown area of Bikaner district shows positive changes over the time period. Highest positive change in area in Bikaner tahsil followed by Nokha & Kolayat. But western tahsil of Lunkaransar slightly negative changes over time period. In this area there is not reach of Indira Gandhi canal at that time period.

3.3.2 Change in land use land cover during 1985-88 to 1995-98: This is time period when Indira Gandhi canal reach in interior part of tahsil. In land use patter this is show distinctive change over time period. In first category of forest there is changes in forest area is very high.

There is positive changes occur in all tahsil, except Bikaner tahsil show negative changes over time period. Land put to non agricultural changes also show increase trend over time period. This is increase in maximum in Lunkaransar tahsil followed by Bikaner, Nokha & Kolayat tahsil. Barren & wasteland show a mixed trend over this time period. There Bikaner & Lunkaransar where main canal go, there show negative changes of this category, while in other two tahsil show positive changes over time period. Except Bikaner there all three tahsil show a negative changes in permanent pasture & grazing land.

Culturable wasteland, current fallow land & other than current fallow land over the time period show negative changes. This is show the impact of IGNP over the area. This is show shifting of wasteland & fallow land in agriculture area. This is clearly depicted by the increase in net sown area over the time period. Maximum changes occur in Bikaner tahsil, followed by Kolayat, Nokha & Lunkaransar. Than impact of Indira Gandhi canal clearly visible on desert land of Bikaner.

3.3.3 Change in land use land cover during 1995-98 to 2003-06: Indira Gandhi canal show clear cut impact on the desert land of Bikaner. In forest category there changes is positive. Mainly forest covers increase in area of canal. There in city area of Bikaner tahsil also show an increase over time period. Highest changes occur in the area of Nokha tahsil. In second category of land put for non agricultural show a slightly increase in all tahsil. Barren & wasteland also show increase trend in area over time period in Nokha & Lunkaransar tahsil. While in Bikaner & Kolayat tahsil show decline in this category. Permanent pasture & grazing land also show a mixed trend over this time period, but decline in overall is predominate.

Culturable wasteland in Nokha tahsil show increase in very high over this time period, while all three tahsil show decline in this category. Current fallow land increase in this time period in all three tahsil except Nokha. But in Nokha this is also very low changes over time period. Highest increase Kolayat tahsil followed by Lunkaransar & Bikaner. While in other than current fallow in Kolayat show increase over time period. Than net sown area in Kolayat tahsil show maximum decline over this time period. While Nokha & Lunkaransar tahsil show decline in area of other then current fallow land. In net sown are there slightly decrease in area in Lunkaransar tahsil. While increase in Bikaner (3.39%) & Nokha (.70%) show increase but compare to previous time period it is very low.

***3.4 CHANGES IN LAND USE & LAND COVER IN* GANGANAGAR & HANUMANGARH DISTRICT:** Prior to 1995 there is only one district Ganganagar. Than after Ganganagar bifurcated into 16 tahsils comprising into two district namely Ganganagar & Hanumangarh. For comparison purposes in land use there is only twelve tahsil in both districts considered. These tahsils are namely Anupgarh, Bhadra, Ganganagar, Hanumangarh, Karanpur, Nohar, Padampur, Raisinghnagar, Sadulsahar, Sangaria, Suratgarh & Tibbi. There 4 new tahsil carved out from existing tahsil. Gharsana & Pilibanga tahsil carved out from Anupgarh tahsil. Rawatsar tahsil separated from Nohar tahsil. Vijaynagar tahsil created from Suratgarh tahsil. Than all 4 new tahsil merged with old tahsils for comparison in land use & land cover changes.

3.4.1 Change in land use land cover during 1979-82 to 1985-88: In Ganganagar & Hanumangarh district there is increase in the forest area over time period. Highest changes in Bhadra tahsil followed by Nohar & Raisinghnagar. While other tahsil show increase in forest cover is very low compare to above three tahsil. Land put to non agricultural uses is show increase in all tahsil in Ganganagar & Hanumangarh district. Highest increase in Suratgarh which is 20.41% than followed by Anupgarh & Nohar. While in other tahsil there is not so much change occur during this period. In this time period there is impact of Indira Gandhi canal show a clear impact. There is decrease in barren & wasteland in mainly where Indira Gandhi canal flow. Maximum changes occur in the region of the Hanumangarh, Suratgarh, Anupgarh & Nohar. Permanent pasture in Ganganagar & Hanumangarh is also very low. It increases only in Suratgarh & Anupgarh tahsil, while other tahsil show no changes or negative changes in this category. Area under miscellaneous tree, crops & groves shows increase in many tahsil namely Raisinghnagar, Suratgarh & Sangaria have prominent changes. Negative changes in the Tibbi & Padampur tahsil, while other tahsil show average positive changes during time period.

Culturable wasteland show negative changes in the all tahsil, except three tahsil namely Ganganagar, Bhadra & Sangaria show positive changes. It means during this time period there is increase in the area of wasteland. There negative changes in all of the tahsil in between 30 to 50%. Karanpur & Anupgarh show increase in area of current fallow land, while remaining 10 tahsil show decrease in area. This is clearly showed for less than one year fallow land area decrease over time period. Other than current fallow land also shows negative changes in all tahsils, this is clearly show there is visible impact of the Indira Gandhi canal in this region. There increase in area of net sown area in all tahsil over the time period.

Highest changes occur in the Anupgarh tahsil (25.90%) followed by Suratgarh, Nohar, Raisinghnagar & Bhadra.

3.4.2 Change in land use land cover during 1985-88 to 1995-98: Forest area continuously increase over time period. In this time period there is increase in area in all tahsil. Maximum changes in occur in Suratgarh, Tibbi, Raisinghnagar & Bhadra. Ganganagar, Karanpur, Padampur, Sadulsahar & sangria show no changes in forest canopy. Land put use for non agricultural land area show increase over time period except Suratgarh, Padampur & Tibbi tahsil where maximum negative changes occur. Anupgarh & Nohar show increase in this category. Barren & wasteland show highest increase in Suratgarh followed by Nohar, while maximum reduction in area of Anupgarh. Remaining tahsil has no sign changes in his area. Area under permanent tree reduced over the time period mainly in tahsil of Raisinghnagar, Anupgarh & Nohar, while in category of miscellaneous there both reduction & increase in area over the time period. But in absolute term it is very low changes in area.

Culturable wasteland land shows reduction in many tahsil mainly in Anupgarh, Bhadra, Hanumangarh, Sangaria & Raisinghnagar. Increase in mainly area near canal region in this time period. Current fallow land shows reduction over the time period. There canal irrigated area comprising Bhadra Hanumangarh, Tibbi & Suratgarh area show increase in this category. This is increase in salinity adjacent to canal area. While other than current fallow land show increase in almost tahsil. It clearly shows than negative impact of Indira Gandhi canal over the region. Than net sown area during this time period have very less growth rate & in some tahsil it occurs negative. Only in Anupgarh tahsil there is marginally high increase in net sown area (23%). Than net sown area reduced over the time period in Ganganagar & Hanumangarh district.

3.4.3 Change in land use land cover during 1995-98 to 2003-06: In forest area there is increase in area maximum in Bhadra & Nohar, while other tahsil shows very less and no changes over the time period. Land use put for non agricultural purpose show increase in area over time period, but in Anupgarh &Tibbi there are negative changes. Barren & wasteland reduced in Anupgarh, Nohar & Suratgarh, while it is slightly increase in Tibbi tahsil. Remaining tahsils have no sign of increase or decrease over time period. Area under permanent pasture shows reduction in many tahsils, namely Anupgarh, Bhadra, Nohar & Suratgarh. While it increases only in Hanumangarh tahsil, it is around 20%. Area under miscellaneous tree, crops & groves shows a reduction pattern in all tahsils.

Culturable wasteland increase in area during this time period. In this time period there are maximum changes occur in the area near canal region. Reduction in area mainly in the Bhadra, Nohar & Anupgarh tahsil. Current fallow & other than current fallow land show increase in area over time period. There all tahsil show positive increase in area of these 2 categories. Nohar, Padampur, Raisinghnagar, Sadulsahar & Ganganagar show the maximum changes over the time period. Then in net sown area shows an adverse impact over the time period. There is all tahsil in Ganganagar & Hanumangarh district shows negative changes over the time period. That means decrease in absolute area in net sown area. Suratgarh & Karanpur tahsils shows maximum reduction in net sown area over this time period. Padampur, Raisinghnagar, Sadulsahar & Anupgarh tahsils also show a high reduction in net sown area. Tibbi show minimum reduction in area over the time period.

3.5 LAND USE & LAND COVER (TAHSIL WISE ANALYSIS):

3.5.1 ***BIKANER DISTRICT:*** Bikaner district have four district namely Bikaner, Lunkaransar, Nokha & Kolayat. There changes of land use & land cover over time period in Bikaner district. For changes in pattern compare 1979-82 to 2003-06. This is show changes occur during 25 years. Tahsil level analysis shows representation of the lad use & land cover pattern.

1. ***BIKANER TAHSIL:*** Bikaner tahsil located north east direction of Bikaner district. Bikaner tahsil have total area is 931251 hectare. For comparison there is following table show land use & land cover use two different time period 1979-82 & 2003-06.

Table 3.1 Land use & land cover category in Bikaner tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
BIKANER(1979-82)	27831	27211	7373	6880	0	569420	39004	45072	208461	931251
BIKANER(2003-06)	65998	46161	1456	17414	0	283122	69927	73544	371917	931251

In Bikaner tahsil forest tahsil increase over 25 years. Culturable wasteland area reduced over this time period. This is show clear cut impact of Indira Gandhi canal on Bikaner tahsil. Now wasteland area converted into net sown area by reclamation processes. It reduced from 61 % in 1979-82 to 30 % over time period of 25 years.

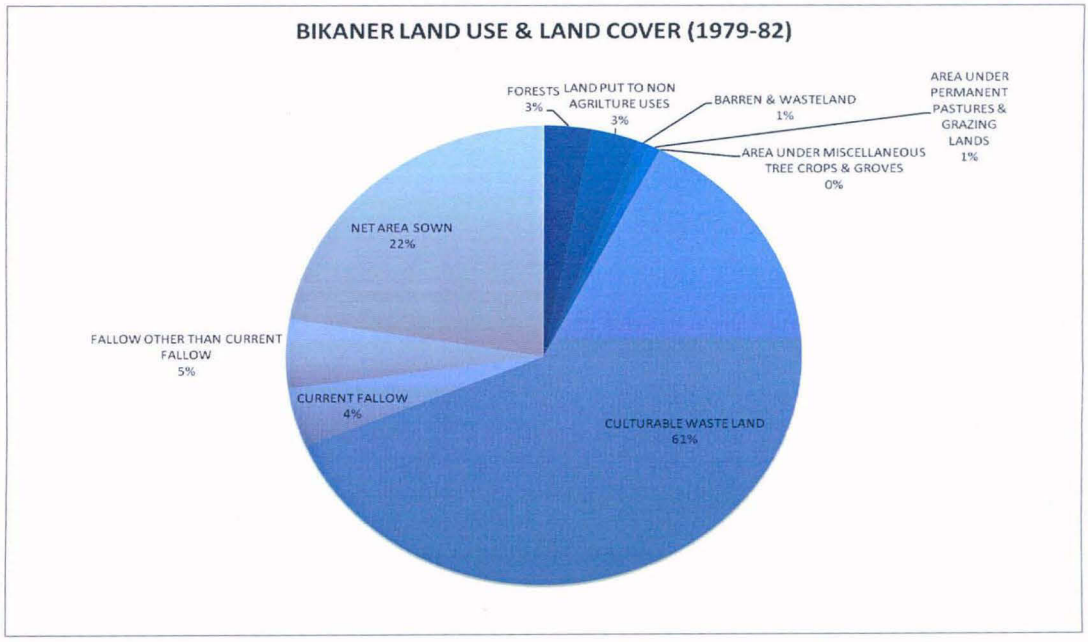


Figure 3.1 Bikaner land use & land cover (1979-82)

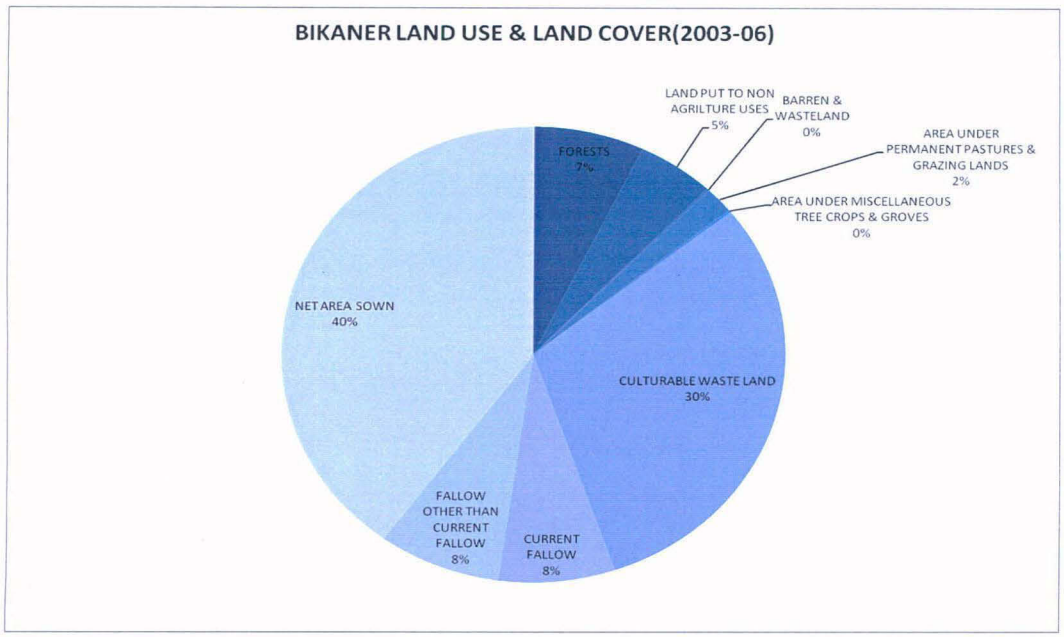


Figure 3.2 Bikaner land use & land cover (2003-06)

Net sown area increase by 22 % to 40 % during this time period. Current fallow land & other than current fallow land also increase over this time period. This show manly some area left out due to water logging & salinity problem.

2. ***LUNKARANSAR TAHSIL:*** Lunkaransar tahsil situated northern direction of Bikaner district. In Lunkaransar tahsil forest area increase over time period is very high. Lunkaransar tahsil mainly sandy desert area. This remarkable change mainly due to Indira Gandhi canal comes in this region.

Table 3.2 Land use & land cover category in Lunkaransar tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
LUNKARANSAR(1979-82)	25	24593	1736	22595	0	276400	30752	43688	238040	637829
LUNKARANSAR(2003-06)	26497	154866	262	8929	0	94763	41876	40435	270201	637829

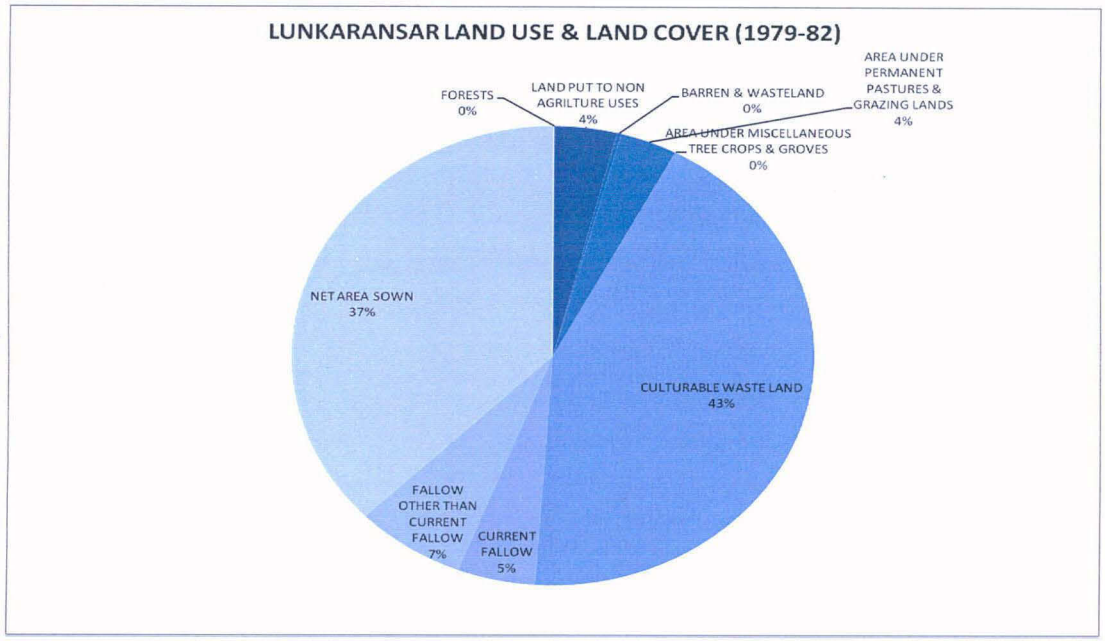


Figure 3.3 Lunkaransar land use & land cover (1979-82)

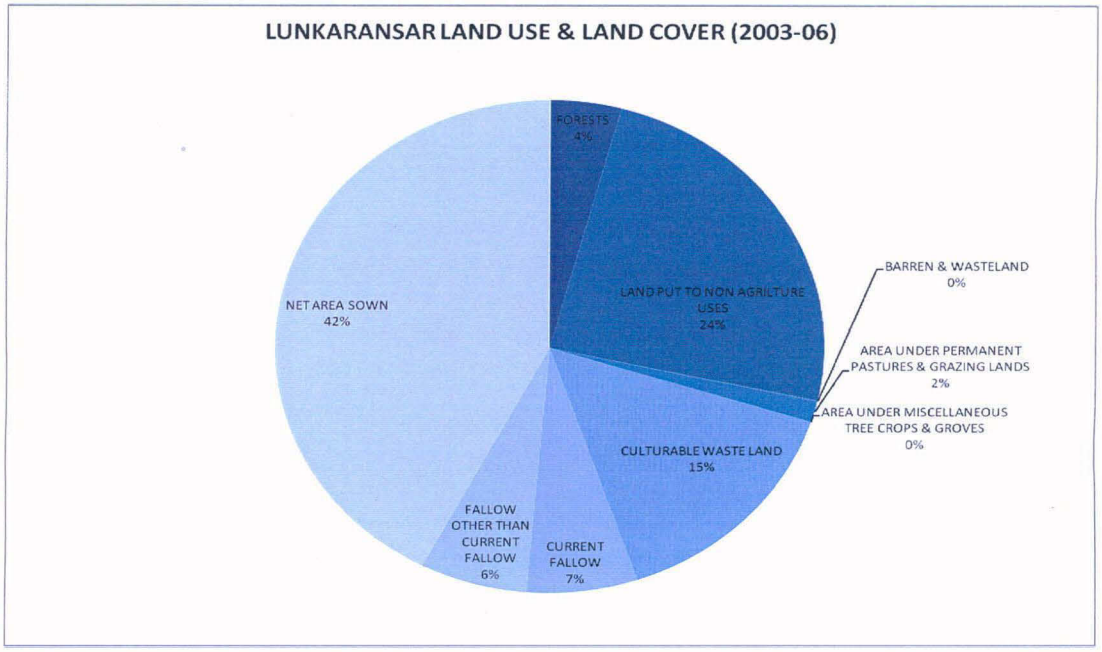


Figure 3.4 Lunkaransar land use & land cover (2003-06)

Culturable wasteland area reduced over the time period. In 1979-82 it is 43 %, which reduced to 15 % in 2003-06. Net sown area increase is not much as Bikaner tahsil. It is only

37 % to 42 % in 1979-82 to 20003-06. Land put to non agriculture area also increase over time period. While current fallow & other than current fallow more or less remain same.

3. ***NOKHA TAHSIL:*** Nokha tahsil situated in southern part of Bikaner district. It has least area in all tahsils. In forest area there is not very much remarkable change over time period.

Table 3.3 Land use & land cover category in Nokha tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
NOKHA(1979-82)	159	14252	31	6929	0	57516	31462	42751	226536	379636
NOKHA(2003-06)	895	17961	323	3645	0	17773	18514	30776	289749	379636

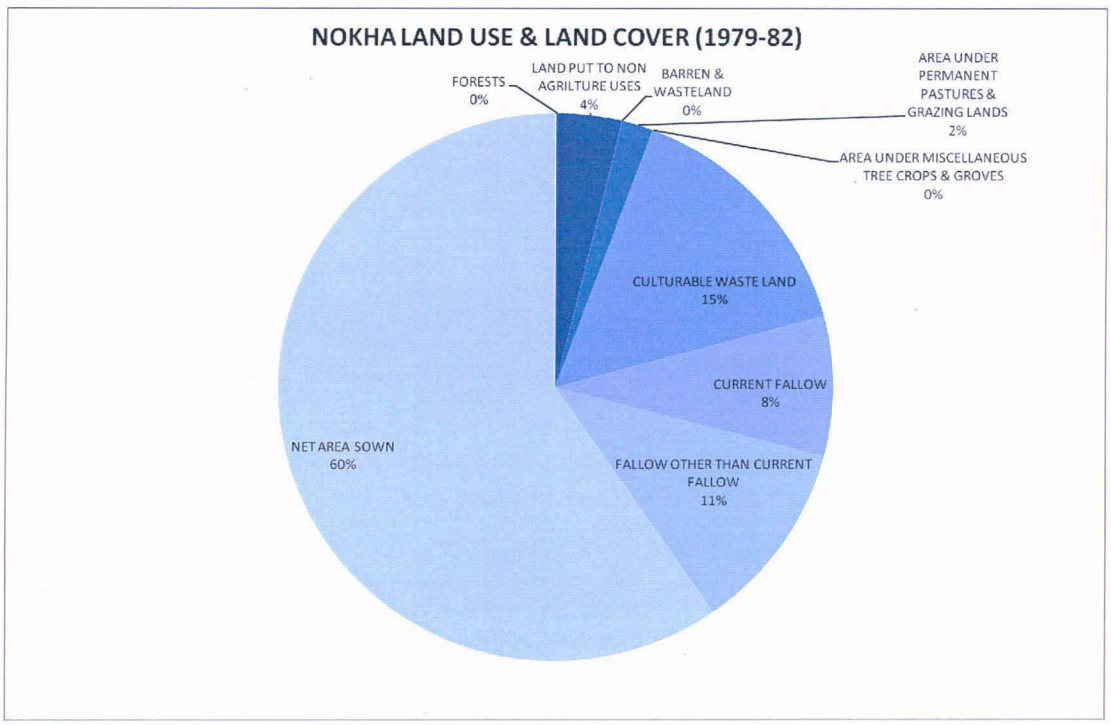


Figure 3.5 Nokha land use & land cover (1979-82)

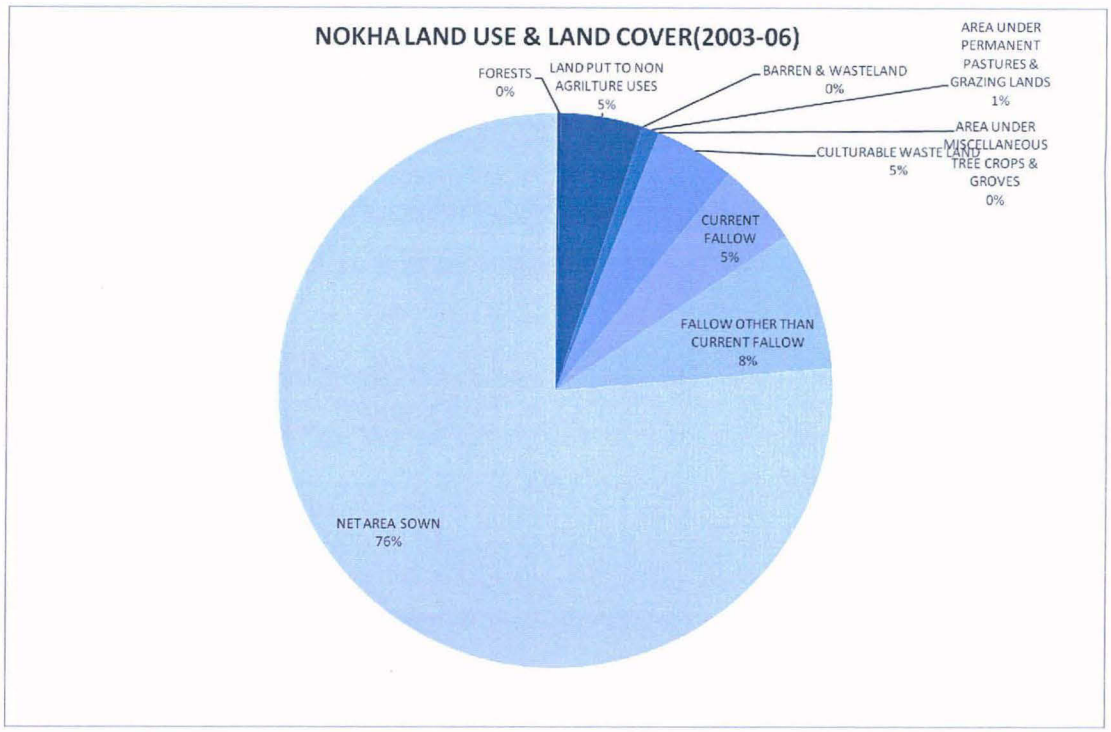


Figure 3.6 Nokha land use & land cover (2003-06)

Culturable wasteland, current fallow land & other than current fallow land reduced over time period. Net sown area increase from 60 % to 76 %. In Bikaner district Nokha is only tahsil which have three fourth lands under net sown area.

4. ***KOLAYAT TAHSIL:*** Kolayat tahsil situated in western direction of Bikaner district. Kolayat is second largest tahsil after Bikaner in Bikaner district. It has vast area of sand dunes in western side. Only in this tahsil land put to non agricultural area reduced over time period. In this part main branch of Indira Gandhi canal not reached, only some sub branches reaches.

Table 3.4 Land use & land cover category in Kolayat tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
KOLAYAT(1979-82)	634	61582	0	3313	0	469709	33390	38732	184624	791983
KOLAYAT(2003-06)	7495	39325	22372	13997	103	329022	78556	80165	220948	791983

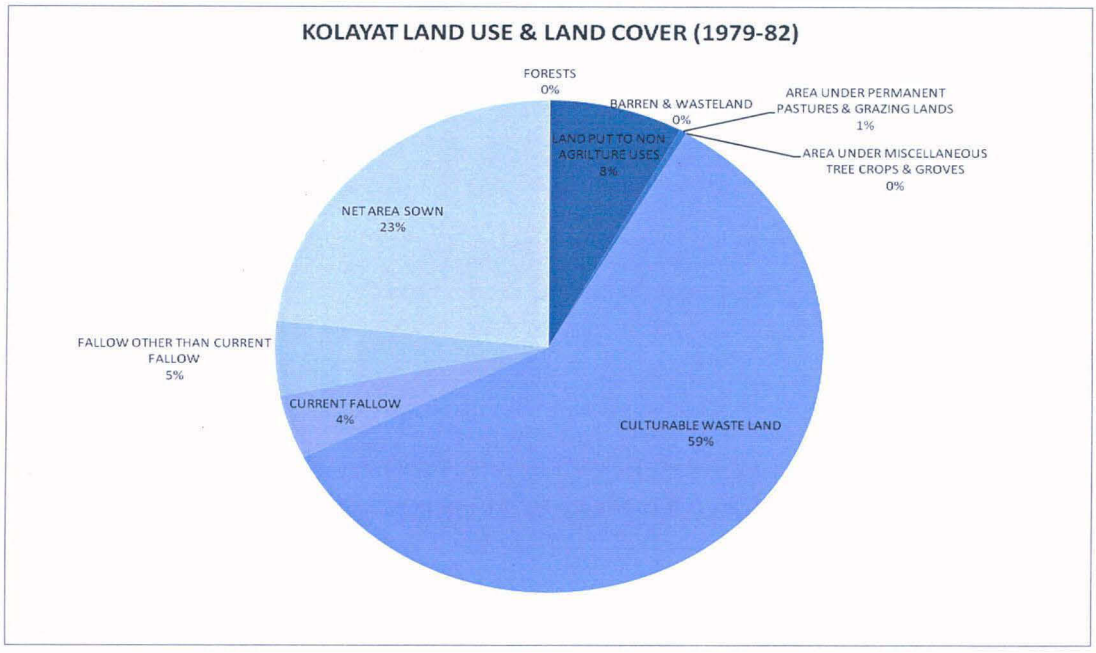


Figure 3.7 Kolayat land use & land cover (1979-82)

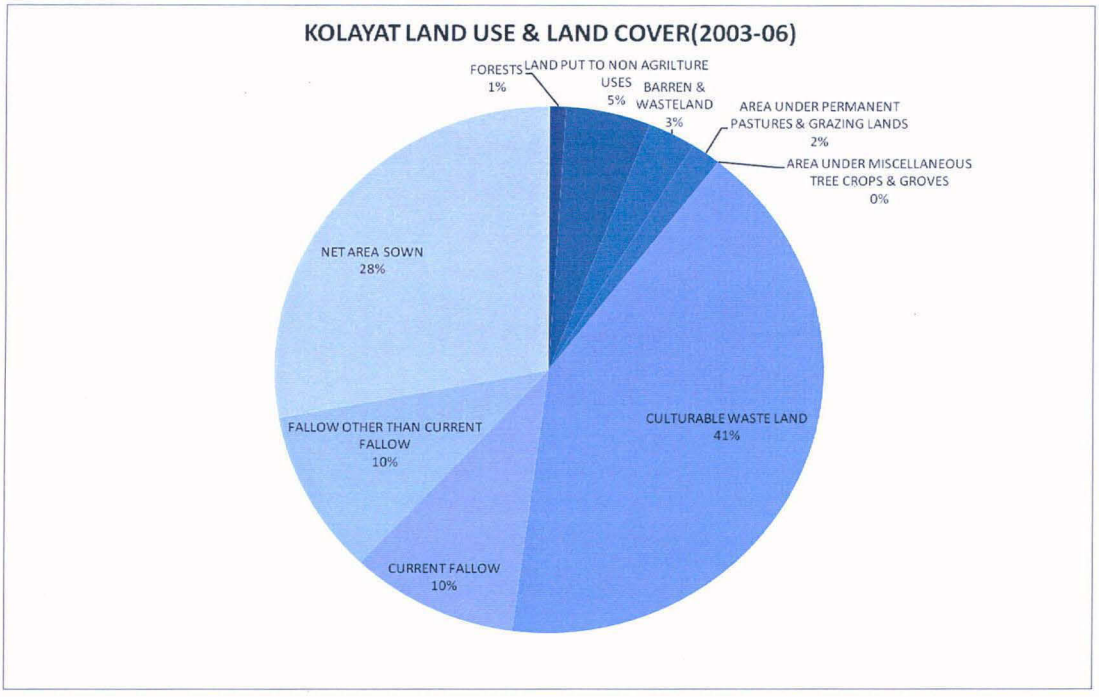


Figure 3.8 Kolayat land use & land cover (2003-06)

Culturable wasteland reduced over time period, while current fallow land & other than current fallow land increase over time period. Net sown area increase, but it is not so much. Kolayat tahsil have least area under net sown area compare to another three tahsils.

3.5.2 GANGANAGAR & HANUMANGARH DISTRICT: Ganganagar & Hanumangarh district located in northern part of Rajasthan. Indira Gandhi canal enter Hanumangarh from Haryana. Prior to 1995 there is only one district name Ganganagar. Than after it bifurcates into two parts namely Ganganagar & Hanumangarh. In present there are 16 tahsils in both districts. For comparison purpose there is 12 tahsils in 1979-82, so both district categorized into 12 tahsils.

1. ***ANUPGARH TAHSIL:*** Anupgarh tahsil situated southern part of Ganganagar tahsil. It makes boundary with Bikaner district. During 25 years there increase in forest area is just doubled.

Table 3.5 Land use & land cover category in Anupgarh tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
ANUPGARH(1979-82)	18431	18291	7971	7752	4692	90907	15650	29207	143555	336455
ANUPGARH(2003-06)	38126	20976	97	120	47	16187	41837	31817	187248	336455

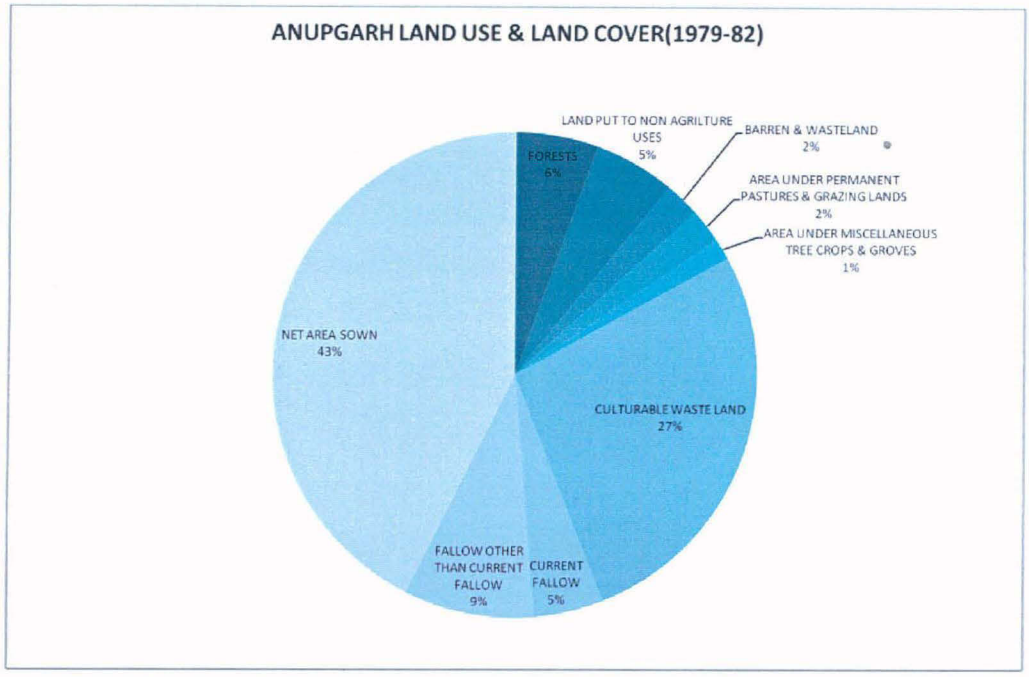


Figure 3.9 Anupgarh land use & land cover (1979-82)

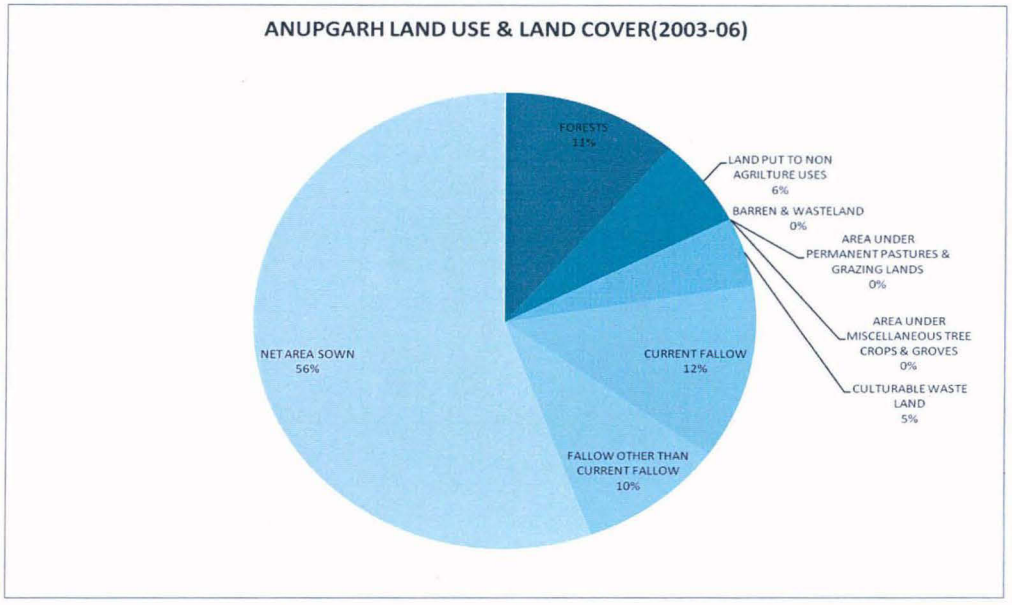


Figure 3.10 Anupgarh land use & land cover (2003-06)

Culturable wasteland reduced considerably over time period. It decreased from 27 % to 5 %. Current fallow land & other than current fallow land increase over time period. Net sown area increase over this time period, but not so much. Their main canal not reaches only

some sub branches reached here. Gang canal also main canal in Ganganagar, but it main influence only in northern part of Ganganagar district.

2. ***BHADRA TAHSIL*:** Bhadra tahsil situated in south- eastern part of Hanumangarh district. Forest area increase over time period. In Bhadra there is Culturable land is very low compare to another tahsils.

Table 3.6 Land use & land cover category in Bhadra tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
BHADRA(1979-82)	11	7884	0	2767	0	186	19863	740	142274	173725
BHADRA(2003-06)	2615	7788	183	799	0	11	13080	2090	147158	173725

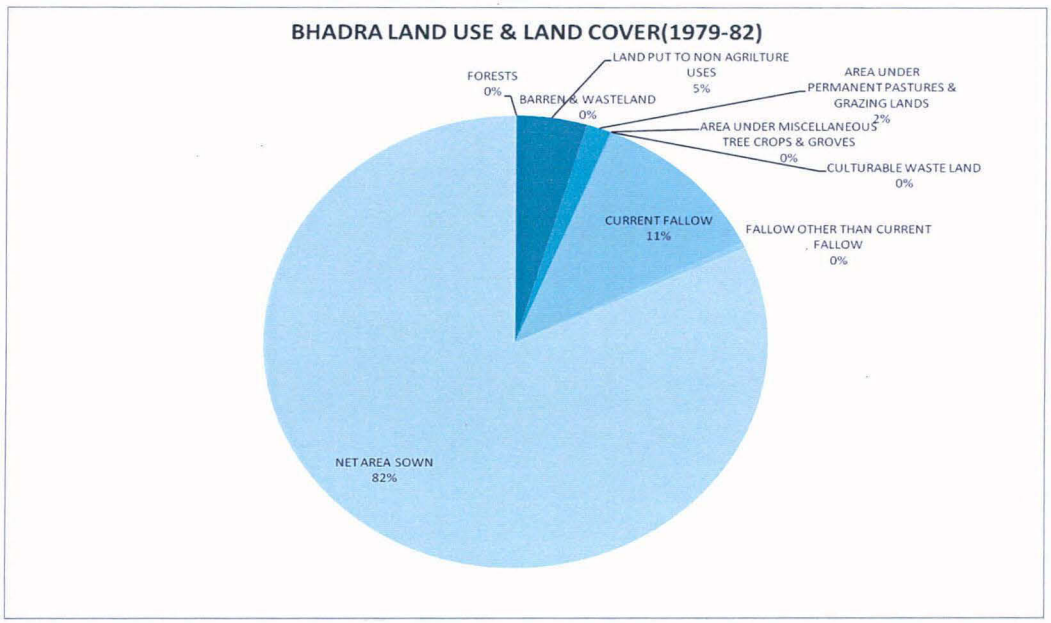


Figure 3.11 Bhadra land use & land cover (1979-82)

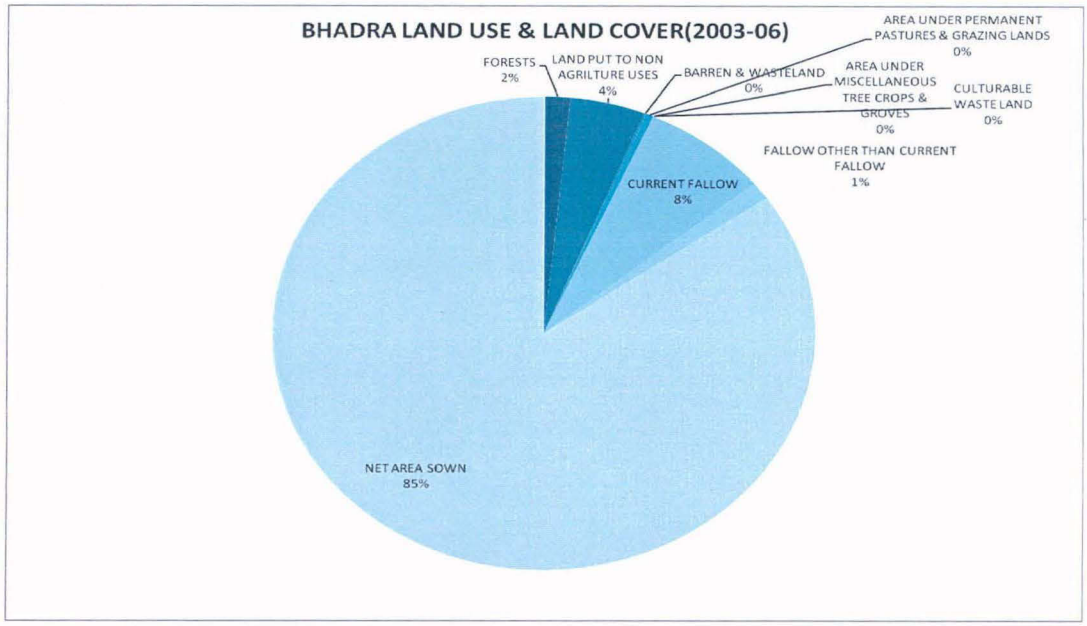


Figure 3.12 Bhadra land use & land cover (2003-06)

Current fallow land reduced over time period. Net sown area is as high 82 % to total land in Bhadra tahsil, which is an increase to 85 % over the time period. It is show Bhadra have fertile land of Ghaggar river.

3. ***GANGANAGAR TAHSIL:*** Ganganagar tahsil is situated in northern part of Ganganagar district touches boundary with Punjab. In Ganganagar there forest cover is nil. There mainly some miscellaneous tree, crops & grove in this area.

Table 3.7 Land use & land cover category in Ganganagar tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
GANGANAGAR(1979-82)	0	7430	0	0	770	397	4446	640	84953	98637
GANGANAGAR(2003-06)	0	7790	0	62	965	887	6307	2595	80031	98637

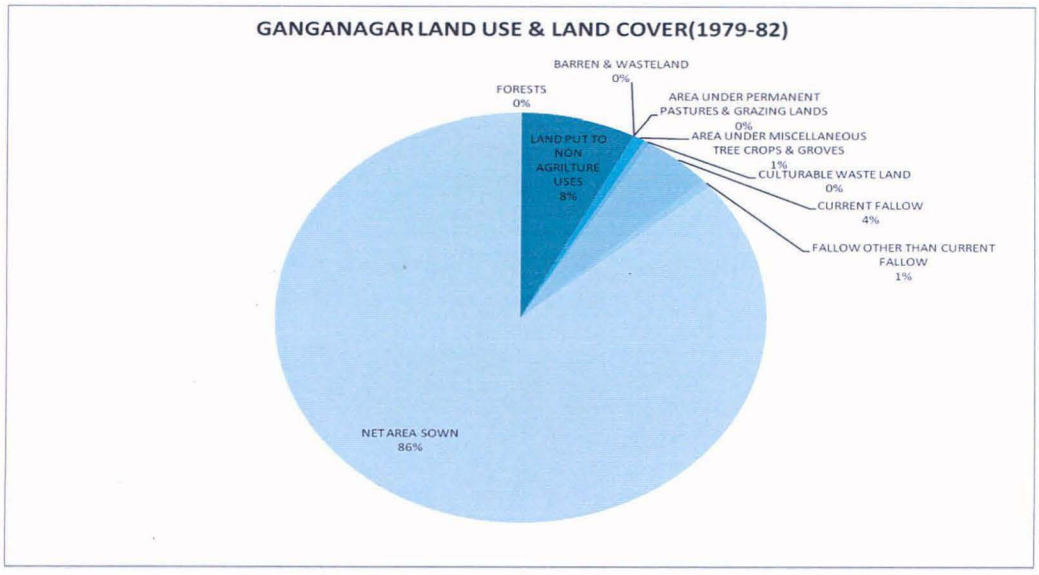


Figure 3.13 Ganganagar land use & land cover (1979-82)

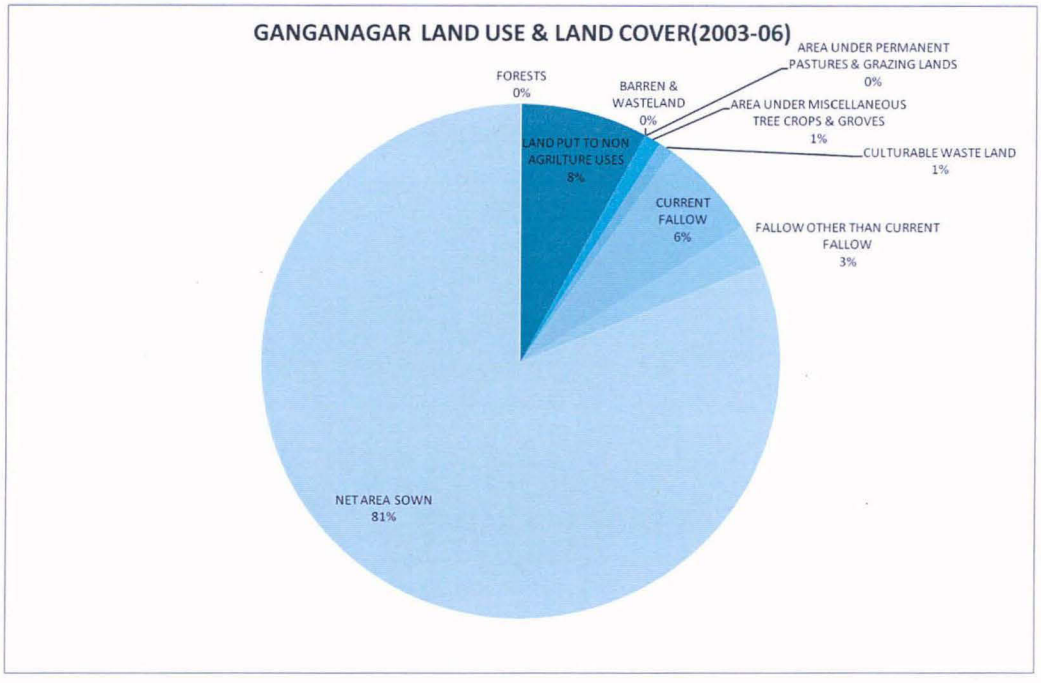


Figure 3.14 Ganganagar land use & land cover (2003-06)

Culturable wasteland area is also low in tahsil. Current fallow & other than current fallow land increase over time period. Net sown area in 1979-82 was 86 %, which reduced to 81 % in 2003-06. Gang canal impact is more than Indira Gandhi canal in Ganganagar tahsil.

4. ***HANUMANGARH TAHSIL:*** Hanumangarh tahsil situated in north western part of Hanumangarh district. There forest area increase over time period, but it is not much significant over time period. Culturable wasteland is not as higher in Hanumangarh tahsil.

Table 3.8 Land use & land cover category in Hanumangarh tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
HANUMANGARH(1979-82)	2281	11263	177	66	7	354	12149	1170	95834	123302
HANUMANGARH(2003-06)	2937	11482	0	58	0	18	5576	1914	101317	123302

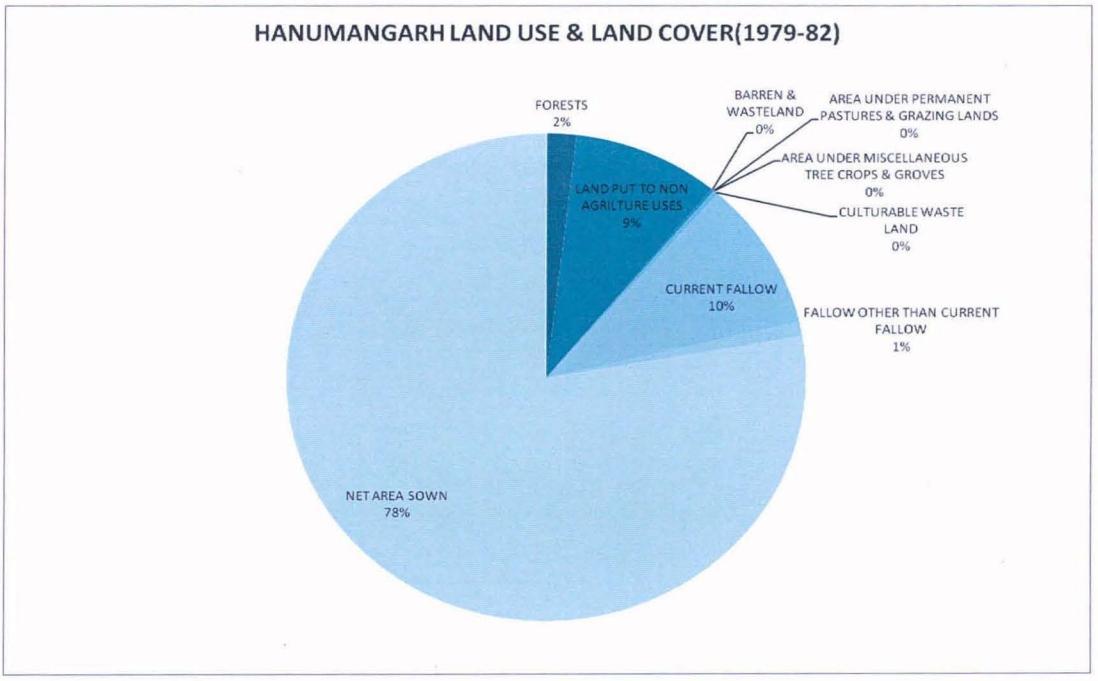


Figure 3.15 Hanumangarh land use & land cover (1979-82)

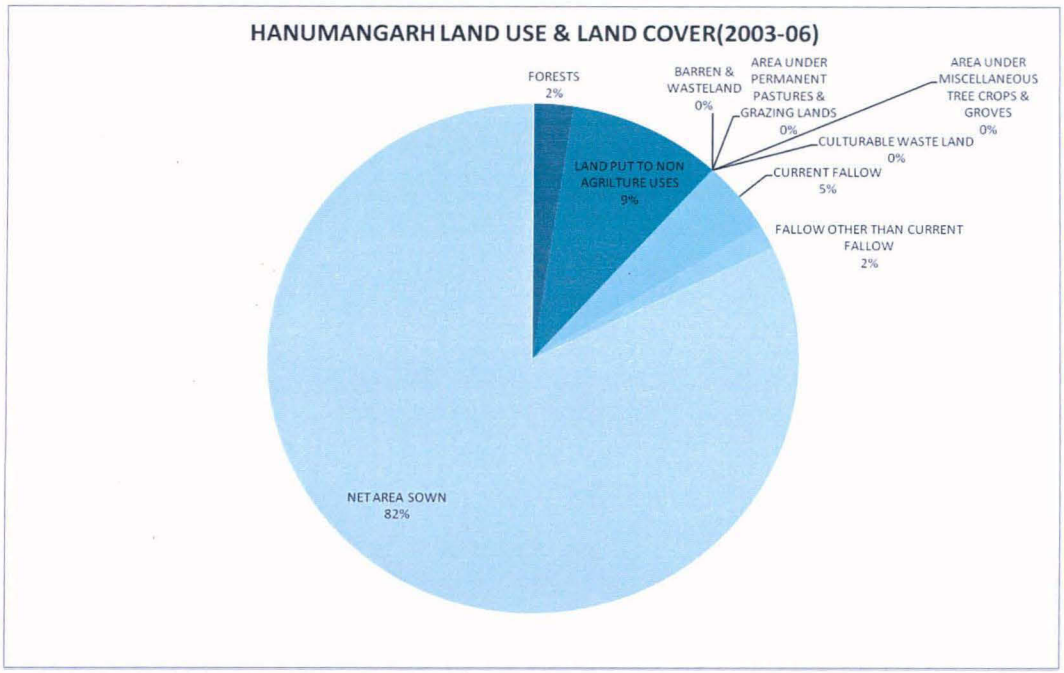


Figure 3.16 Hanumangarh land use & land cover (2003-06)

Current fallow land & other than current fallow land reduced over time period. While net sown area increase over time period. It is as much as high is 82 % in year 2003-06.

5. ***KARANPUR TAHSIL:*** Karanpur tahsil situated in western boundary of Ganganagar district, which makes boundary with Pakistan. In Karanpur there is forest cover is also nil same as Ganganagar tahsil, which is adjacent to former. There only some miscellaneous tree, crops & groves in this area. Culturable land is also very low in this area.

Table 3.9 Land use & land cover category in Karanpur tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
KARANPUR(1979-82)	0	5801	0	0	483	11	3970	94	71528	81887
KARANPUR(1979-82)	0	5820	0	0	634	78	14173	3621	57560	81887

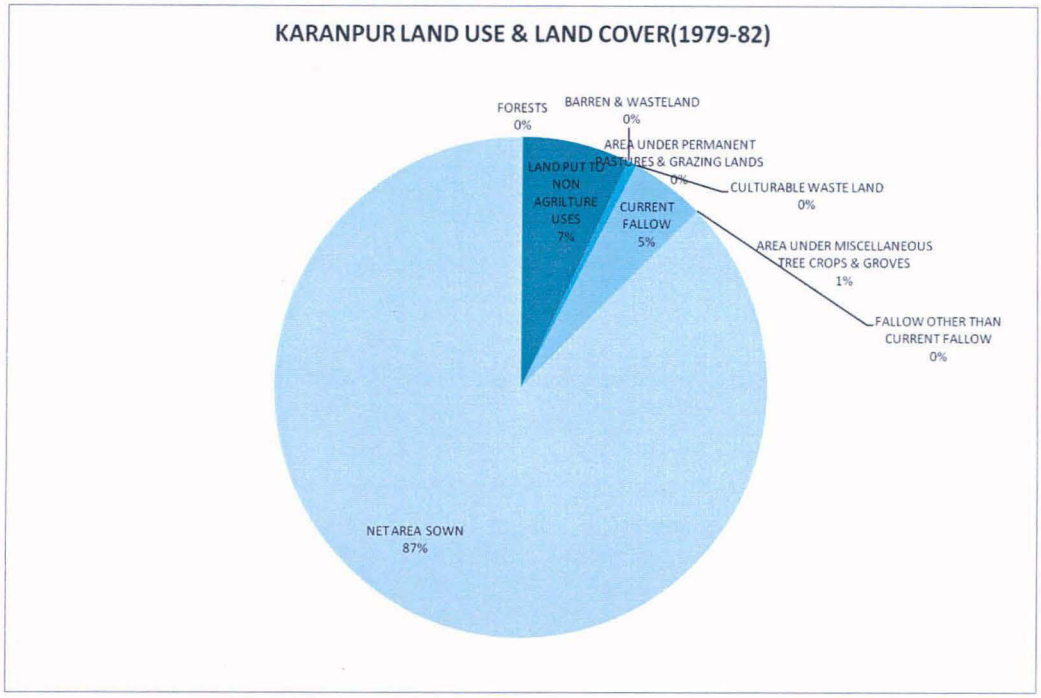


Figure 3.17 Karanpur land use & land cover (1979-82)

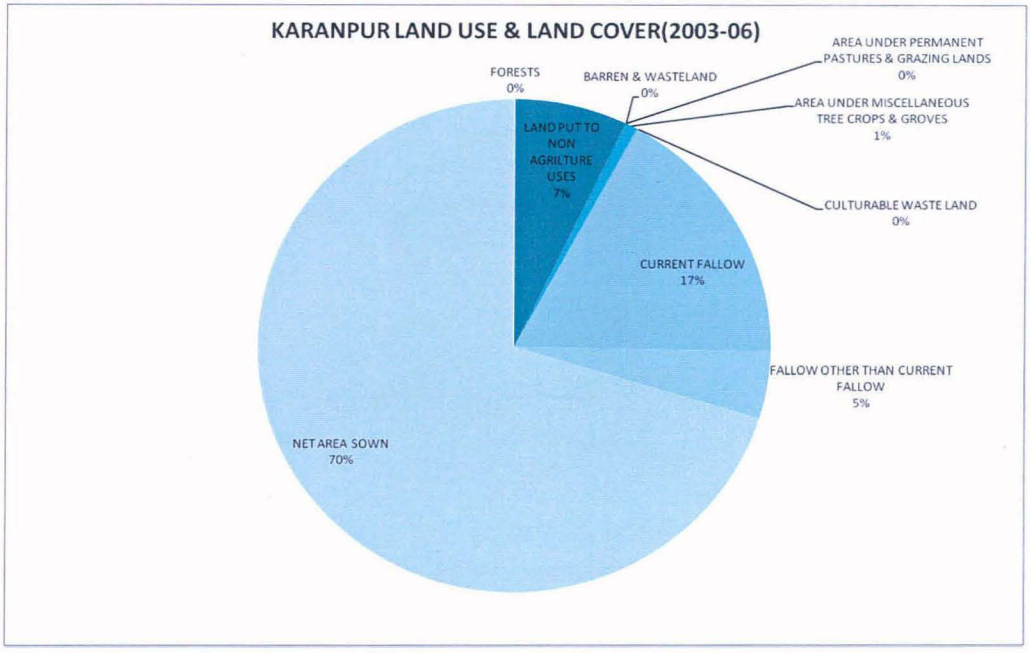


Figure 3.18 Karanpur land use & land cover (2003-06)

Current fallow land & other than current fallow land increase over time period. In Karanpur tahsil there is influence of Gang canal is more than Indira Gandhi canal. This is

show salinity & water logging problems associated with canal irrigated area. Net sown area reduced from considerably from 87 % in 1979-82 to 70 % in 2003-06.

6. ***NOHAR TAHSIL:*** Nohar tahsil is adjacent to Bhadra tahsil. Forest area increase over time period. Permanent pasture & grazing land reduced over time period. Culturable wasteland also reduced during this time period.

Table 3.10 Land use & land cover category in Nohar tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
NOHAR(1979-82)	95	18927	671	10604	2821	10783	62574	15959	311410	433843
NOHAR(2003-06)	8546	17739	555	3049	0	2114	50458	17671	333711	433843

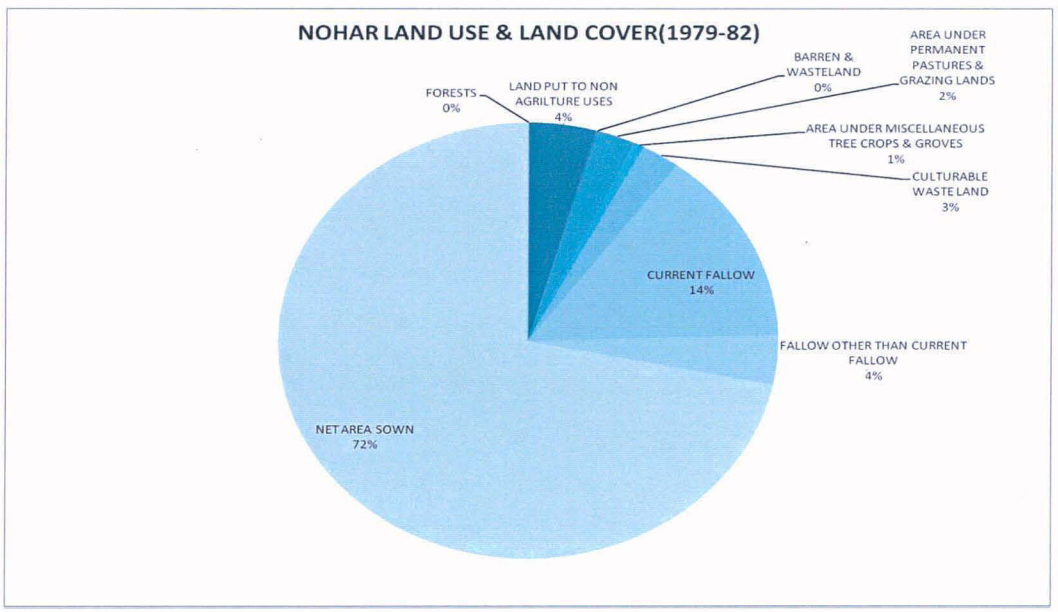


Figure 3.19 Nohar land use & land cover (1979-82)

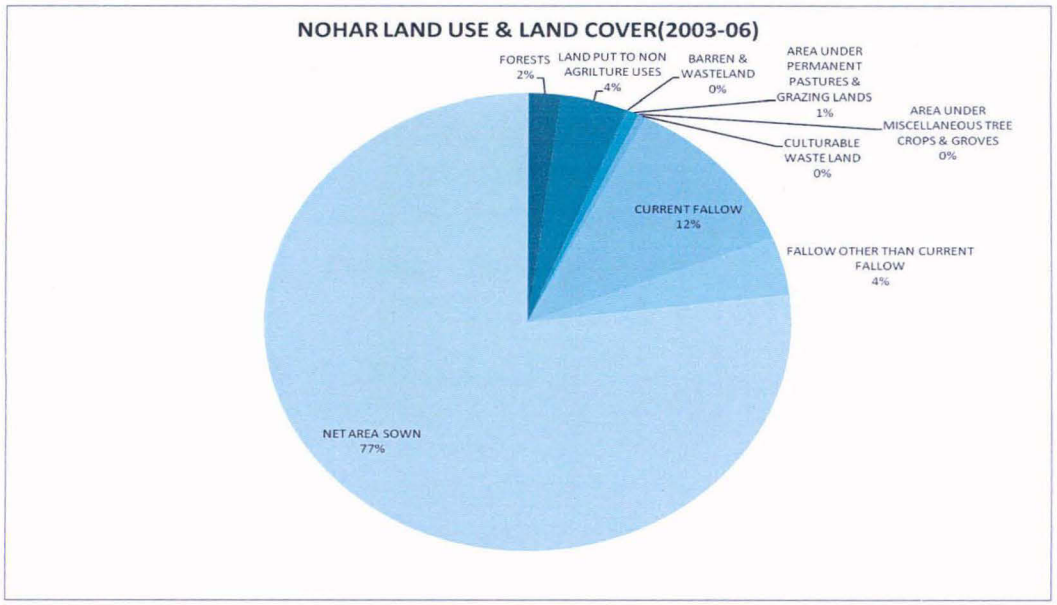


Figure 3.20 Nohar land use & land cover (2003-06)

Current fallow land & other than current fallow land remains more or less same through time period. While increase in net sown area is not very high during this time period. There 72 % to 77 % in 1979-82 & 2003-06 respectively.

7. ***PADAMPUR TAHSIL***: Padampur tahsil just below Ganganagar & Karanpur tahsil. As adjacent tahsil there is forest cover is also nil. In this tahsil miscellaneous tree, crops, groves also very low. Culturable land is very low in this tahsil.

Table 3.11 Land use & land cover category in Padampur tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
PADAMPUR(1979-82)	0	5750	0	0	437	36	7367	633	70251	84475
PADAMPUR(2003-06)	0	5872	0	0	0	45	8961	3594	66004	84475

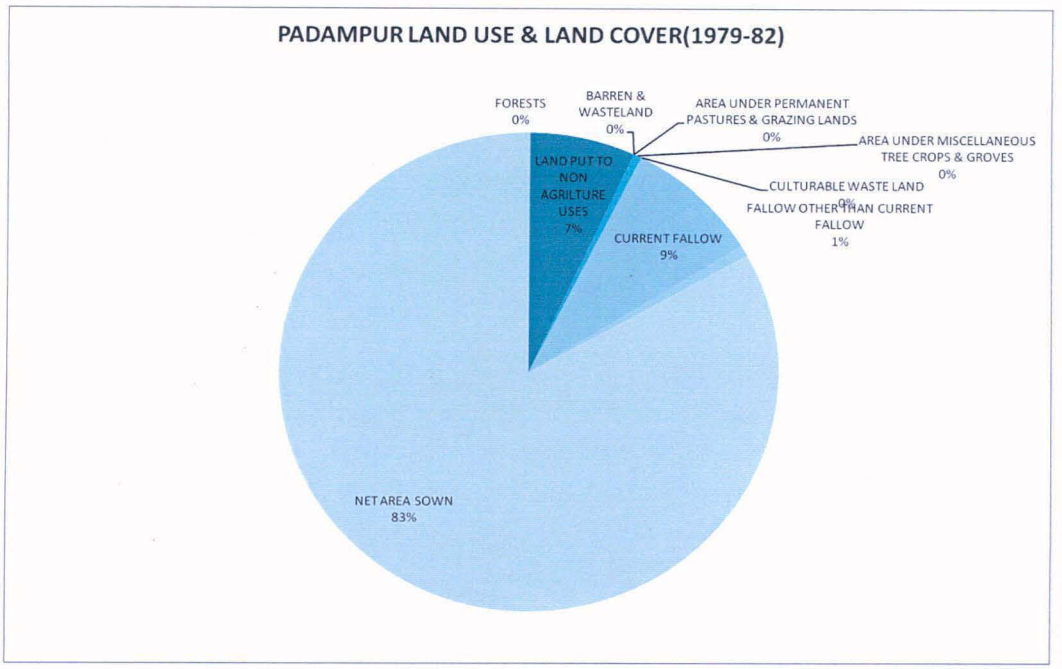


Figure 3.21 Padampur land use & land cover (1979-82)

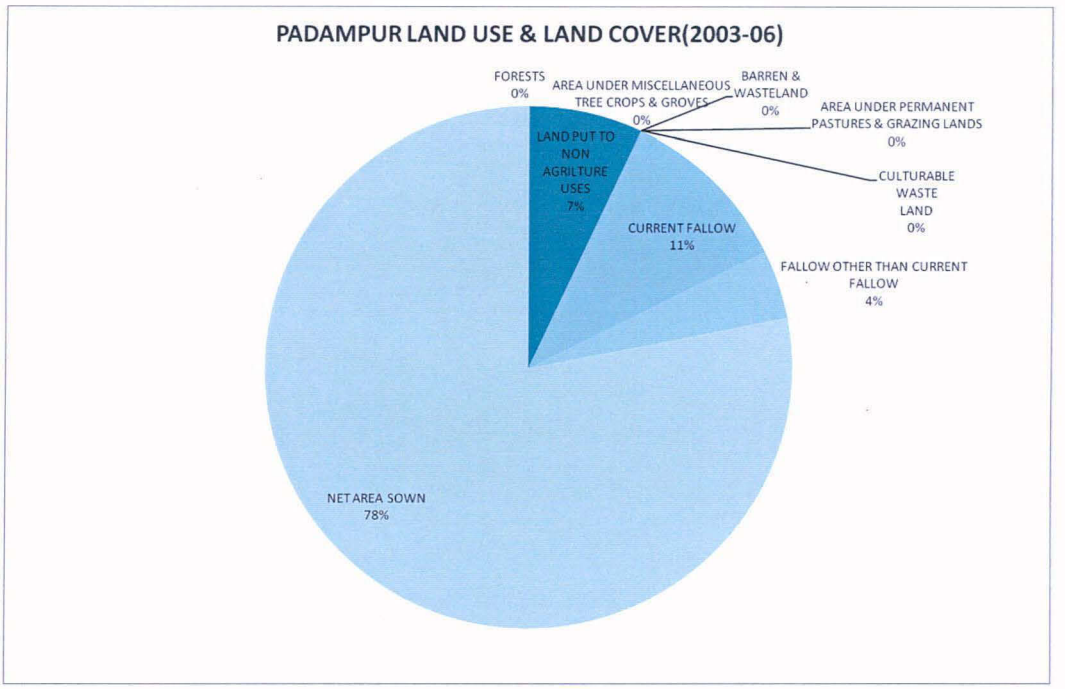


Figure 3.22 Padampur land use & land cover (2003-06)

Current fallow land & other than current fallow land increase over time period, but it remains very low. Net sown area decrease over time period. There also Gang canal show more impact in this tahsil. Both salinity & water logging problems associated in this area.

8. ***RAISINGHNAGAR TAHSIL:*** Raisinghnagar tahsil just below Padampur. This area also irrigated by Gang canal. In this region there only few patches of forest found. While Culturable land remains very low in this area. This is due to proper irrigation facilities provided by canal.

Table 3.12 Land use & land cover category in Raisinghnagar tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
RAISINGNAGAR(1979-82)	102	7515	0	0	63	3931	15248	3678	101018	131555
RAISINGNAGAR(2003-06)	789	7960	0	0	136	606	18208	8312	95544	131555

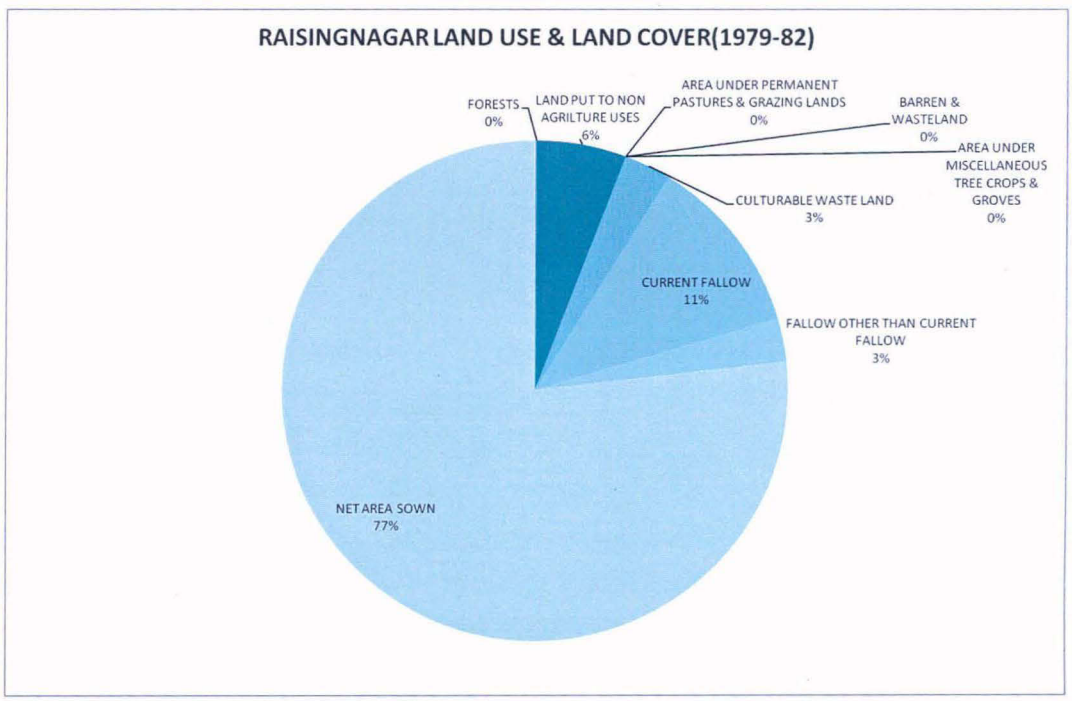


Figure 3.23 Raisinghnagar land use & land cover (1979-82)

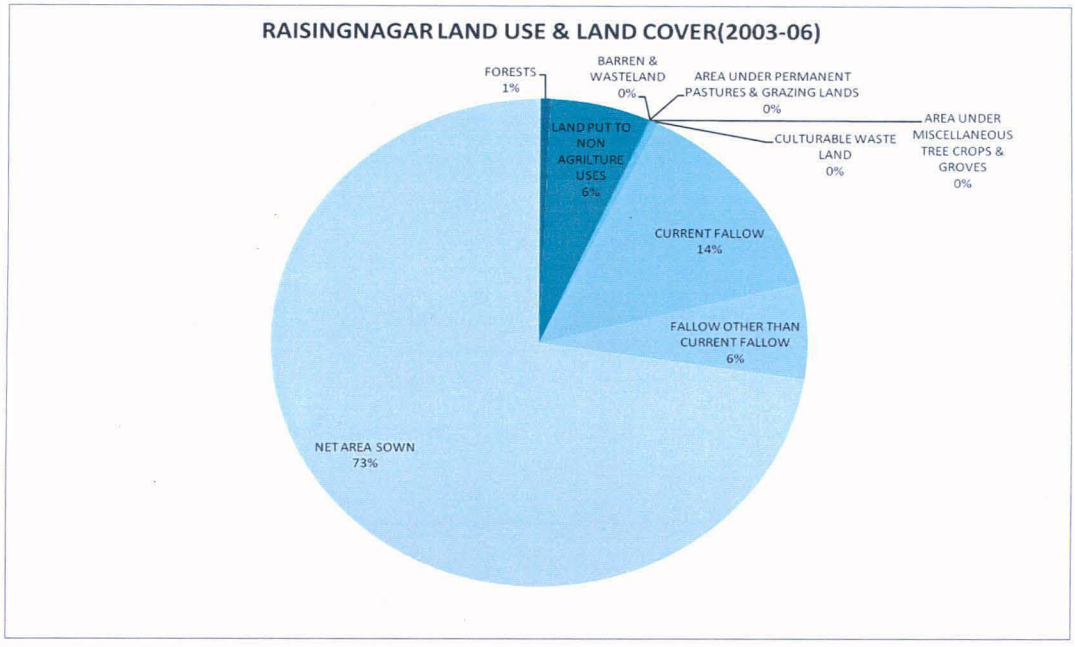


Figure 3.24 Raisinghnagar land use & land cover (2003-06)

In this tahsil also current fallow land & other than current fallow land increase over time period. While net sown area reduced during this time period. This is reduced from 77 % to 73 % over the time period.

9. ***SADULSAHAR TAHSIL:*** Sadulsahar located eastern side of Ganganagar tahsil. Forest covers same as Ganganagar tahsil is nil. In this area Culturable land increase over time period, but increment is not high.

Table 3.13 Land use & land cover category in Sadulsahar tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
SADULSAHER(1979-82)	0	5323	0	0	31	131	8895	865	61786	77031
SADULSAHAR(2003-06)	0	5341	0	0	46	2687	8600	2943	57413	77031

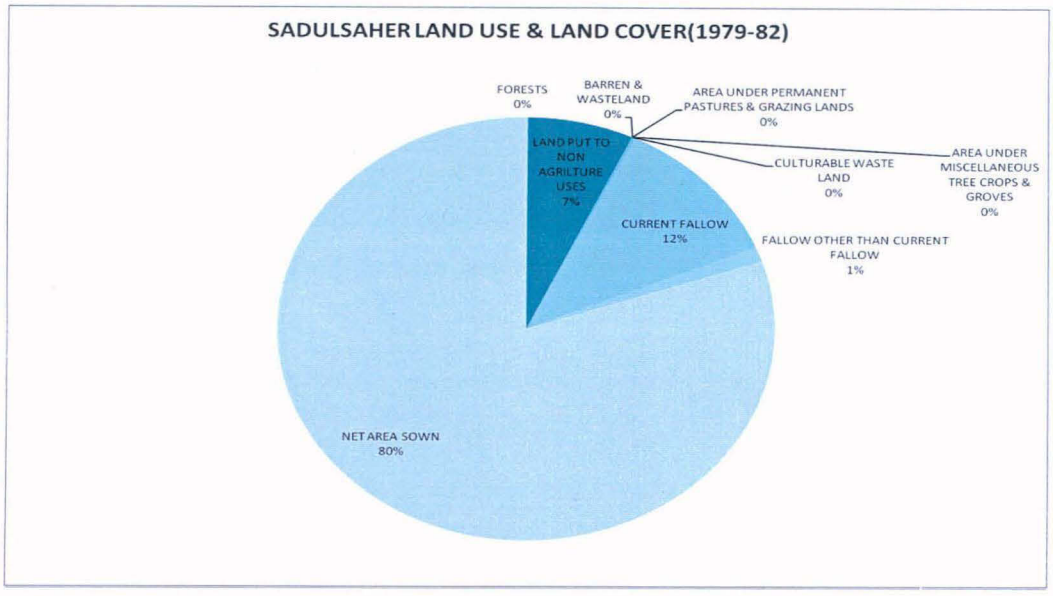


Figure 3.25 Sadulsahar land use & land cover (1979-82)

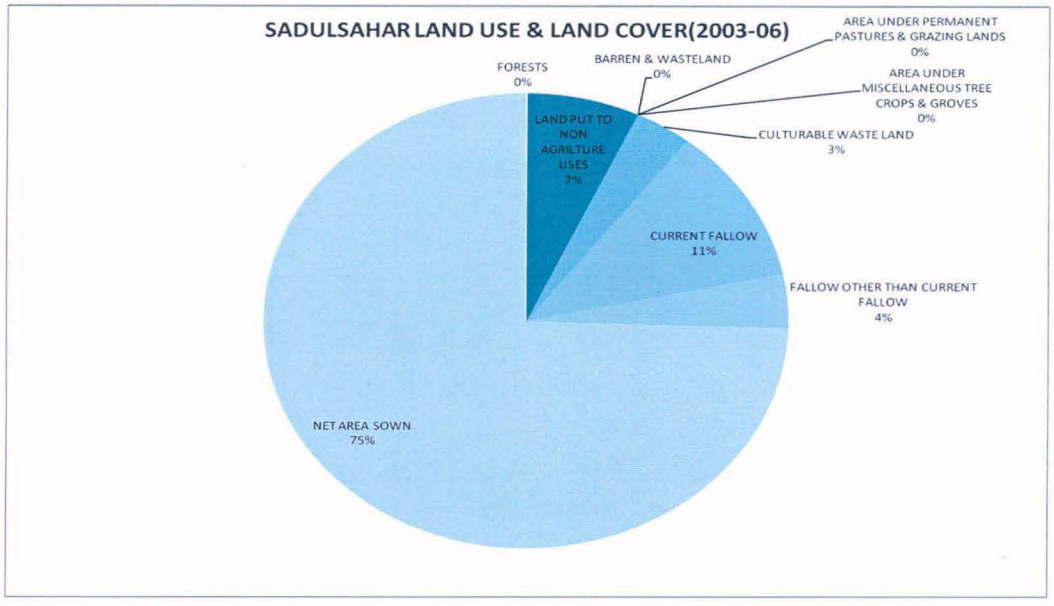


Figure 3.26 Sadulsahar land use & land cover (2003-06)

In Sadulsahar current fallow land reduced during this time period, but other than current fallow land increase over this time period. Reduction of current fallow land is not as higher. Net sown area reduced over time period from fourth fifth to total area to three fourth.

10. ***SANGARIA TAHSIL:*** Sangaria tahsil located northern side of Hanumangarh tahsil. This tahsil also lack of forest canopy. There is also very low area under Culturable wasteland. There is a sub branch of Indira Gandhi canal reaches in this tahsil.

Table 3.14 Land use & land cover category in Sangaria tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
SANGARIA(1979-82)	0	4975	0	0	13	10	3537	112	57201	65848
SANGARIA(2003-06)	0	5126	0	0	0	0	3206	41	57476	65848

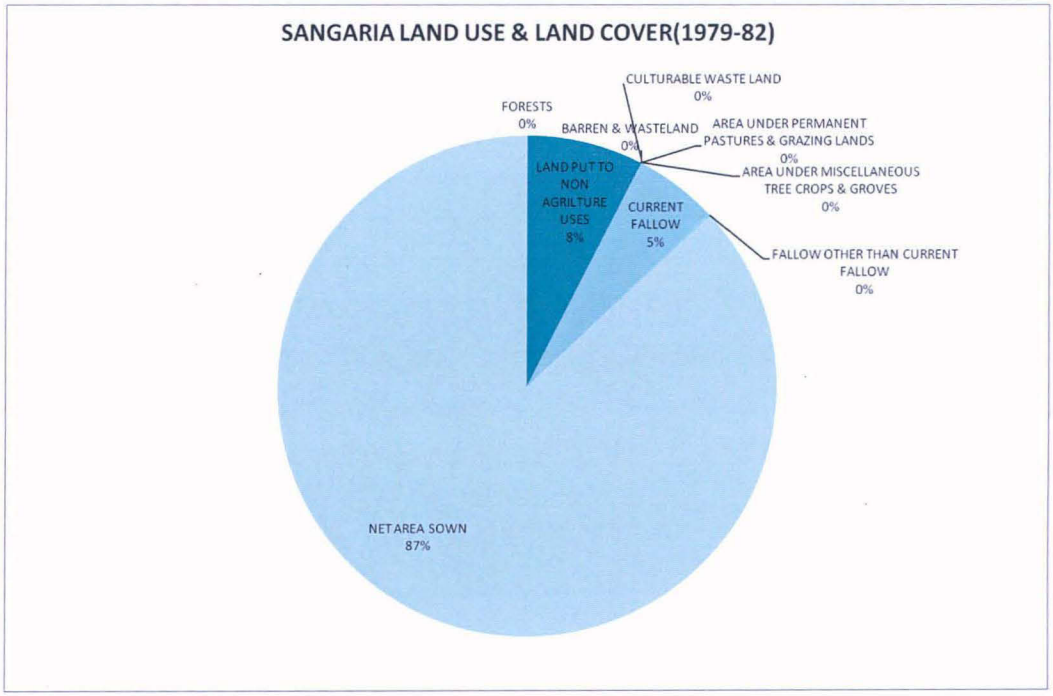


Figure 3.27 Sangaria land use & land cover (1979-82)

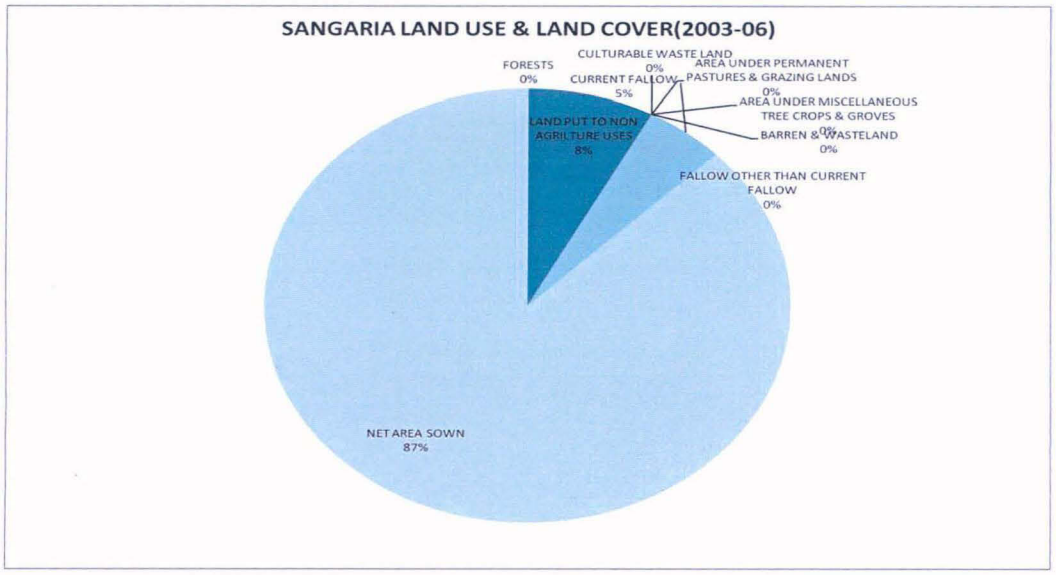


Figure 3.28 Sangaria land use & land cover (2003-06)

In Sangaria tahsil there is very low changes occur in all three category of current fallow land, other than current fallow land & net sown area.

11. ***SURATGARH TAHSIL:*** Suratgarh tahsil is the main tahsil of Ganganagar where maximum flow of Indira Gandhi canal. Their main branch also flows through Suratgarh. Forest area during this time period increases. Culturable waste land is very high in Suratgarh during 1979-82, which is reduced in 2003-06. This decrease from 20 % to 12 %.

Table 3.15 Land use & land cover category in Suratgarh tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
SURATGARH(1979-82)	5333	17609	2958	2598	121	79018	39038	40637	208093	395405
SURATGARH(2003-06)	23866	21348	2099	124	59	47750	57986	72447	169726	395405

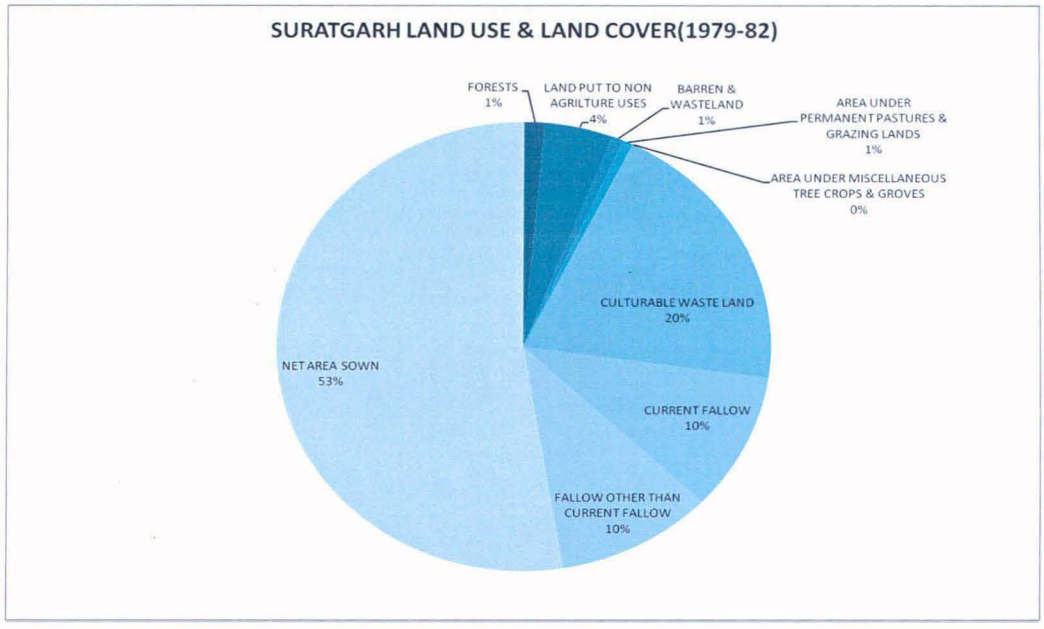


Figure 3.29 Suratgarh land use & land cover (1979-82)

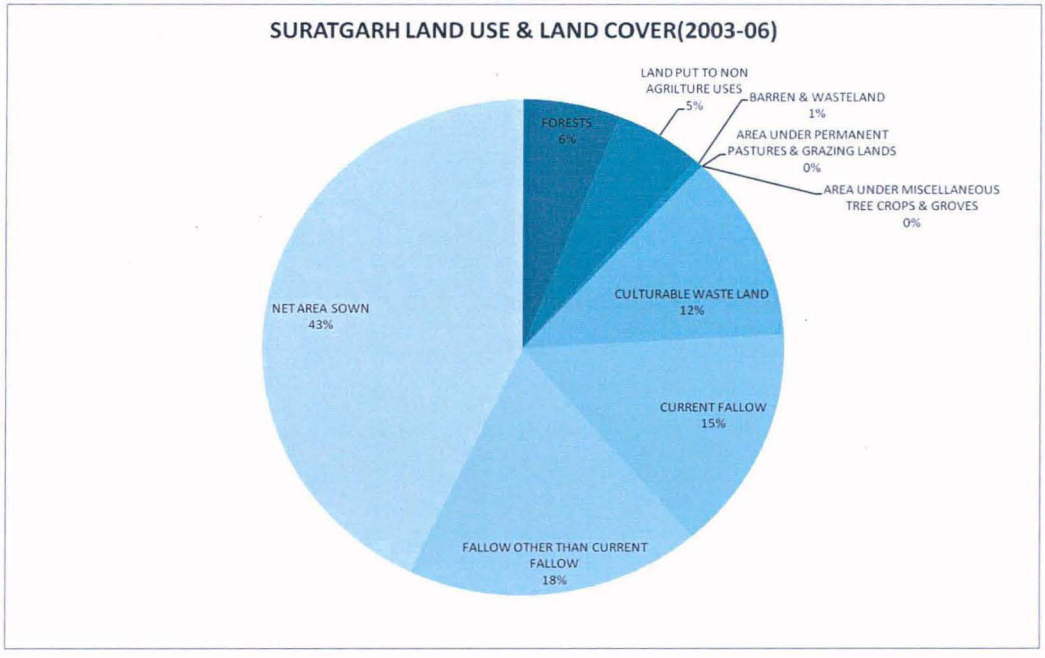


Figure 3.30 Suratgarh land use & land cover (2003-06)

Current fallow land increase over time period. It increases 10 % to 15 % over this time period. While other than current fallow land also increases from 10% to 18 %. In absolute term other than fallow land increase more during this time period. Net sown area reduced over time period. It reduced from 53 % to 43 % during this time period. Suratgarh

also sand dunes area, than there is minimum area under net sown area compare to other tahsil of Ganganagar & Hanumangarh.

12. ***TIBBI TAHSIL:*** Tibbi tahsil situated in eastern direction of Hanumangarh tahsil. There forest area is very low. Land put to non agriculture uses also reduced during this time period. It mainly due to creation of Hanumangarh as a new district in 1995.culturable land is also very low in this area.

Table 3.16 Land use & land cover category in Tibbi tahsil (1979-82 & 2003-06)

(area in hectare)

TAHSIL	FORESTS	LAND PUT TO NON AGRILTURE USES	BARREN & WASTELAND	AREA UNDER PERMANENT PASTURES & GRAZING LANDS	AREA UNDER MISCELLANEOUS TREE CROPS & GROVES	CULTURABLE WASTE LAND	CURRENT FALLOW	FALLOW OTHER THAN CURRENT FALLOW	NET AREA SOWN	TOTAL
TIBBI(1979-82)	24	6226	0	0	33	170	4759	486	62567	74265
TIBBI(2003-06)	214	5975	150	0	21	260	2598	1365	63683	74265

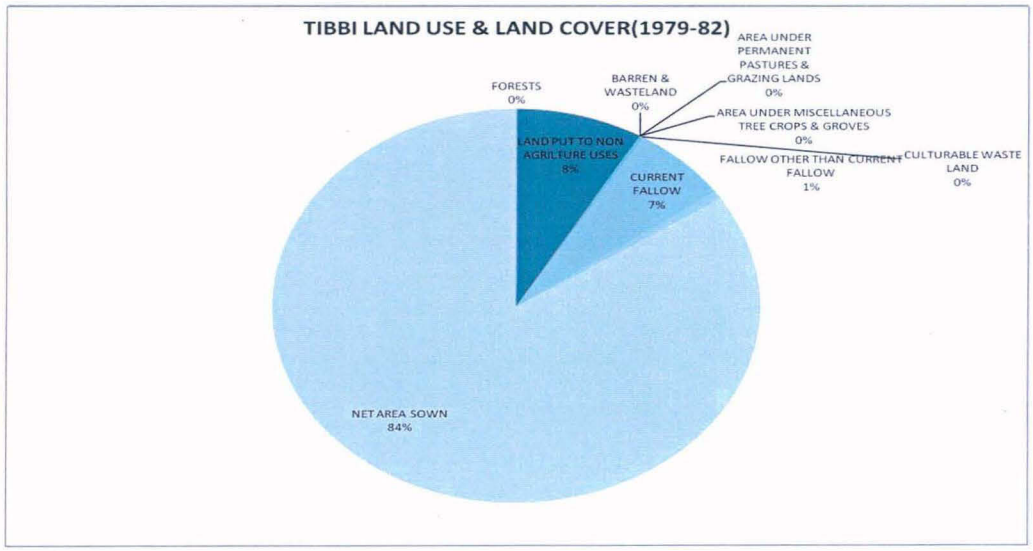


Figure 3.31 Tibbi land use & land cover (1979-82)

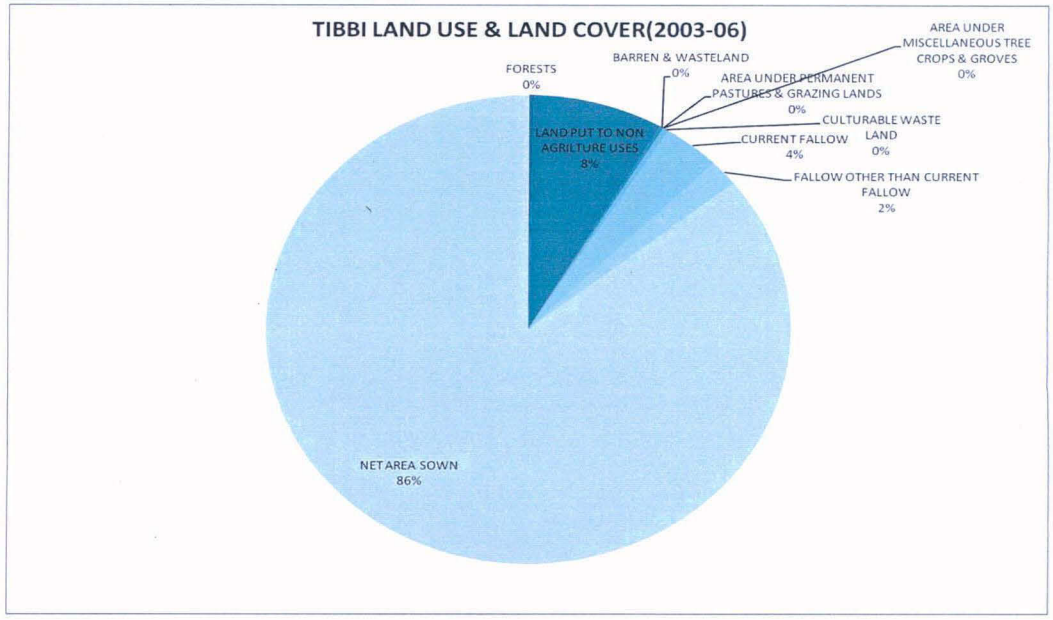


Figure 3.32 Tibbi land use & land cover (2003-06)

In Tibbi current fallow land reduced during this time period, while other than current fallow land increase. But reduction of current fallow land is more than increment in absolute term. Tibbi show increase in net sown area during time period. It is as high as 86 % in 2003-06.

Chapter Four

Applications of GIS & Remote Sensing in Land Use & Land Cover Detection in Study Area

4.1 INTRODUCTION:

Land cover is distinct from land use despite the two terms often being used interchangeably. Land use is a description of how people utilize the land and socio-economic activity - urban and agricultural land uses are two of the most commonly known land use classes. At any one point or place, there may be multiple and alternate land uses, the specification of which may have a political dimension. Land use and land cover is of dynamics nature and need proper monitoring for the sake of optimum utilization of land resources. Land cover and land use are often assumed to be identical, they are rather quite different. Land cover may be defined as the biophysical earth surface while land use is often shaped by human, socioeconomic and political influences on the land.

The land use & land cover pattern of a region is an outcome of the natural & socio-economic factor and their utilization by man in time & space. Land is becoming a scarce resource due to immense agricultural and demographic pressure. Hence, information on land use & land cover and possibilities for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. This information also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. According to Wilkie and Finn (1996), the collection of remotely sensed data facilitates the synoptic analyses of Earth - system function, patterning, and change at local, regional and global scales over time; such data also provide an important link between intensive, localized ecological research and regional, national and international conservation and management of biological diversity.

4.2 Analysis of Land use and Land cover Pattern:

Land cover refers to different features covering the earth's surface including vegetation cover, water body , rocky outcrops etc. the land use term refers to man's use of the land and its cover (FAO;1990). The land use and land cover study of the region has been attempted in order to identify and map the various type of land use and land cover classes in the region both by visual and digital interpretation. The major procedure in achieving the temporal maps of land use is through combined help of toposheets and application of remote sensing data, which provide an aid in the rapid assessment of the land use in a GIS environment. And the land use classification is presented by the statistical data that present the land use distribution of the study area.

The primary aim of this study is to replace visual analysis of the image data with quantitative techniques for automating the identification of features in a scene. This process of study involves the analysis of multispectral image data and application of statistically based decision. The common land use and land cover classification procedures is of two types: supervised classification and unsupervised classification. In the present study unsupervised classification of land use & land cover has been used in which spectral classes are grouped first, based solely on numerical information in the data, and are then matched by the analyst to information classes (if possible). The basic premise is that values within a given cover type should be close together in the measurement space whereas data in different classes should be comparatively well separated. Unsupervised classification involves clustering algorithms that examine the unknown pixels in an image and aggregate them into a number of classes based on the natural groupings or clusters present in the image values (Lillesand and Kiefer, 2002).

Land use & land cover category in all three district namely Ganganagar, Hanumangarh & Bikaner divided into five categories:

1. *Barren & wasteland:* The land which may be classified as the wasteland such as barren hilly terrains, desert lands, ravines, etc. normally cannot bring cultivation with available technology. In this category there saline area also included, where agriculture land left due to the problem of hard pan & water logging.

2. *Forests*: It is important to note that area under actual forest cover is different from area classified as forest. Forests can be classified in different ways and to different degrees of specificity. It may be reserved, protected, classified or many type as open, dense etc.
3. *Urban built up area (Land put to non agricultural uses):* Land under settlements (rural and urban), infrastructure, industries, shops, etc. are included in this category. An expansion in the secondary and tertiary activities would lead to an increase in this category of land use. It refers to that part of land use which covers the area used for making houses and associated features.
4. *Canal area:* This area mainly under in urban built up area, but for delineation purpose there is new category.
5. *Agriculture area:* In this category there is mainly covers net sown area, current fallow land & other than current fallow land.

4.3 Results of Land use and land cover classification:

The land use and land cover map prepared from the Landsat imagery of 1977, 1989, 1999 and 2008 has revealed the spatial distribution, and dynamic nature of different classes in the area which results into formation of complex physiographic features. All the satellite imageries have been acquired for October month. All satellite imageries were spectrally standardized, geo-registered to UTM zone 43N. Unsupervised classification used for analysis of land use & land cover of given area.

4.3.1 GANAGANAGAR DISTRICT: Ganganagar is northern most city of Rajasthan State of western India. Ganganagar latitude & longitude 29° 55' N & 73° 52' E respectively. Mean altitude of Ganganagar is 163 meter. Gang & Indira Gandhi canal changes desert land in a green town. Gang canal & Indira Gandhi canal, which carries the excess waters of Punjab and Himachal Pradesh to the region, making Ganganagar district known as "the food basket of Rajasthan".

Ganganagar land use & land cover has been shown by using unsupervised classification. Change has been studied for the period from 1977 to 2008. These change show by difference in area & percentage term.

Table 4.1 Ganganagar Land Use & Land Cover (area in hectare)

GANGANAGAR LAND USE & LAND COVER(area in hectare)				
	YEAR			
CATEGORY	1977	1989	1999	2008
BARREN LAND	190678	156535	142382	161574
AGRICULTURE LAND	768844	773802	780520	733111
SETTELMENT	61786	69223	71120	75425
FOREST	43549	60679	60999	80894
CANAL	16724	21341	26561	30578
TOTAL	1081581	1081581	1081581	1081581

Ganganagar land use & land cover by using GIS show a distinctive trend. From 1977 to 2008 changes in land use & land cover clearly shown by table. In 1977 barren land occupy 17.63 % which decrease over time period. It reduced 14.47 % & 13.16 % in 1989 & 1999 respectively. It shows clear cut impact of Indira Gandhi canal & Gang canal on barren land of Ganganagar. But due to water logging & salinity there increase in barren land in year 2008. It is 14.94 % in this year. Arora (2003) examine the water logging problem in IGCP area.

Table 4.2 Ganganagar Land Use & Land Cover (area in %)

GANGANAGAR LAND USE & LAND COVER(area in %)				
	YEAR			
CATEGORY	1977	1989	1999	2008
BARREN LAND	17.63	14.47	13.16	14.94
AGRICULTURE LAND	71.09	71.54	72.16	67.78
SETTELMENT	5.71	6.40	6.58	6.97
FOREST	4.03	5.61	5.64	7.48
CANAL	1.55	1.97	2.46	2.83

Ansari & Rehman (2000) evaluates the changing cropping pattern in Thar Desert. The Indira Gandhi Canal Project (IGCP) is a very typical and one of the most gigantic projects in the world, aiming transform the desert waste land into agriculturally productive area as well as maintaining the eco system of the region. Agriculture land mainly consists of net sown

area, current fallow land & other than current fallow land. Area under agriculture increase from 1977 to 1999. It changes from 71.09 % in 1977 to 72.16 % in 1999. But in year 2008 there drastic change in area, it reduced up to 67.78 %.

Settlement (urban built up area) increase over time period, which is 5.71 % in 1977 increase to 6.97 % in year 2008. In Ganganagar there many agriculture related industry established, which leads to increase in settlement area. Forest area in Ganganagar is very low; it is low as only 4 % in 1977. It slightly increases to 7.48 % to total area in 2008. Canal area increase over time period.

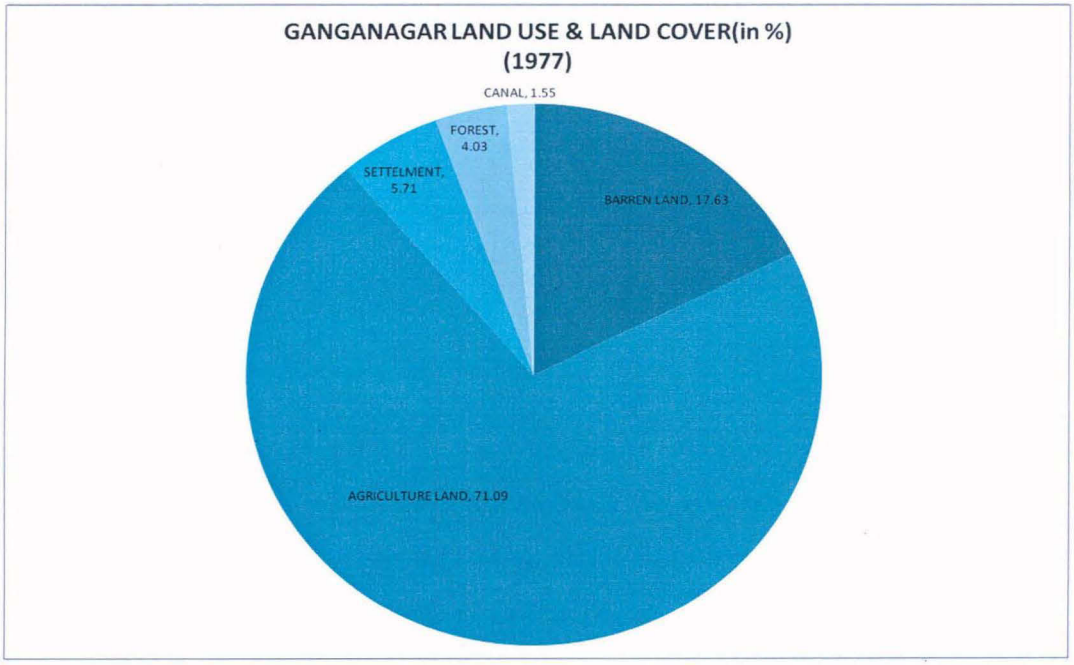


Figure: 4.1 Ganganagar Land Use & Land Cover (in %) (1977)

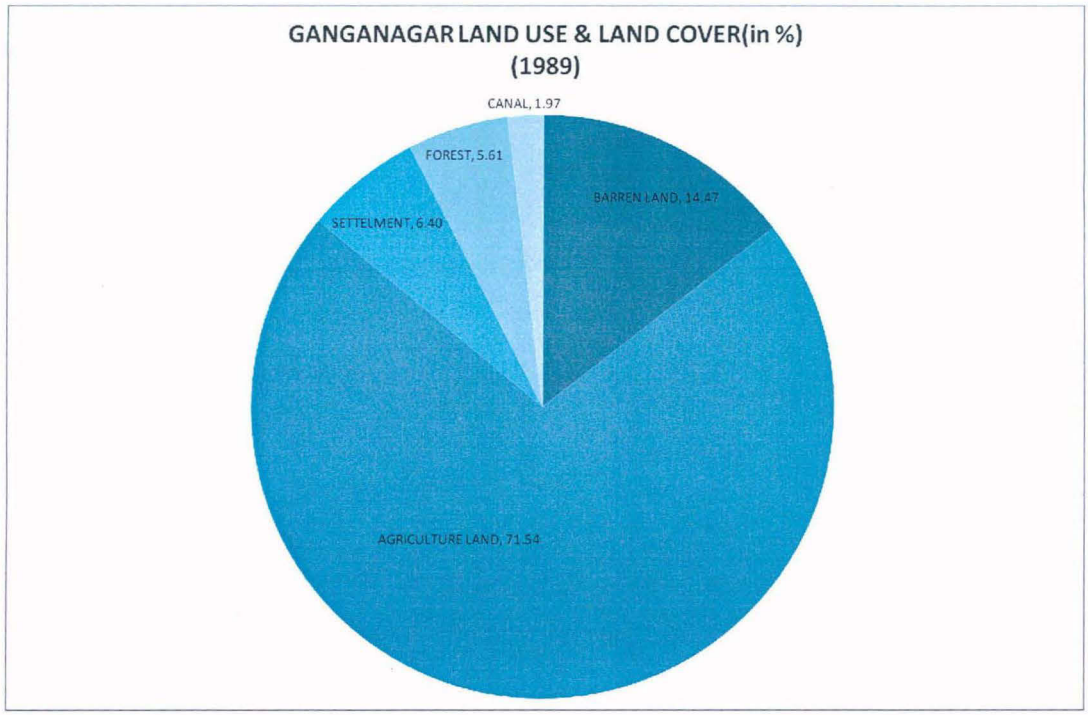


Figure: 4.2 Ganganagar Land Use & Land Cover (in %) (1989)

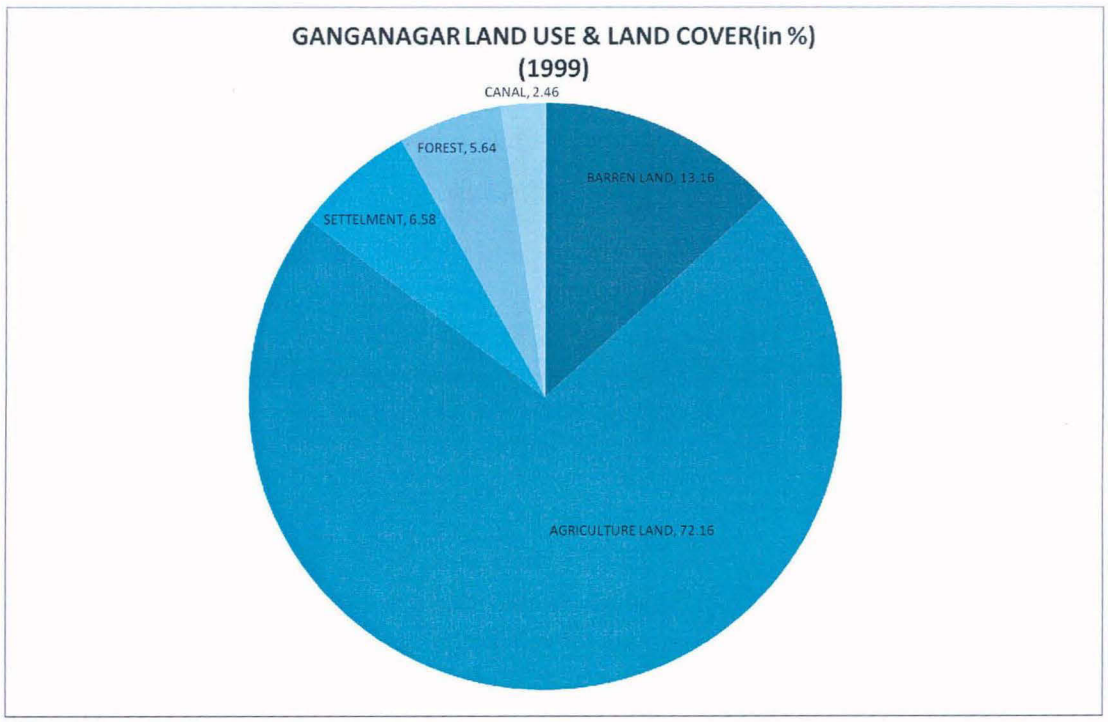


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Figure: 4.3 Ganganagar Land Use & Land Cover (in %) (1999)

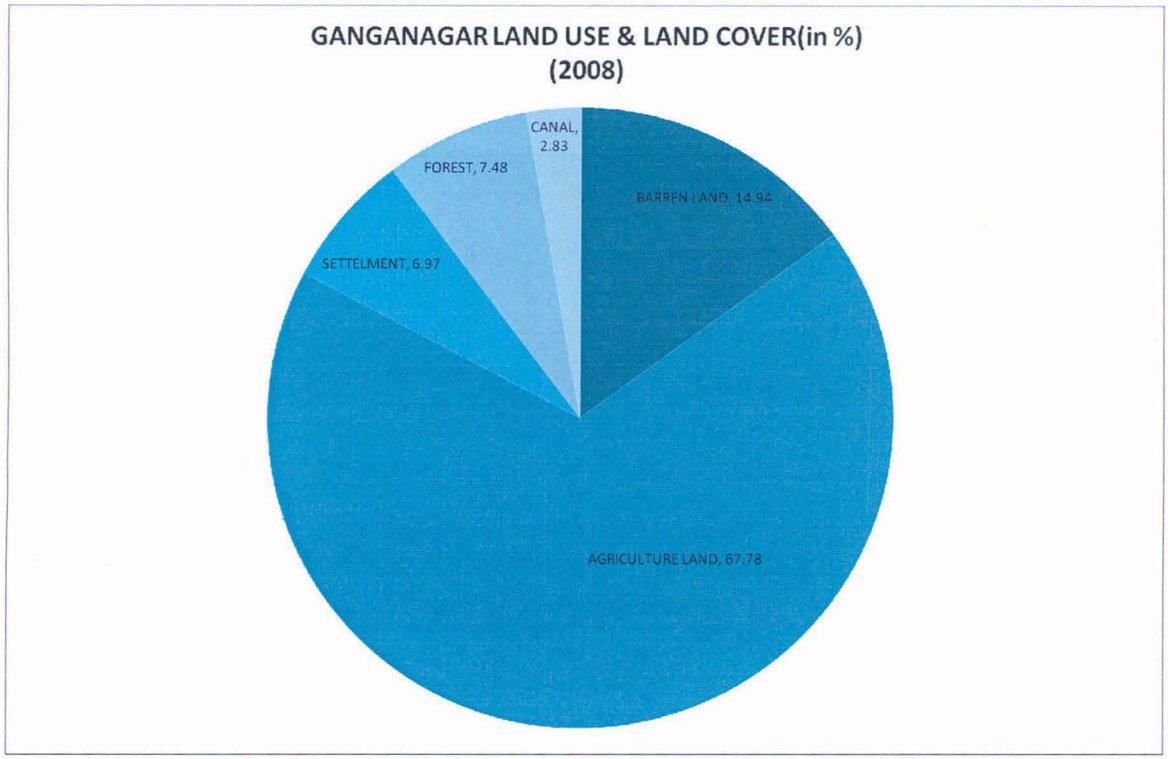
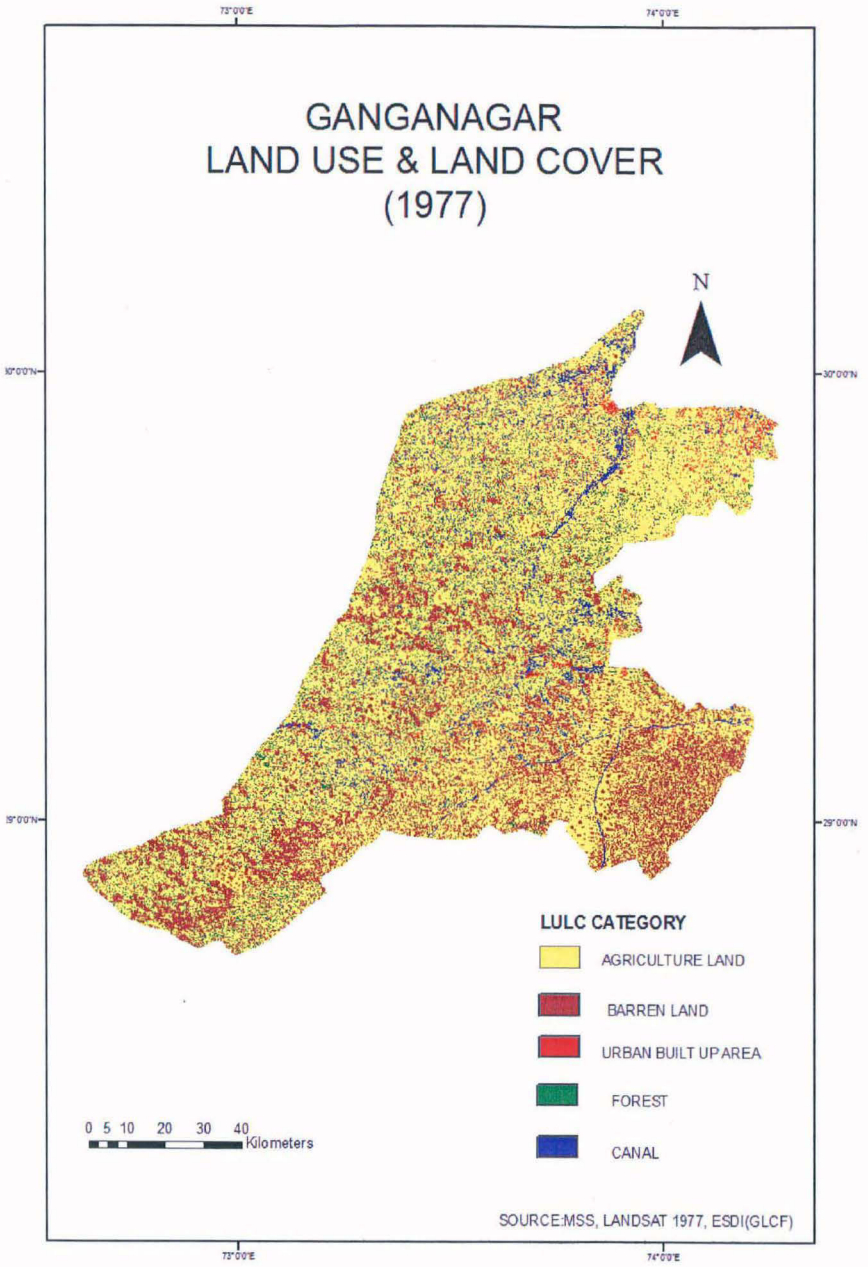


Figure: 4.4 Ganganagar Land Use & Land Cover (in %) (2008)

In Ganganagar land use & land cover clearly show the agriculture area increase from 1977 to 1989 & again increase in 1999. But in the year 2008 it reduced, barren land reduced during first two time change, but increase in last time change. Surrounding of canal area there water logging problems increase, which leads to problems of development of Sam in this area. Salinity in Ganganagar increase over the time period. This spotted as blue spotted in the unsupervised classification of Gnagaganagar map surrounding to canal irrigate area.



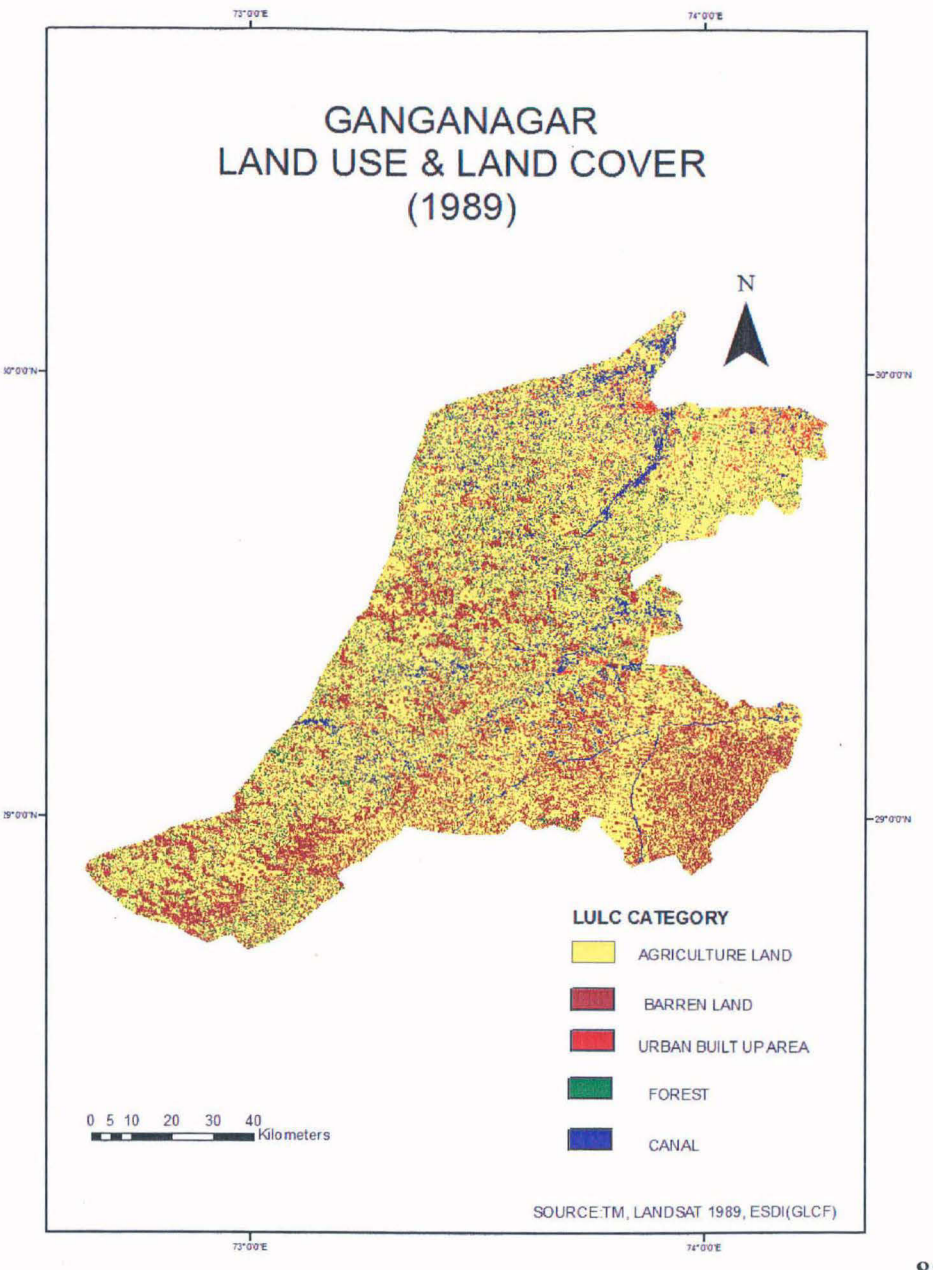
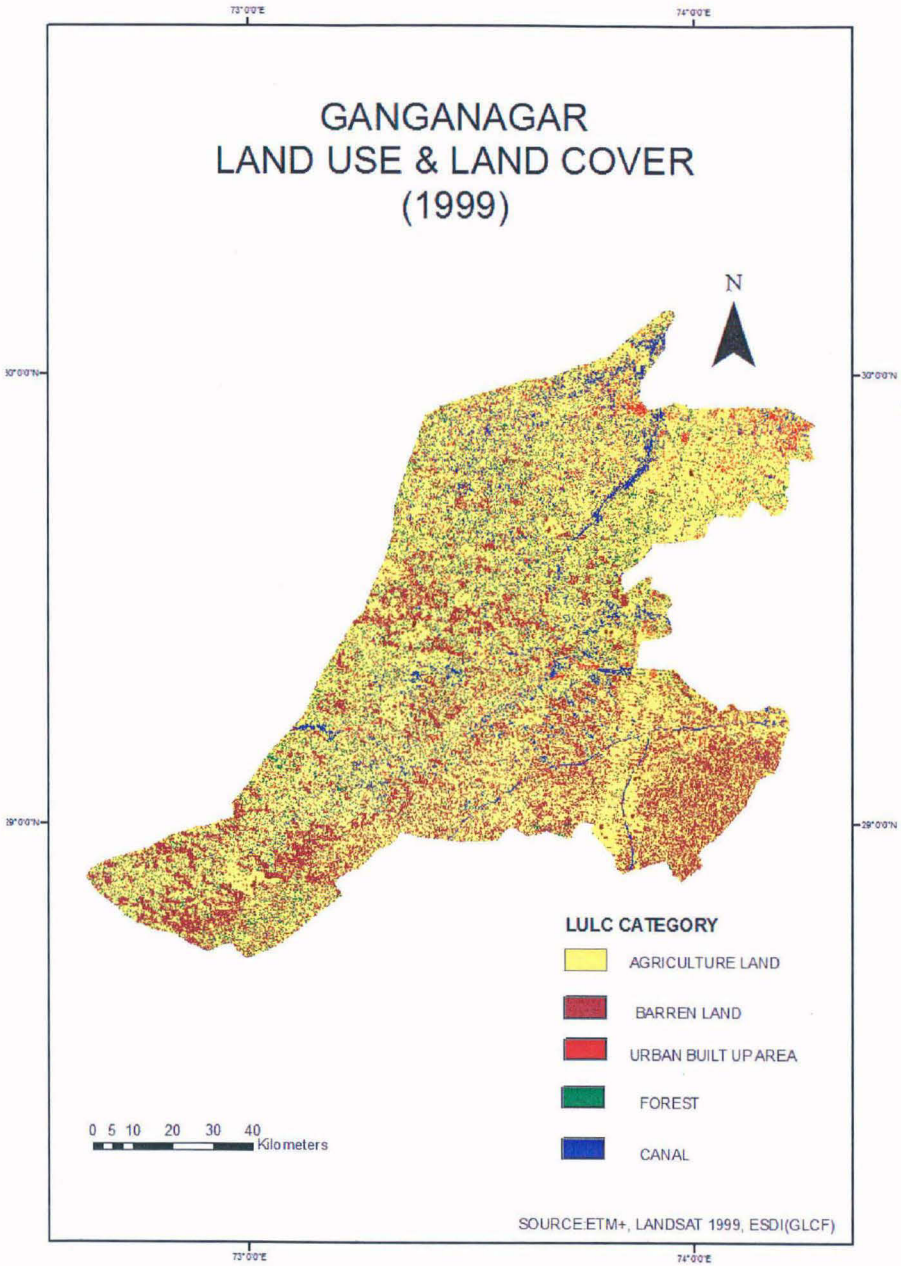


Figure 4.5 Ganganagar Land Use & Land Cover 1979 & 1989



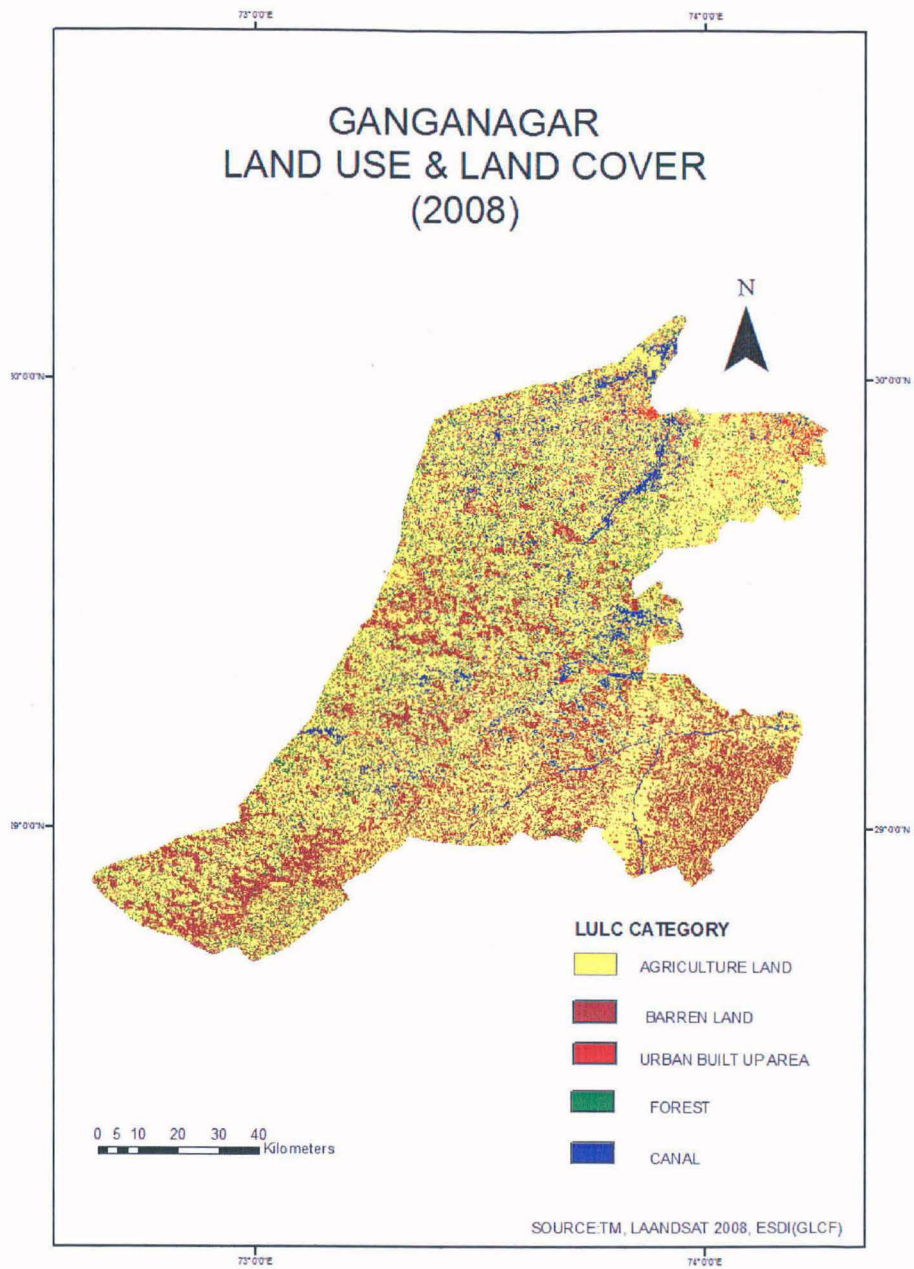


Figure 4.6 Ganganagar Land Use & Land Cover 1999 & 2008

4.3.2 HANUMANGARH DISTRICT: Hanumangarh district is located between 28o 45' 35" and 29o 57'25" latitude and 74o 17' 51"and 74o 31' 04" longitude covering an area of 9659.09 sq.km. The district is part of Bikaner Division. Administratively the district is divided into 7 tahsils and 3 development blocks. In Hanumangarh barren land in 1977 was 52310 hectare, which composes 5.94 % of total area. Barren land reduced in year 1989 & 1999 respectively 3.74 % & 2.91 %. This is show impact of Indira Gandhi canal in Hanumangarh district. Similar to Ganganagar district Hanumangarh also show increase in barren land. This barren land as form of saline land, hard pan & water logged area. In this area this problem mainly known as 'Sam'. In recent years this problems increase very rapidly.

Table 4.3 Hanumangarh Land Use & Land Cover (area in hectare)

HANUMANGARH LAND USE & LAND COVER(area in hectare)				
	YEAR			
CATEGORY	1977	1989	1999	2008
BARREN LAND	52310	32910	25678	38753
AGRICULTURE LAND	770930	784467	772706	737871
SETTELMENT	25678	27817	38988	48111
FOREST	14304	17603	21320	31668
CANAL	17761	18185	22290	24580
TOTAL	880983	880983	880983	880983

Agriculture area in Hanumangarh is 87.51 % in 1977, which highest in year 1989 is 89.04 %. Than it decrease to 87.71 in next time period. Than it considerably reduced in year 2008 is 83.76 %. Agriculture area near canal area change in barren & saline land. Nohar & Bhadra show highest barren land changes during this time period. Barren land shows increase the land degradation problems in area.

Table 4.4 Hanumangarh Land Use & Land Cover (area in %)

HANUMANGARH LAND USE & LAND COVER(area in %)				
	YEAR			
CATEGORY	1977	1989	1999	2008
BARREN LAND	5.94	3.74	2.91	4.40
AGRICULTURE LAND	87.51	89.04	87.71	83.76
SETTELMENT	2.91	3.16	4.43	5.46
FOREST	1.62	2.00	2.42	3.59
CANAL	2.02	2.06	2.53	2.79

Urban built up area (settlement) increase over time period, but it is lower than Ganganagar district. Forest area in Hanumangarh is very low; it is less than Ganganagar district. In 1977 there is only 1.62 % geographical area under forest, it increase very slightly up to 3.59 5 after 30 years. Canal area increases over time period. It increases to 24580 hectare in year 2008.

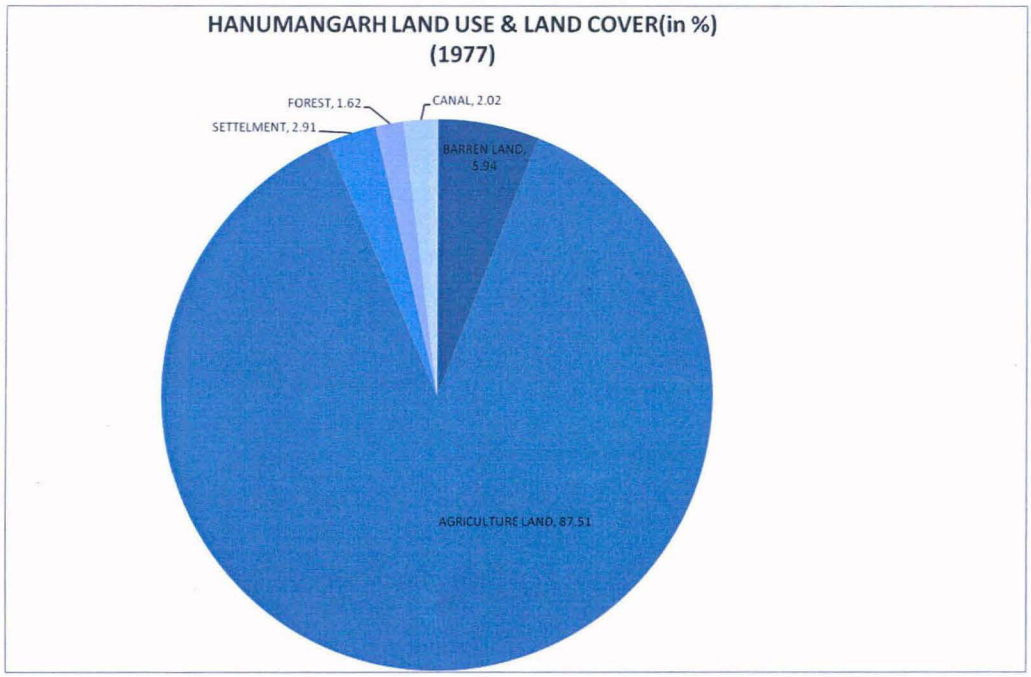


Figure: 4.7 Hanumangarh Land Use & Land Cover (in %) (1977)

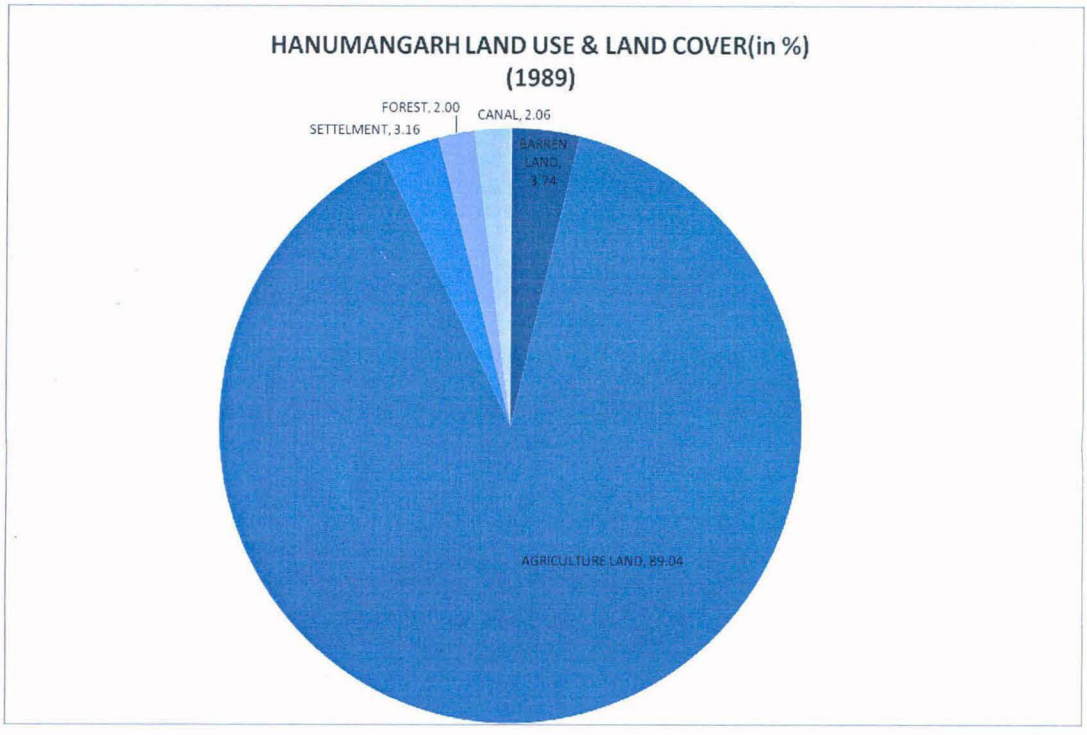


Figure: 4.8 Hanumangarh Land Use & Land Cover (in %) (1989)

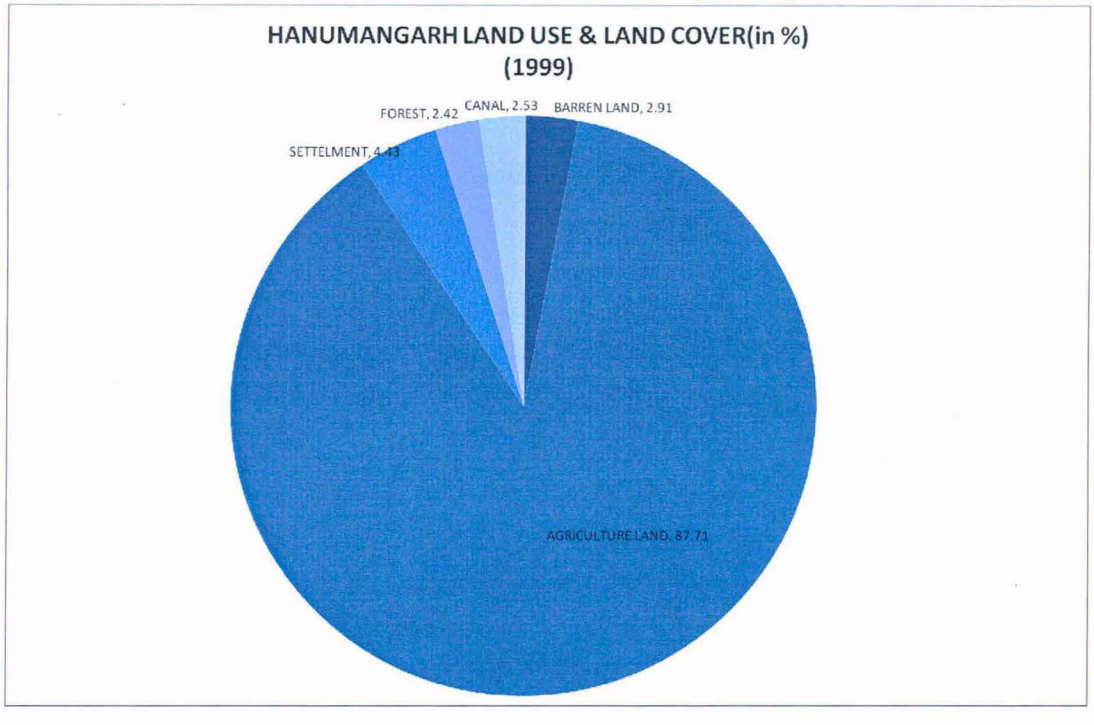


Figure: 4.9 Hanumangarh Land Use & Land Cover (in %) (1999)

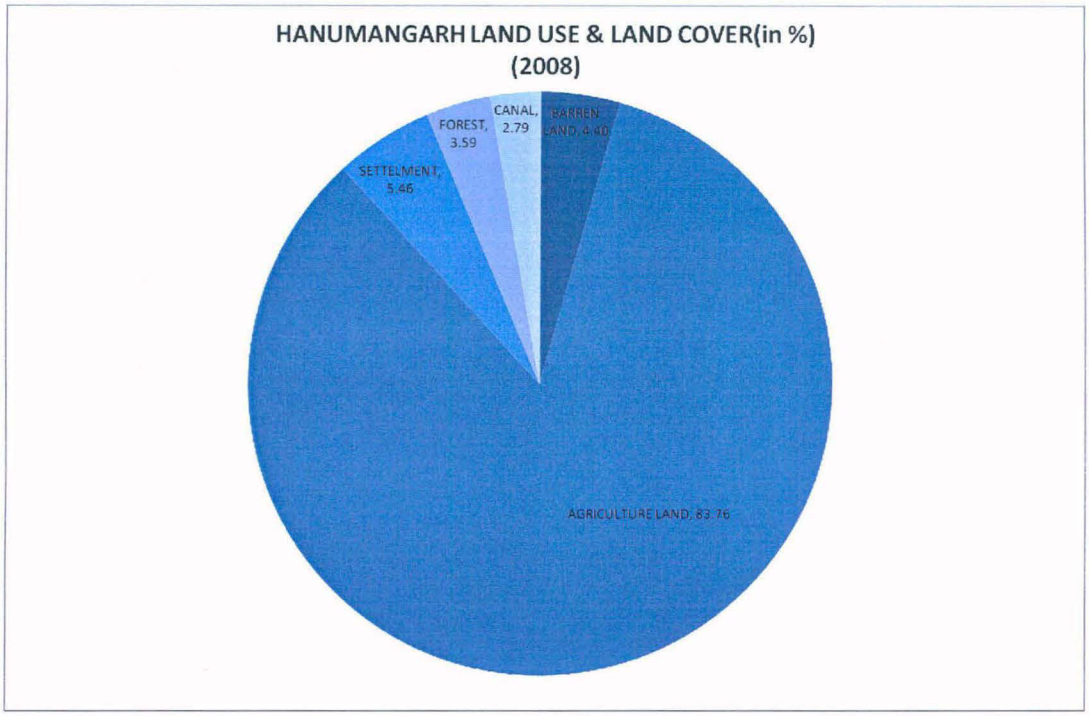
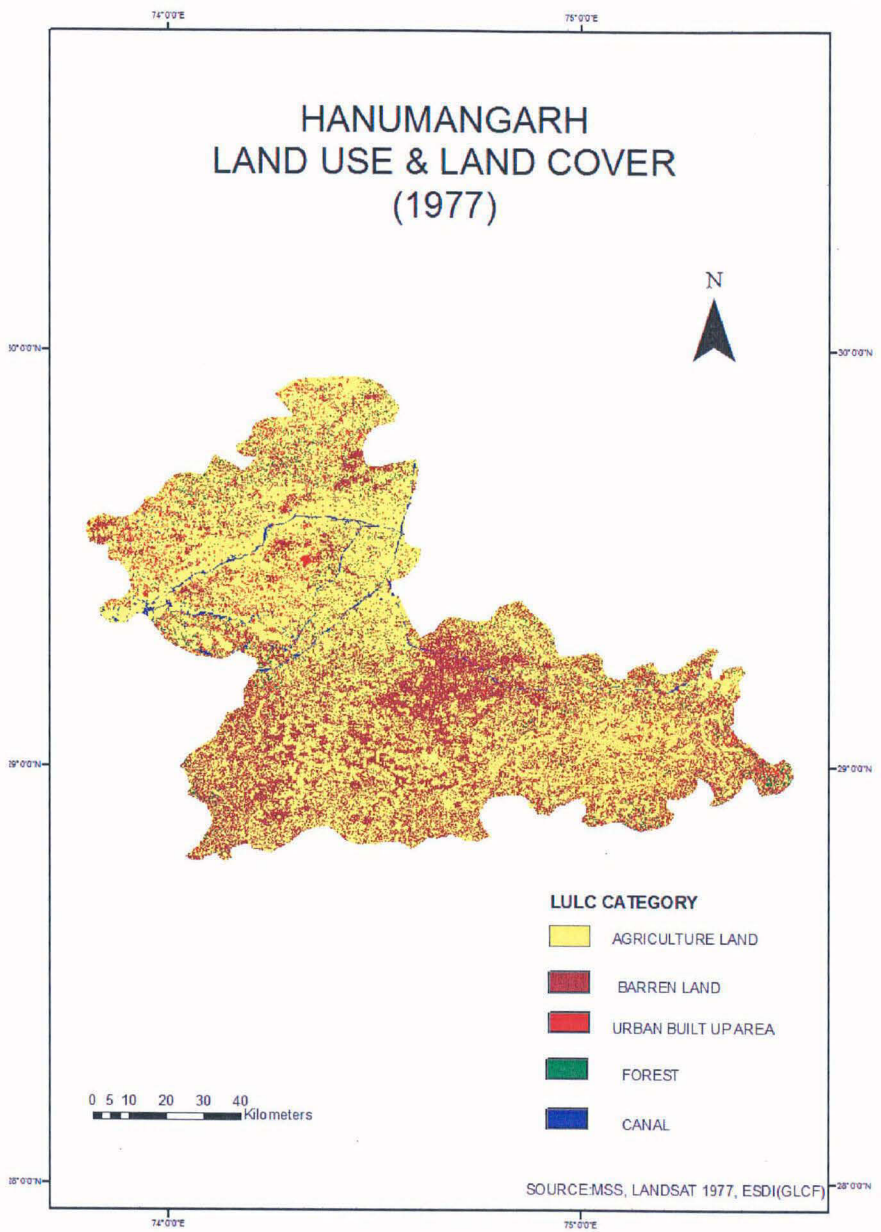


Figure: 4.10 Hanumangarh Land Use & Land Cover (in %) (2008)

Hanumangarh is starting point of Indira Gandhi canal in Rajasthan. In unsupervised classification there show the agriculture land increases over time period. This maximum change occurs during 1977 to 1989, than 1999. In year 2008 there reduction in agriculture area in Hanumangarh district compare to previous time period. Barren land reduced in first two time period. Than it increases in next time period. This increase in mainly associated with problem of Sam in Hanumangarh district. Hard pan which contain the layer of gypsum, cause the accumulation of water surrounding canal area. This lead to increase in the water logging problem in irrigated area of Indira Gandhi canal. Increase of barren land in Hanumangarh to compare to Ganganagar is high.



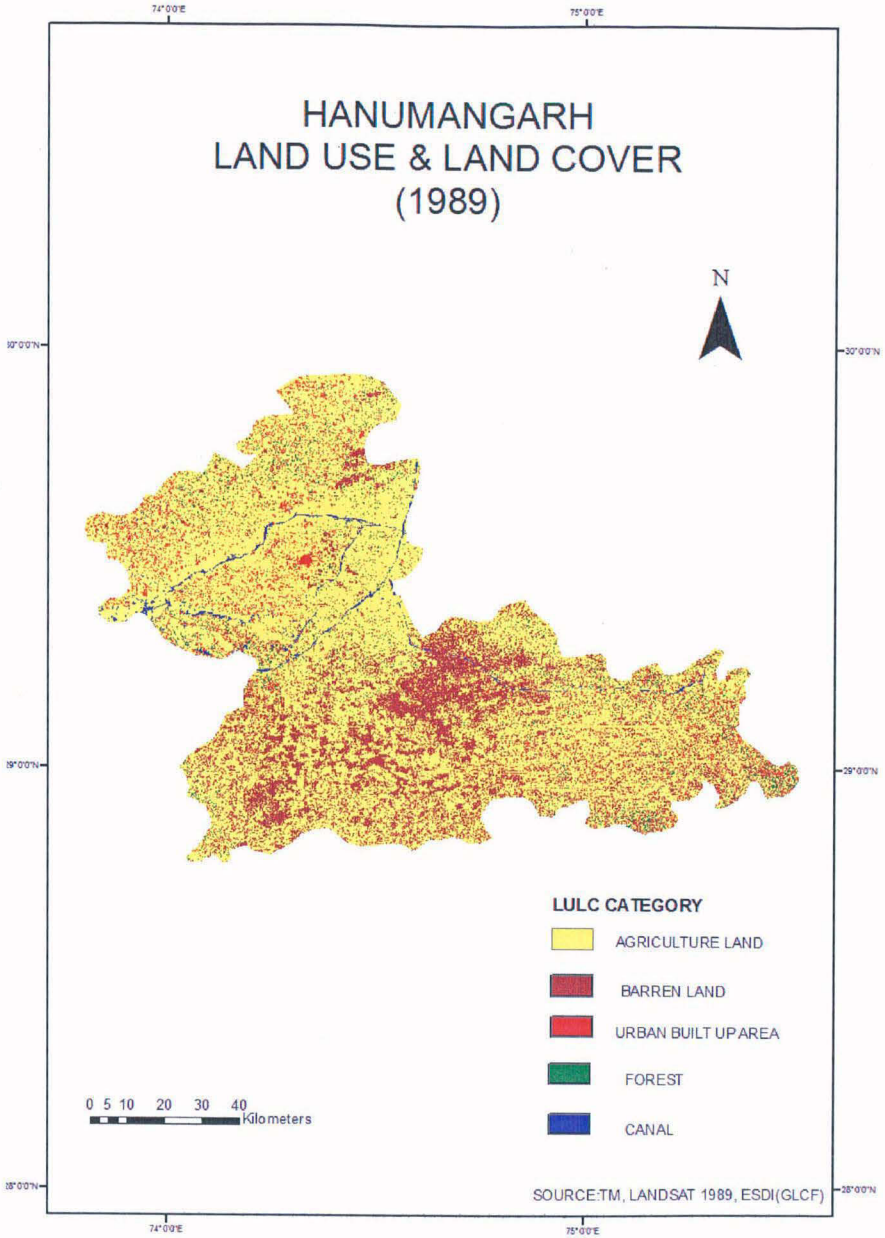
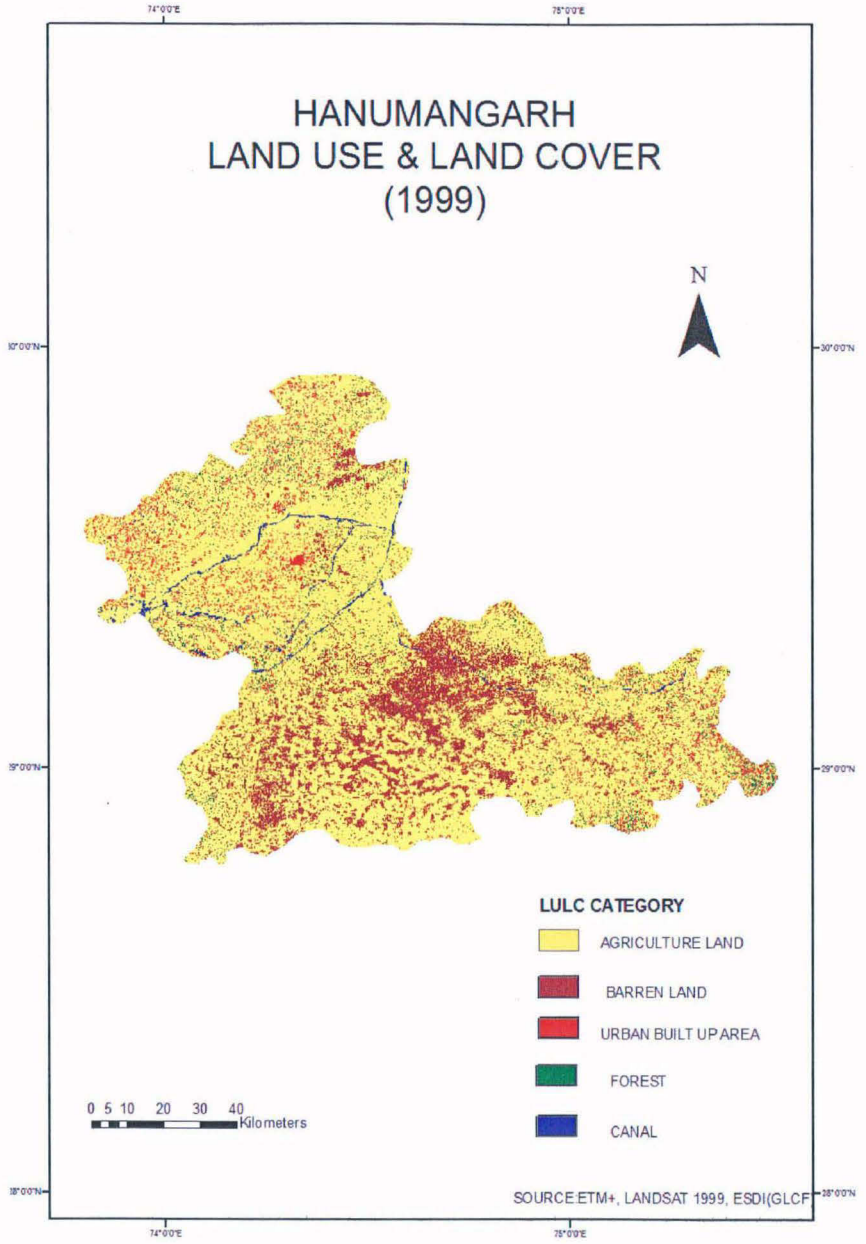


Figure 4.11 Hanumangarh Land Use & Land Cover 1977 & 1989



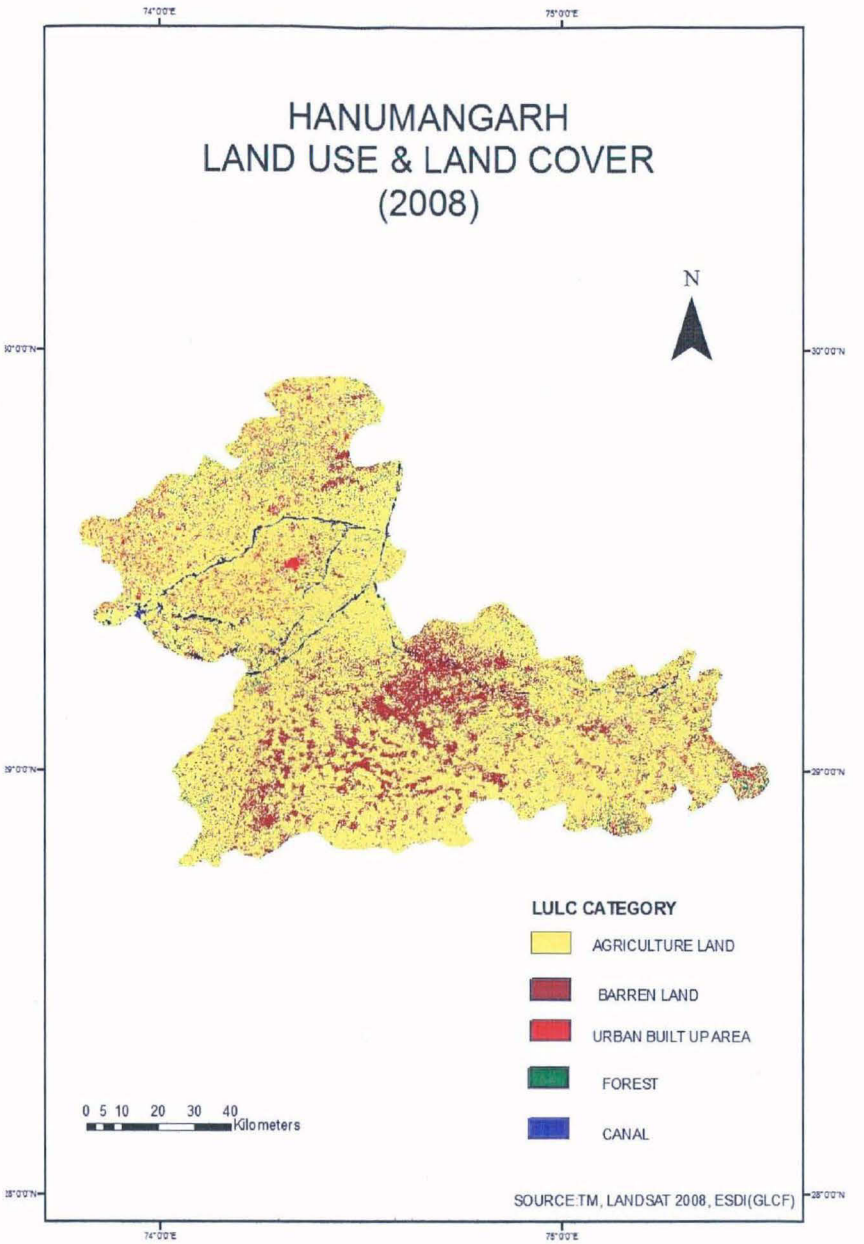


Figure 4.12 Hanumangarh Land Use & Land Cover 1999 & 2008

*4.3.3 **BIKANER DISTRICT:*** Bikaner district is located in the north-western part of Rajasthan and encompassed between north latitudes 27°11' to 29°03' and east longitudes 71°52' to 74°15' covering geographical area of 30247.90 Sq. km. It is bounded on the north by Ganganagar District, on the east by Churu and Nagaur Districts, on south by Jodhpur and Jaisalmer districts and on the west by International border with Pakistan. There sandy deserted landscape along with rocky outcrop prevailed. Before introduction to Indira Gandhi canal there barren land found in most of part of Bikaner. In year 1977 there is barren land as high as 50 % in Bikaner district. Which is highest than other two study area. After introduction of Indira Gandhi canal area, there landscape changes from barren land to agriculture area. Indira Gandhi canal reached up to middle of Bikaner district in year 1977. Indira Gandhi canal water use for mainly drinking & irrigation purposes. In 1977 there mainly water reached in two tahsils namely Lunkaransar & Bikaner. Afterward it reaches all four tahsils. Agriculture is low in year 1977 which consist only 42.76 % of total geographical land area. In year 1989 there not very much increases in agriculture land area. It goes up to 43.57 % of total geographical area.

Table 4.5 Bikaner Land Use & Land Cover (area in hectare)

BIKANER LAND USE & LAND COVER(area in hectare)				
	YEAR			
CATEGORY	1977	1989	1999	2008
BARREN LAND	1350683	1249989	841187	749093
AGRICULTURE LAND	1162510	1184598	1536003	1565451
SETTELMENT	87764	104852	140954	143076
FOREST	88367	119272	122556	145685
CANAL	29220	59833	77844	115238
TOTAL	2718543	2718543	2718543	2718543

Impact of Indira Gandhi canal now clearly visible on deserted land of Bikaner in recent decades. There barren land reduced from 45.98 % in 1977 to 30.94 % in 1989. First time in year 1989 agriculture land area surpasses barren land. It increases up to 56.50 % to total geographical area. In next time period there increase in not very high, it reaches only 57.58 % in year 2008.

Table 4.6 Bikaner Land Use & Land Cover (area in %)

BIKANER LAND USE & LAND COVER(area in %)				
	YEAR			
CATEGORY	1977	1989	1999	2008
BARREN LAND	49.68	45.98	30.94	27.55
AGRICULTURE LAND	42.76	43.57	56.50	57.58
SETTELMENT	3.23	3.86	5.18	5.26
FOREST	3.25	4.39	4.51	5.36
CANAL	1.07	2.20	2.86	4.24

Bikaner district is main center of industrial activities in colonial time period. Settlement compare to another two district is high in Bikaner district. It increases progressively through time period. Chaudhary (1996) examine the settlement development in Indira Gandhi canal command area in Thar Desert. It was expected that the canal irrigation would put the economy of desert area on new footing by enabling intensive cultivation. Forest area in Bikaner is high comparing two another district of Indira Gandhi canal areas. Alongside Indira Gandhi canal area there forest covers increase over time period. In 1977 it is 88367 hectare, which increases to 145685 hectare in year 2008. Canal area is also increase over time period. Main canals, branches, sub branches increases over time period.

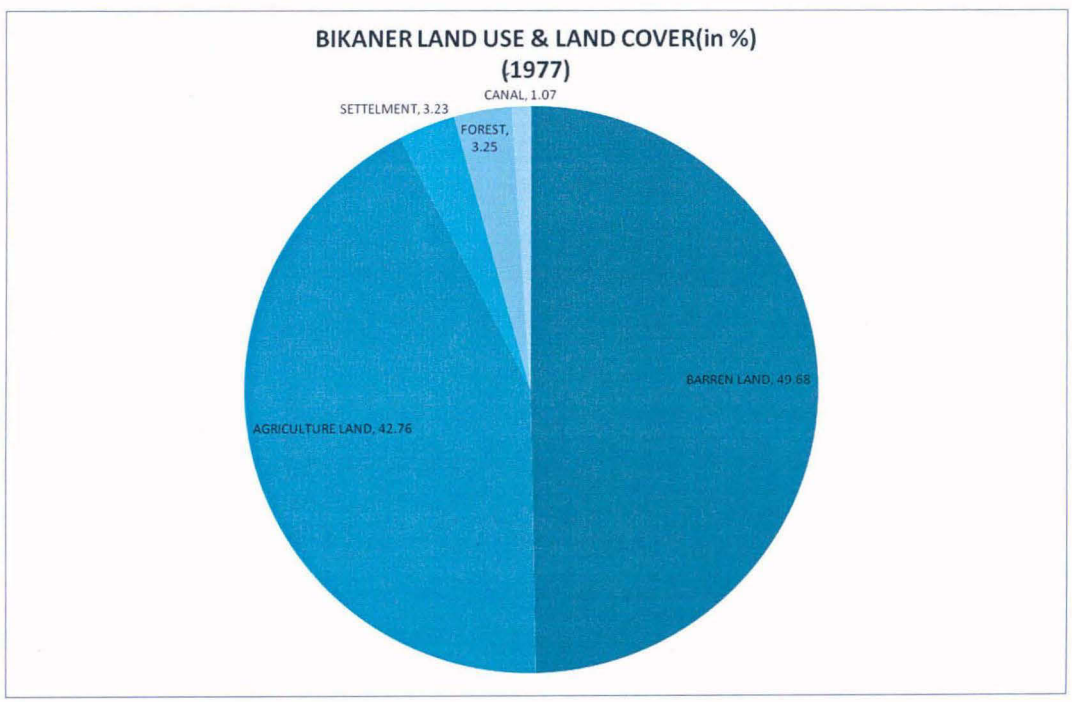


Figure: 4.13 Bikaner Land Use & Land Cover (in %) (1977)

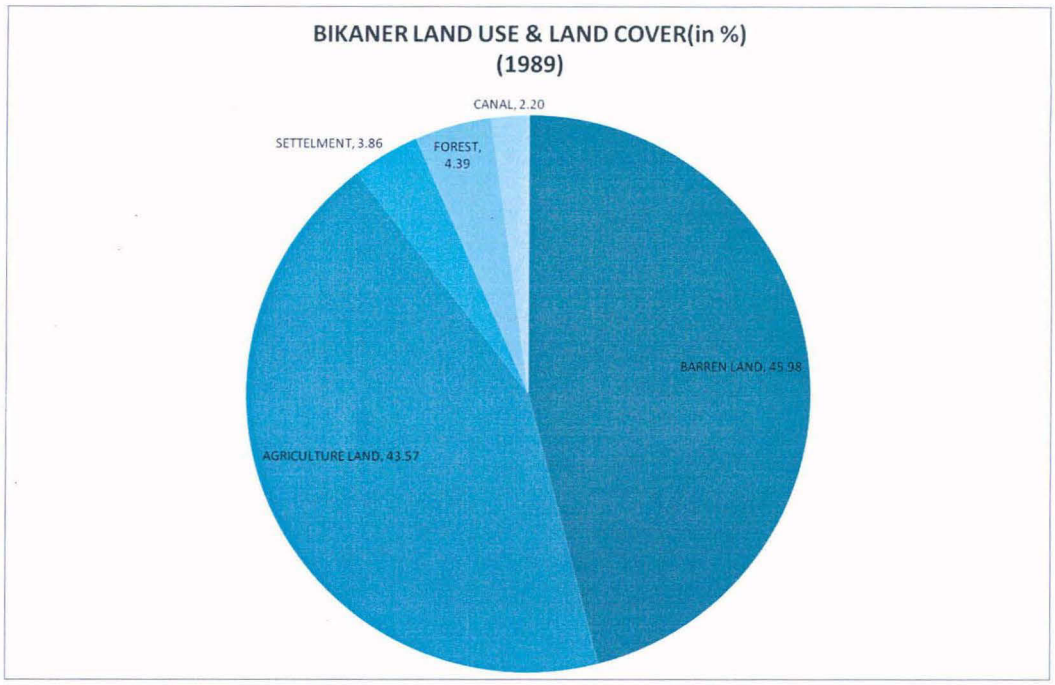


Figure: 4.14 Bikaner Land Use & Land Cover (in %) (1989)

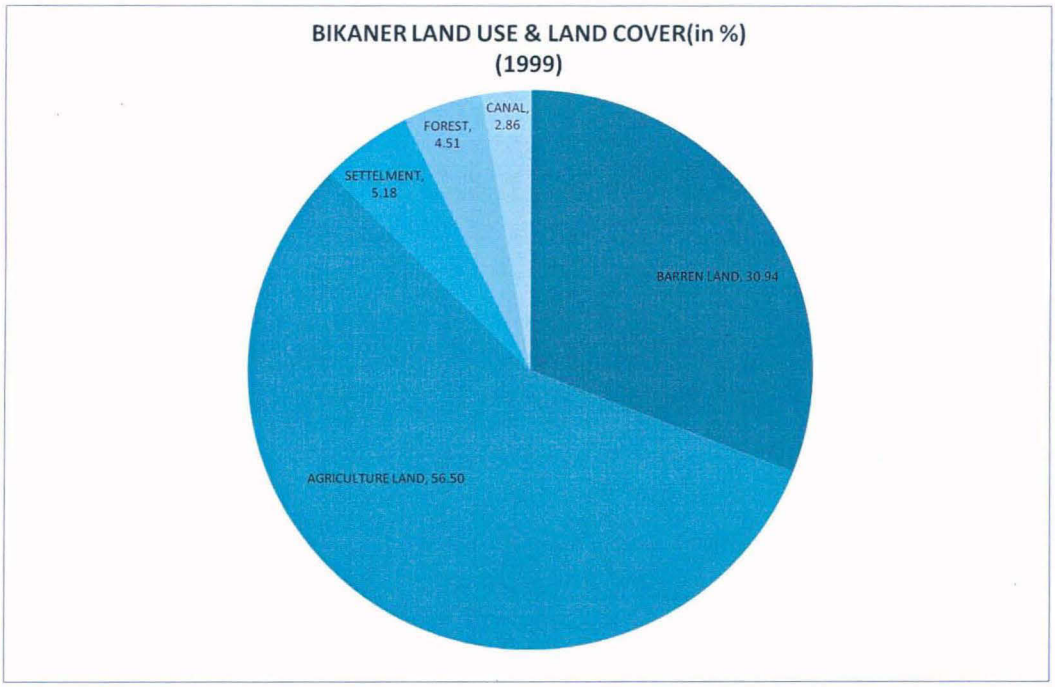


Figure: 4.15 Bikaner Land Use & Land Cover (in %) (1999)

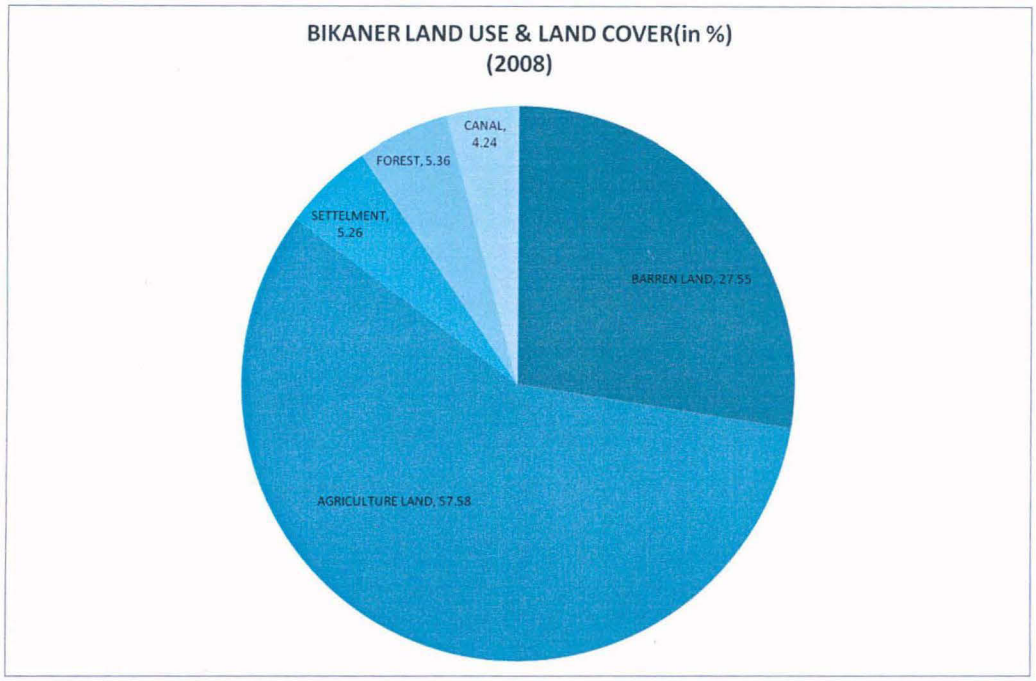
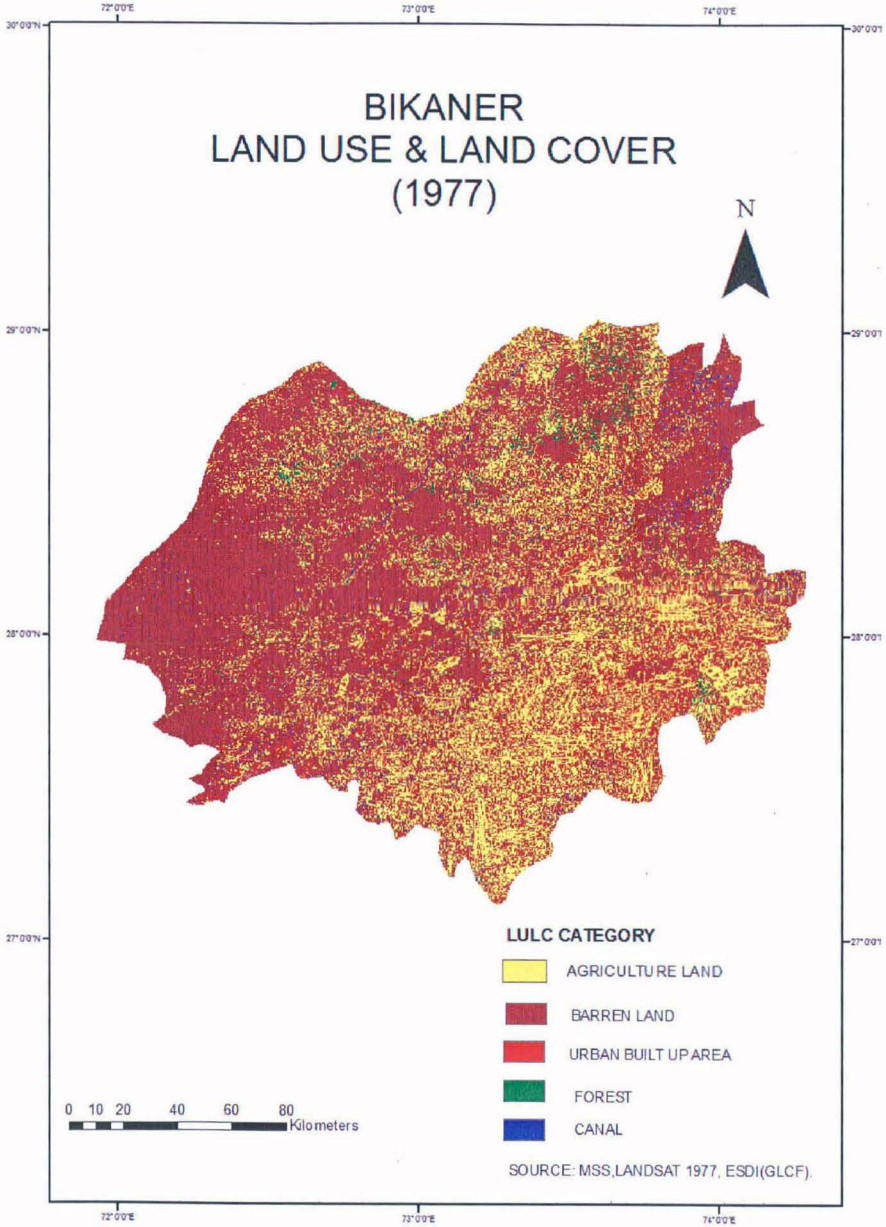


Figure: 4.16 Bikaner Land Use & Land Cover (in %) (2008)

Bikaner is located in western part of Rajasthan. There mainly barren area mainly sand dunes, which not suitable for agriculture is high. After introduction of canal in desert land of Bikaner, agriculture area increase all time period. Earlier, where is very low agriculture, which depends upon traditional source of water resources. After canal introduction area increase significant, this leads to increase in the area of forest in Bikaner district. Some area of stage 1 show increase in problem of water logging & salinity. But it mainly confined in northern side of district. Barren land reduced over time period. This barren land converted into agriculture land use of water from Indira Gandhi canal. Than Bikaner is now converted into a green pasture in deserted land of western Rajasthan.



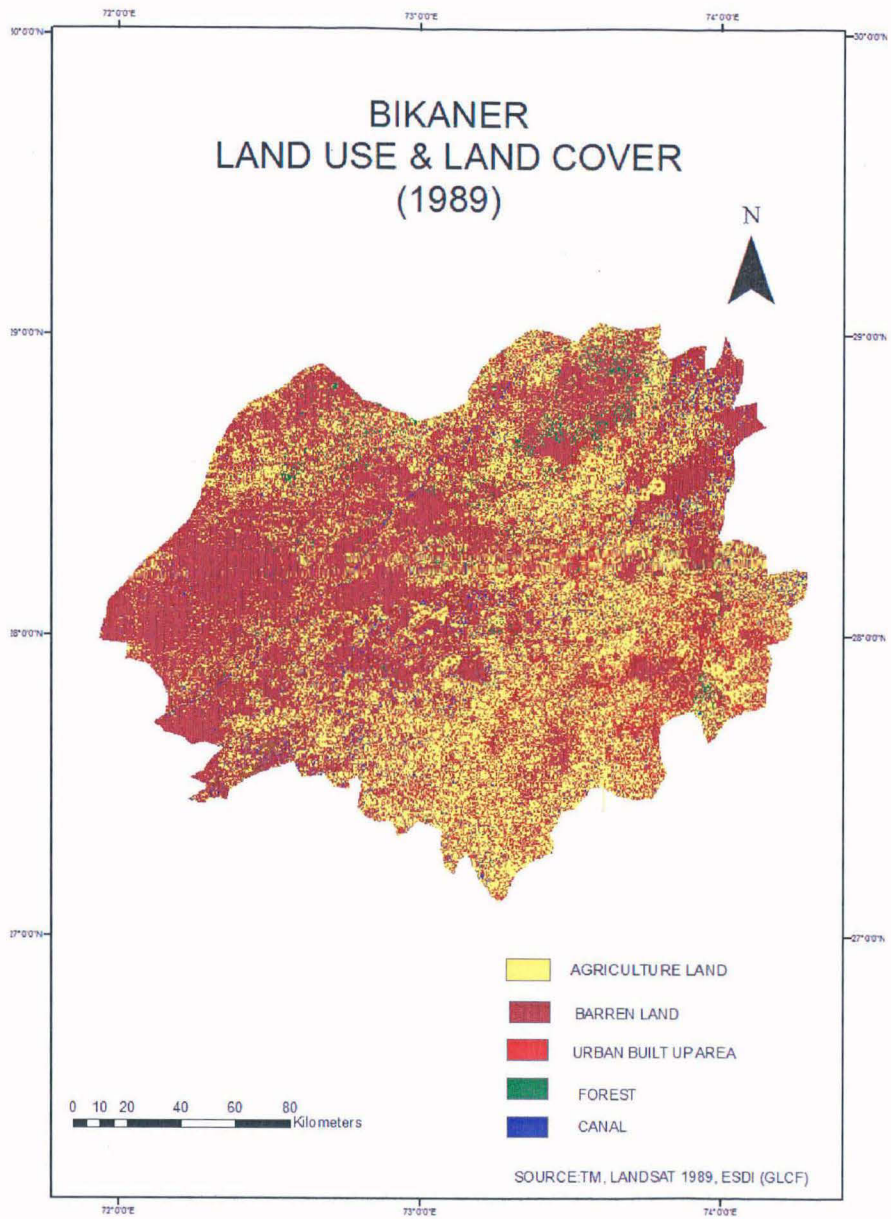
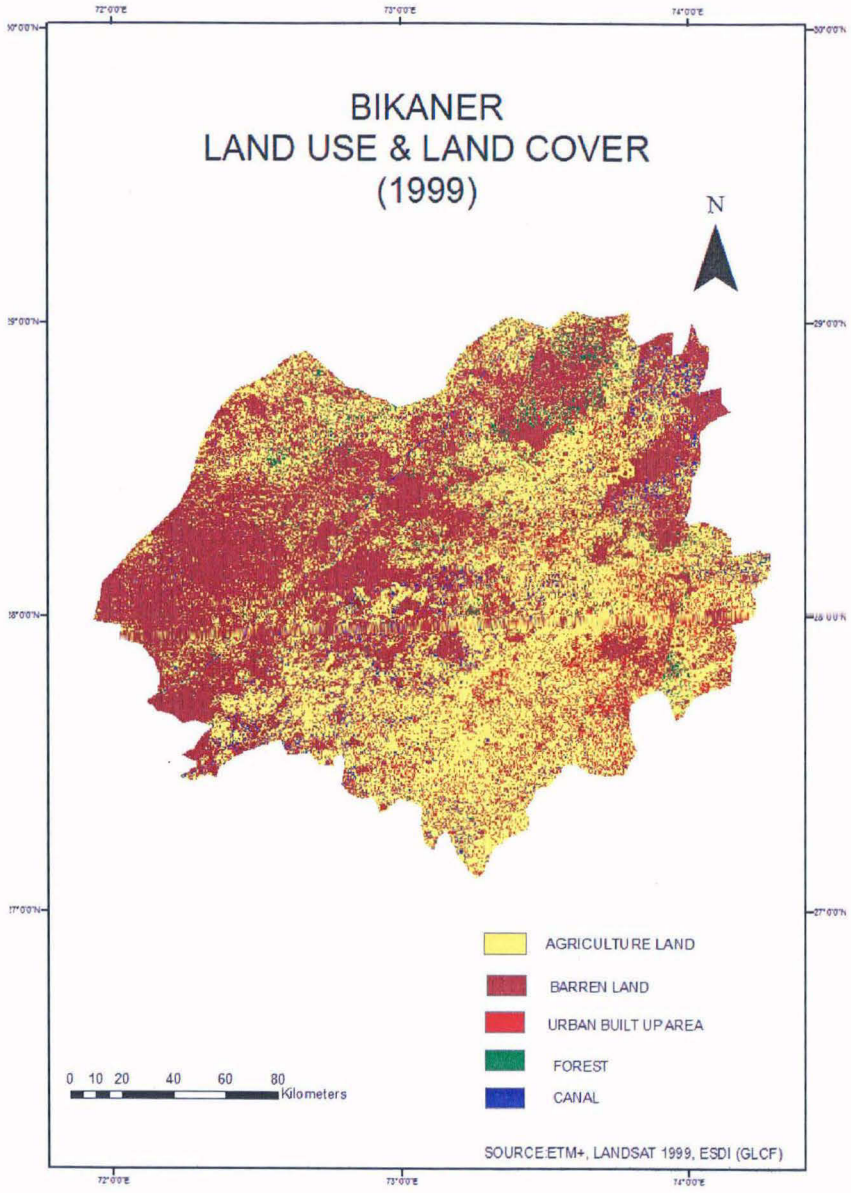


Figure 4.17 Bikaner Land Use & Land Cover 1977 & 1989



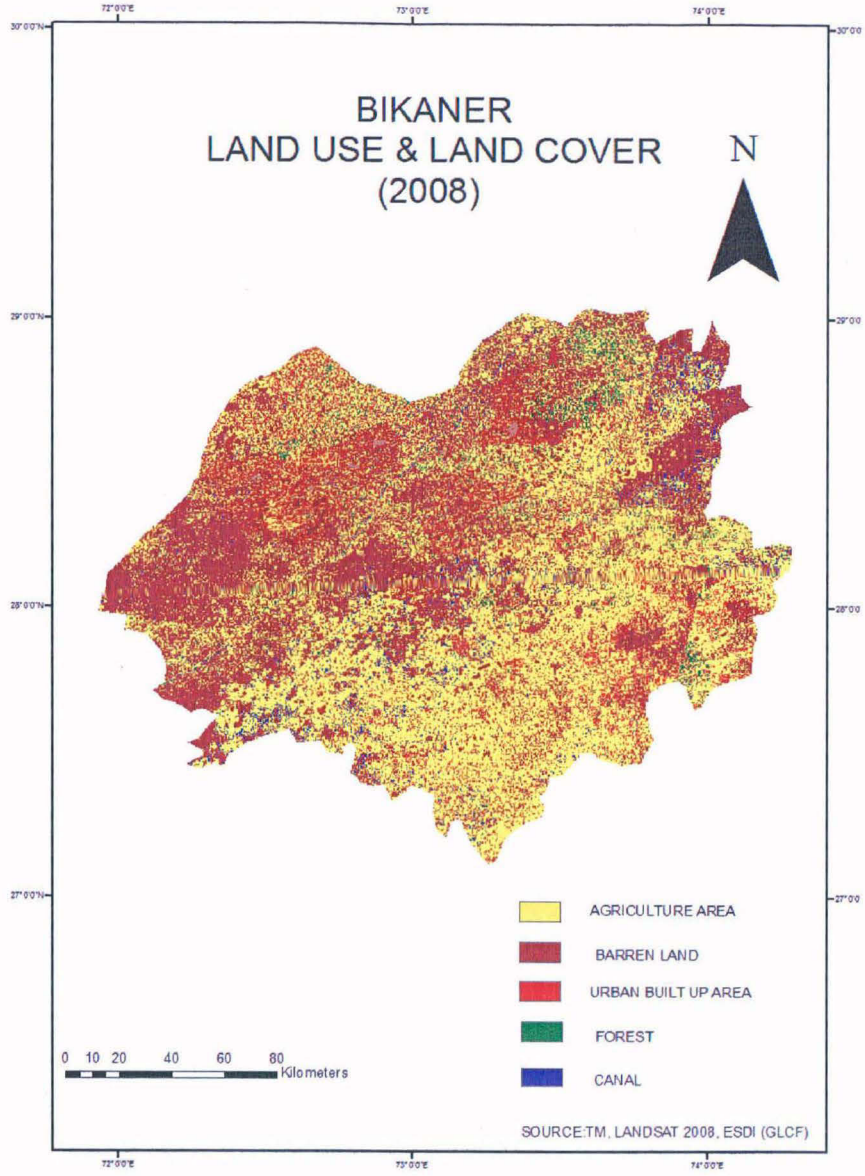


Figure 4.18 Bikaner Land Use & Land Cover 1999 & 2008

4.4 SALINITY & WATERLOGGING PROBLEM IN IGNP:

The Indira Gandhi Canal is one of the biggest canal projects in India. The Indira Gandhi Canal Project was conceived in April, 1948 with the noble aim of improving the living condition of human being and to cater to the minimum needs of cattle populations in the region. It starts from the Harike Barrage at Sultanpur, a few kilometers below the confluence of the Sutlej and Beas rivers in Punjab state. It runs south-southwest in Punjab and Haryana but mainly in Rajasthan for a total of 650 kilometers and ends near at Ramgarh, near Jaisalmer, in Rajasthan.

As the work on construction of stage 2 project was in progress apprehension were raised about non suitability of the area for irrigation, particularly on two grounds. Firstly, the area was not considered suitable for irrigation on account of poor quality soil & existence of sand dunes. Secondly it was feared that the area is underlined by thick layer of kankar at shallow depth, which would not allow the percolating irrigation water to join good water & cause perched water table.

The high salinity of ground water resources as manifested at present in greater part o command restrict the scope for development of ground water for adoption of mixed water management , expect to a limited extent, in view of the large proportion of canal water requirement for dilution to make the water usable. There is possibility of upcoming of saline water and fresh water interface and contamination of ground water in future aquifers, built up over the present aquifers, with inferior quality of water unless pumping is controlled and preventive step taken.

The presence of kankar layer, clay, shale and compact sandstone of low permeability, where present, between the interface the well depth, will restrict the rise of the interface, which will be in the form of an inverted cone at certain depth below the bottom of pumping well. Where water logging and Salinisation of ground water occur a vertical or inclined interface will develop. The movement of inter face will be accelerate if well are not located at safe distances from interface. The disturbance to the hydrodynamic balance between the fresh water and saline water can be reduced if pumping is done from dug wells rather than tube wells, ass the former, by virtue of shallower depth and larger diameter, will be skimming off fresh water layer.

When the interface between fresh and saline water is vertical, symmetrical well system is installed, one each on either side of interface. It may be noted that re use within pumping trough of ground water recycled from repeated irrigation will result in progressive deterioration in ground water quality. At present, the ground water moves in north westerly to

westerly direction under low hydraulic gradient ranging mostly from 0.5 to 2.0 m/km, with local variations. It is likely that hydraulic gradient may increase with porosity of large sub surface drainage across the international border. However, the density of observation wells is too low to accurately delineate the form of water table. The profile of the water table broadly conforms to natural land surface profile. Pre irrigation water levels were more or less stable with seasonal and cyclic fluctuations.

However, people in some quarters raised serious doubts about the suit-ability of the arid lands, termed "fragile lands," for intensive agriculture and challenged the use of irrigation on these lands, on the grounds that the light sandy soils of the desert may be unsuitable for irrigated farming or for any type of intensive cultivation. Also, large parts of the region have hardpan at shallow depths. Irrigated farming under these conditions increases the risk of soil erosion, desertification, water logging, and salinisation (Ramanathan and Rathore 1994). These objections were overruled by the state government (Vyas, V.S., 2004). It pointed out that improvement in the vegetation cover and the extension of afforestation (which would be possible with the supply of water assured through irrigation) would stabilize sand dunes and halt the process of desertification. Similarly, the occurrences of hardpan at shallow depths would call for a more judicious use of water, which was seen as a blessing in disguise.

Initially, the project area had a deep water table, and the provision of drainage was not included in the original development plan. When the Environmental Impact Assessment (EIA) was not considered important for IGNP, nor was an EIA ever made (Sharma, K.D. 2001). Monitoring of the water table was also not a high priority. Therefore, it took until 1973 for awareness of the problem to reach the stage whereby systematic monitoring began, and the monitoring network was considerably expanded in the early 1980s. As per the irrigation terminology (Sharma, 1999), about 54% of the Stage I area was "potentially sensitive", 4% of the area "critical" and 3% of the area water logged during the year 1998. The mean water table rise is 1.1 m per year and nearly 3960 sq km will be liable to water logging by the end of 2001 (Sharma & Mathur, 1991). However, a far more serious water logging problem is likely to appear in Stage II. Owing to an underground hard substratum of gypsum within 10 m of the surface, about 34%o of the area (1205 sq km) is vulnerable to water logging (Rahmanai & Soni, 1997). According to Chauhan (1988), thousands of hectares of land will be submerged in 25 to 30 years. In Lune-ki-dhani, Dabli Kalan, Dabli Khurd and Rampur villages in Stage I and near Madasar village in Stage II, 0.6-3.5 m water is standing in the cultivated fields. The houses have collapsed and villages are abandoned.

The impact of water logging in IGNP is mainly on the individual farmers whose land is affected.

Table 4.7 Water Logged Area in IGNP (in hectare)

WATER LOGGED AREA IGNP(in hectare)					
Category	Year				
	1994	1995	1996	1997	1998
Stage I					
Waterlogged	13750	9680	10192	14750	17220
Critical	22000	17760	18970	20670	24140
Potentially sensitive	292960	160760	198643	207300	297820
Stage II					
Waterlogged	1000	526	1000	800	800
Critical	4062		4500	5470	5740
Potentially sensitive	17900		19000	19000	19000
SOURCE: K. D. SHARMA (2001)					

The basic cause of water logging is an imbalance within the groundwater body underlying the affected area. The imbalance is due to the plentiful water available and the limited land developed for its use, resulting in over-irrigation in the area developed initially. Due to capillary action, the water rises to the surface with dissolved salts and evaporates, leaving the salt behind, thus leading to secondary salinisation of the soil and groundwater. In the IGNP area, the natural groundwater balance has been disturbed, and water logging has arisen due to a number of causes. These include:

1. Large percolation losses from the irrigation water applied to farmers' fields, mainly due to an increase in water supply rates, permeable soils and rudimentary irrigation practices.
2. Seepage losses from channels providing particularly large localized sources of recharge water.
3. Overuse of escape channels from the canal system, leading to extensive inundation in the areas used to dispose of the escape discharges;
4. Relatively low levels of development of the use of groundwater for irrigation (although conjunctive use of groundwater is increasing).

5. Restrictions to regional groundwater flow which lead to reduced groundwater outflow on a regional basis, with shallow low-permeability horizons producing perched water tables in some locations;
6. Some water logging is almost inevitable in the absence of natural drainage, either through surface water or groundwater systems, from the area;
7. Other localized factors (such as geomorphological features or inundation of flood waters) which exacerbate problem in some areas.

A rising water table leads to prolonged saturation of the soil at shallow depths, which strongly affects the growth and yield of crops. A high water table also leads to salinisation of the upper soil where evaporation rates are high; moisture movement from the water table to the evaporating surface at the top of the soil carries salts in solution, and these are left in the soil. In the IGNP area, waterlogged areas are characterized by:

1. Drastic reduction in yield of most crops, leading to a switch to wet-foot crops such as paddy with their larger water requirements; these produce reasonable yields for a year or two before the water logging and salinisation get too bad even for these crops.
2. Consequent fall in income for the farmers, leading to sale of assets, employment shifts from cropping their own land to livestock herding and agricultural labouring.
3. Surface inundation of the excess water results in health hazards and environmental degradation.

Scholar like Ram & Chauhan evaluates the impact assessment of IGCP on land use in Hanumangarh district. Use of multi-date IRS LISS-III data in conjunction with the topo maps and field surveys, significant changes in land use as influenced by canal irrigation, have been identified and mapped. Since the introduction of canal irrigation in 1958 about 33% district area in Hanumangarh have been brought under irrigated farming with 179% irrigation intensity. On the other hand the emergence of water logging & salinisation hazard turned about 11,000 ha irrigated double cropped land into wasteland. Further 15,300 ha area is under critical limit of water logging. A number of village settlements are deserted and people have moved to nearly safer sites (Ram & Chauhan, 2002).

Impact of Indira Gandhi Canal on crop presented by Kaswan on his paper as eco profile of crop production in IGNP command area. Farmers of the command have harvested good yields of crops for long time. After two decades of the introduction of canal irrigation, the

problem of water logging and soil Salinisation started in the IGNP command. The twin problem not only adversely affected crop production in canal command but also created ecological problems. Water scarcity due to adoption of high water requiring crops was noted in the command. Attempt has been made to assess the problem of land and water management on the one hand and high production of quality crops on the other. The growth rates of area, production and productivity of major crops have been computed using exponential function to the data for the point of time and area under study. Khetawali distributory (KWD) of Indira Gandhi Canal Project (IGCP) command was selected as the study area (Kaswan, 2010).

Indira Gandhi Canal Project in the Indian arid zone is the largest irrigation project in the world. It promised to green the desert but has also waterlogged vast tracts of land and more stands in danger of being turned saline through this process. A number of factors viz. large percolation losses from the irrigation water applied to farmers' fields, seepage losses from channels, overuse of escape channels from the canal systems, relatively low levels of groundwater development, restriction to regional groundwater flow due to subsurface barriers and absence of natural drainage, are responsible for water logging, Salinisation and disturbance of natural groundwater balance in the region. An optimal policy to control the problems associated with water logging and Salinisation includes lower water allowance, water management using efficient irrigation methods, conjunctive utilization of surface water and groundwater, planting trees and artificial drainage. In present condition adjacent area water logged along Indira Gandhi canal area. This problem mainly in Hanumangarh & Ganganagar district.

Scholar like Sharma also elaborates water logging & salinity problem in command area. A canal project, the Indira Gandhi Canal Project (IGCP), brought Himalayan waters to the xeric environment and changed it all in the past two decades. Sand dunes have become green, cattle rearing have been replaced by intensive farming, sound water harvesting practices have disappeared, and eucalyptus plantations have supplanted the native desert plants. In some areas, the water table has risen to just one meter below the surface, mainly due to a hard underground substratum of gypsum that lies at a depth of 10 m. As a result of capillary action, water rises to the surface together with dissolved salts; the water evaporates, leaving the salt behind, thus leading to secondary Salinisation of soil and groundwater. The IGNP was supposed to boost food production through water intensive crops like rice, cotton, mustard, and groundnut. But due to faulty water management and perennial seepage collections, a number of surface water bodies have formed and mosquitoes have started to

breed. 'The result is an upsurge of mosquito-dominated malaria, never reported before in the desert", says BK Tyagi (Centre for Research in Medical Entomology, Madurai). "When there was less water, people were prudent in water use. Now there is abundance and a lot of water is wasted", says Arvind Ojha (Urmul Trust, Bikaner). "Unless irrigation patterns are changed, this area will turn into a wet desert". According to Ojha, people are now beginning to realize that total dependence on the canal for their livelihoods is unsustainable. In drought years, when the canal goes dry, even animal fodder has to be imported from other states.

While immediate gains from the canal appear obvious, very little thought has been given to the inherent potential of unleashing a variety of ecological hazards in the none too distant future. Unlike the arid zones of the Middle East and North Africa, the Thar Desert lacks the draining capacity that is vital for balanced irrigation. The recent discovery of a layer of gypsum right under part of the canal could explain why the water is prevented from seeping into the canal bed (Rao, 1992). Obviously, the application of irrigation water in such area would lead to accumulation of water and ultimately of saline material. Precipitated salt may be trapped in the soil, making the land unfit for cultivation. As a result of this low seepage rate the water level and the pressure on the bunds of the canal has been higher than originally calculated. This has led to the weakening of bunds at many points on the canal and necessitated repairs. Another problem facing the canal is the accentuation of the movement of sand in the region. The second phase of the project entails its extension through a linear canal system that wills virtually cut through the sand dunes and result in loose sand. The prevailing winds may transport the loosened sand eastward to engulf the more fertile lands on the fringe of the desert, thereby contributing to further desertification.

Many scholars using GIS & RS for identifying problem of water logging & salinity. Like Arora (2003) examine the water logging problem in IGCP area. In this article author tell about the different water logging situation in command area. There use of FCC LISS 3 image use for find out the water logging problem. Pre and post monsoon images of IRS IC LISS III were used to generate waterlogged area and land use &land cover maps of the study area. Land use & land cover maps were also developed on the basis of unsupervised classification, which were then improved on the basis of ground truth. Various collateral data with respect to land use and waterlogged areas and other information were collected from various IGNP departments, research farms and farmers. Author show different land use & land cover with help of remote sensing & GIS technology.

4.5 POTENTIAL REMEDIAL MEASURES:

A number of techniques which could be useful in mitigating the problems of water logging and salinisation or delaying the adverse effects have been discussed by Mann & Chatterji (1978), Chatterji (1985), Shankarnarayan & Sarkar (1985), and Chatterji & Saxena (1988). These include construction of open drainage, horizontal subsurface drainage, "vertical" drainage, soil management, artificial recharge, fish culture and growing aquatic cash crops. The principal methods of establishing a more favorable groundwater balance include:

1. Reducing groundwater recharge this is an effective way of combating the problem. The measures include.
2. Reducing irrigation water supply, however, farmers continue to be very reluctant to allow surface water supplies to be reduced.
3. Reducing seepage from channels, and water management losses (such as through canal escapes).
4. Improving the efficiency of irrigation water use at farm and field levels.

Increasing groundwater abstraction this can be achieved through use of "natural" abstraction systems (such as plants: "bio-drainage") or artificial drainage systems. The "bio-drainage" is cost effective and environment friendly. The artificial drainage systems are broadly classified as "vertical" (wells) or "horizontal" (tile drains). The pumping of surface water, where this is in intimate contact with the groundwater body, can also be an effective measure. The "vertical" drainage, by way of construction of shallow skimming wells, is a technically feasible and economically viable solution to combat water logging as demonstrated in the adjoining regions in the States of Punjab and Haryana (Rao et al, 1986). An optimum policy for controlling water logging will almost certainly involve measures both to reduce groundwater recharge as well as to increase groundwater abstraction. General measures that could be adopted throughout the region in order to reduce (or stop) the rate of rise of the water table includes:

1. Partial substitution of groundwater for surface water supplies where the groundwater quality is adequate for this purpose.
2. Promotion of methods of irrigation that is more water-efficient such as drip and sprinkler irrigation systems. Sharma & Mathur (1991) proposed efficient irrigation management practices and reduced water allowance for the IGNP command area.
3. Planned planting and care of trees that will use groundwater through bio-drainage.

4. The installation of a drainage system—either to prevent inflow of drainage water from the northwest or to drain areas with particularly large needs.
5. Mixing of groundwater discharging from shallow wells in large canals to increase the volume of irrigation water available downstream, although there would be a slight decrease in the quality of the irrigation water.

The construction of irrigation schemes without the adequate consideration of drainage provision has well recognized hazards. These have been understood for many years but it is sometimes appropriate to postpone investment in a drainage system if the water table is initially deep, and calculations indicate that there are many years before water logging will be a problem. However, the experience in IGNP suggests:

1. It is very important not to underestimate the impact of low irrigation efficiency in the early years of project development, when water is plentiful (as only part of the area to be irrigated has been developed), and irrigation skills of the farmers are being developed.
2. There must be some provision at the planning stage for drainage—the actual investment can be delayed—but clear plans on how sustainable drainage is going be achieved must be made, and land allotment should allow for drainage needs.

It is apparent that an optimal policy to control the problems associated with water logging will include:

1. More careful irrigation water management, lower water allowance for the farmers, and encouragement to move towards low volume, high efficiency irrigation methods and increased use of groundwater wherever the quality of water is adequate.
2. Increased use of trees to transpire groundwater.
3. Selective use of artificial drainage in areas of particular need.
4. Recognition that it is impractical and uneconomical to attempt to reclaim all affected areas, when plenty of alternative land is available. The cost of environmentally sound, sustainable means of reclaiming all affected land is potentially enormous.

4.6 Indira Gandhi canal achievement in desert area of Rajasthan: The Indira Gandhi Canal is one of the biggest canal projects in India. The Indira Gandhi Canal Project was conceived in April, 1948 with the noble aim of improving the living condition of human being and to cater to the minimum needs of cattle populations in the region. It starts from the Harike Barrage at Sultanpur, a few kilometers below the confluence of the Sutlej and Beas rivers in Punjab state. It runs south-southwest in Punjab and Haryana but mainly in Rajasthan for a total of 650 kilometers and ends near at Ramgarh, near Jaisalmer, in Rajasthan. Its construction started on the 31st March, 1958, inaugurated by then Home Minister Govind Ballabh Pant. It was built with the aim of converting part of the Thar Desert from wasteland to agriculturally productive land. The project area is classified as arid. It is thinly populated and requires large scale effective settlement of people to realise the benefits of transfer irrigable water. The project was planned in two phases for the convenience of planning and construction. It was earlier known as the Rajasthan Canal. The name was changed on the 2nd Nov, 1984. It uses water released from the Pong dam and provides irrigation facilities to the north-western region of Rajasthan, a part of the Thar Desert. It consists of the Rajasthan feeder canal (with the first 167 km in Punjab and Haryana and the remaining 37 km in Rajasthan) and 445 km of the Rajasthan main canal which is entirely within Rajasthan. The IGNP traverses seven districts of Rajasthan: Barmer, Bikaner, Churu, Hanumangarh, Jaisalmer, Jodhpur, and Ganganagar. The Indira Gandhi Canal, a vast manmade river system, is a symbol and tribute to India's engineering skill (Rao, 1992). Broadly speaking, the socioeconomic and biophysical objectives of the irrigation project were to:

1. Halt the process of desertification.
2. Develop agriculture in the command area.
3. Create human settlements in the sparsely populated area.
4. Provide drinking and industrial-use water to the inhabitants of the project area and adjoining regions.

***1. Halting the process of desertification*:** According to some analysts, the introduction of agriculture into arid areas is ecologically unsustainable because, by definition, arid lands are fragile. Irrigation invariably leads to intensive agriculture, which cannot be sustained on these lands. These lands are best suited for extensive agriculture, mainly pasture-based animal husbandry (Ramanathan and Rathore 1994). According to this way of formulating the issue, fragile lands are loosely defined and are equated with marginal lands. Two characteristics distinguish fragile land: environmental sensitivity (propensity to deteriorate) and resilience (ability to retain productive qualities) in the context of common land use (Turner and

Benjamin 1994). Historically, arid lands have sustained intensive agriculture, given an assured and renewable supply of water. Proper land management and land-related investment can overcome ecological constraints. These lands are unsuitable for crop production only if farmers have to rely exclusively on (scanty and irregular) rainfall or an exhaustible source of water, such as groundwater.

On the other hand, extensive farming, particularly animal husbandry, has placed excessive pressure on land resources, aggravating the arid conditions. Excessive grazing, in addition to damaging the vegetation cover, loosens the sandy soils; the winds then shift the sand to adjoining areas, accelerating desertification. This is not an argument in favour of monocrop or Green Revolution agriculture but suggests that, with dependable irrigation, an integrated-farming system - comprising crops and livestock in tune with the local resources and the farmers' needs — could be sustainable on arid lands (Jodha 1990). In such a case, irrigation would promote environmental sustainability on arid land. The experience with irrigation in arid areas of India and abroad supports this conclusion.

Two examples of such experience can be cited from the arid regions of Rajasthan. The most famous and most pertinent is that of Gang Canal. In 1927, the ruler of the State of Bikaner thought of bringing Sutlej waters to the parched arid land in the north of the state and constructed the Gang Canal in the area, which is now known as Ganganagar (Sain 1978). The state followed a judicious settlement policy. Today, Ganganagar is agriculturally the most progressive district of Rajasthan. Its yield rates in important crops, like wheat and cotton, are comparable to those of the Punjab. Agricultural prosperity diversified the economy of the district, which now ranks fourth among 31 districts of the state in terms of industrial development.

This story is being repeated in the region covered by stage I of IGNP. The rate of growth in agricultural production in this region is now close to that of Ganganagar. The economy is diversifying with the growth of agro processing industries. A study by the National Council for Agricultural Economic Research showed that the population is reaping the social and economic benefits of irrigation (Roy 1983). More important, canal irrigation has resulted in large-scale afforestation, especially canal-side afforestation, and, to a limited extent, road-side afforestation. This has affected the microclimate, and erosion has slowed as a result of the increased humidity, moisture, and vegetation cover.

Water logging and salinisation pose the real threat to the environment in the IGNP area. A number of studies revealed that the lands to be irrigated by IGNP in stage II have low groundwater levels (WAPCOS 1992b). Furthermore, hardpan layers at shallow depth allow

no water to permeate downward. Together with the capillary action, this leads to water oozing. Salts in the desert soils further complicate the situation, leading to salinisation. However, the experts differ about the extent and severity of these problems. An alarmist view suggests that water is rising at the rate of 0.8–1 m/year in large parts of the stage II area and that nearly 34% of the area is likely to become waterlogged (WAPCOS 1992b). On the other hand, experts on the Indira Gandhi Nahar Board (IGNB) heavily discount these estimates and suggest that no more than 2–4% of the stage II area is truly vulnerable. A more reasonable view is that the proportion of area affected is neither as high nor as low as the official figures indicate, although the rapid spread of water logging is distinctly possible unless effective steps are taken. A deliberate plan to reduce the water allowance may lead to better water management and less risk of water logging and salinity.

To achieve the water-management objectives, three hurdles have to be overcome: problems related to the political economy of the area, problems related to management of demand, and technical problems. One of the seriously waterlogged areas was adjacent to the Ghaggar Depressions in the stage I area. Initially, the water was diverted and released in these depressions, situated along the banks of Ghaggar River, to save the lands on the banks from the ravages of flood. These lands are owned by the rich and politically well-connected people, whereas the villages adjacent to the Ghaggar Depressions are populated by resource-poor farmers. A permanent liability has been created for the poor farmers by saving the lands for more affluent people. The situation is aggravated because the surplus water in the Ghaggar Depressions is kept in pools to enable the development of fisheries. These fisheries are also owned by the richer farmers of the area (Srivastava and Rathore 1992). Accumulation of water in these depressions contributes to water logging of low-lying lands, which were at one time productive. Such demand-management techniques, such as:

1. Organization of different sections of people in these areas.
2. The extent of the possible loss by the farmers in the stage I area when the existing water regime changes.
3. Possibilities of compensating for these losses (say, with higher-yielding crops that use less water) and of having a general system of incentives and deterrents to induce farmers to move to water-saving cropping patterns.
4. The capability of the state and the bureaucracy to enforce the equitable distribution of water.

Technical challenges include the following:

1. Finding ways to drain excess water.
2. Adopting agronomic practices and cropping patterns that use less water.
3. Fixing the water allowance for different areas, with a view to maintaining soil characteristics and groundwater availability.
4. Building technically sound structures and systems of water conveyance.

The success of these interventions depends largely on the involvement and participation of the beneficiaries, which is an aspect repeatedly overlooked by project-planning authorities.

2. ***Develop agriculture in the command area:*** For irrigation to make an impact on agricultural productivity, several conditions have to be satisfied:

1. A dependable supply of water at source.
2. Creation of irrigation potential at the field level.
3. Efficient conveyance of water.
4. Appropriate cropping patterns.
5. Complementary inputs of improved seeds, fertilizers, etc.

This objective of IGNP was to ensure high levels of agricultural production in the command area. Irrigation of 950000 ha in stage II would yield agricultural products worth an estimated 20 billion INR. The project would result in enough annual fodder for 5.2 million cows or equivalent animal units and facilitate afforestation of 362000 ha, producing 7.16 million INR of forest products annually (Vyas, V.S, 2004.).

The main production gains should be in crop yields. However, from the available information, the actual yields are reaching only part of their potential. For example, actual yields of different crops per hectare, compared with the potential yields of the same crops, vary from 31% for gram to 60% for cotton (Vyas, V.S, 2004). Although undue importance should not be attached to the figures of achievable and potential yields, it is quite clear that further improvements in the yields of various crops are possible.

The first hurdle is the fluctuation in the supply of water at the canal head (based on fluctuations in the supply of water from the rivers). Added to this are the multiple claims of various riparian states on the given supply of water, normal difficulties faced by the tail-end states, and the seasonal variability in the availability of water at the canal head. Because Rajasthan has no reservoir, mechanisms to even out the flow of water to the command area need to be developed. Adopting a rotational scheme among the distributaries and developing

a Warabandi system (a scheme whereby water is allocated on a weekly basis) at the outlet would allow for more equitable (but not necessarily more efficient) distribution of the water. The second challenge is to create irrigation potential (which is basically a function of the construction of the main canal, distributaries, and field channels. A third factor inhibiting the maximization of agricultural production is inefficient water conveyance. This is mainly due to problems of maintenance, accumulation of sand in canal distributaries and outlets, and unchecked growth of weeds. Water-conveyance efficiency in stage II is reckoned to be 72.6% (Ramanathan and Rathore 1994). With the defects in the conveyance system, the availability of water on the farm is less than it is presumed to be at the macro level. Authority ensured low but regular water supply, it was found that better yields could be obtained by a smaller supply of water (Ramanathan and Rathore 1994). In sum, several factors conspire to inhibit the full exploitation of the yield potential of various crops. To remedy all these deficiencies, action is required from several actors, but especially from the settlers in the area.

3. ***Create human settlements in the sparsely populated area:*** The area coming under the command of IGNP in stage II was sparsely populated; in fact, it had a population density of 11 persons per sq km. Very little agriculture was undertaken in the area; the main occupation of the inhabitants was animal husbandry. With the introduction of irrigation and the opening up of land, a large number of settlers had to be attracted to the area to make use of the water. One of the attractive features of IGNP is its explicit objective of enabling small-scale and marginal farmers to take advantage of the irrigation, giving them preference in the settlement of the area. Priorities in the selection of the settlers are clearly defined in the rules for settlement (regularized in 1972). The landless agricultural labourers and the small-scale farmers residing closest to the villages to be settled have first priority, followed by similar classes of people from the same tahsil, district.

Until 1980, practically all allocations went to households in these categories. Among these, priority went to households of the scheduled castes and scheduled tribes. Each settler received about 25 bighas (6.32 ha) of land. These households bought the land at a reserve price, which was considerably lower than the market price, and were given 15 years to pay off the cost. Only since 1988 (since 1980, in stage I) has 50% of the unoccupied government land in the command area been reserved, at market price, for people in nonpriority groups. However, this failed to alter the composition of the settlements in the area. As of June 1991, out of 25678 allotments in the stage II area, only 743 went to people in nonpriority groups (Hooja 1994). A number of allottees never settled on their allotted land but retained their

rights to it so as to accumulate its asset value. This is particularly true of those few original inhabitants of the area who had permanent ownership rights to the land before it came under the command of the project. Their major occupation continued to be animal husbandry (Mathur and Gurjar 1991).

Also, many people who originally came to cultivate the land in the stage II area left after a few years, as the gestation period for making the land suitable for a reasonable level of agriculture proved to be very long. The paucity of settlers on the land, in turn, made it more difficult to develop the area. For example, wherever cultivated holdings were noncontiguous, the field channels were impossible to desilt, making it more difficult for the few remaining settlers. Similarly, without an adequate number of clients, supportive agencies — such as the banks, input depots, marketing depots, and educational and health institutions — were reluctant to start operations in these sparsely populated areas.

A team from the Indian Institute of Management, Ahmadabad (IIMA), conducted an in-depth study of the reasons for the slow movement of settlers into this area (Seetharaman et al.). Major problems identified by the IIMA team were uncertainties about the availability of water; unavailability of tractors at reasonable charges for leveling and tilling; unavailability of credit for agricultural inputs, and, in a few chaks (blocks of holdings below the village, or abadi, level), unavailability of drinking water. After trying to relate progress in the settlement to some basic determinants, the team concluded that:

- The extent of fragmentation of land seemed to affect settlement — the greater the fragmentation, the lower was the rate of settlement;
- The distance of a chak from the nearest diggi (drinking-water reservoir) affected the settlement rate — the greater the distance, the lower was the rate of settlement;
- The distance from the nearest abadi (bigger village) appeared to have no significant impact on the rate of settlement;
- The distance from the nearest road had no significant impact on the rate of settlement;
- The distance from the mandi (marketplace) had a significant impact on the rate of settlement — the greater the distance, the lower was the rate of settlement; and
- The dominance of a single caste in a chak appeared to have little bearing on the rate of settlement.

As a result of the initial difficulties in cultivation, a class of absentee landowners emerged. These original allottees leased their land to poor farmers on a sharecropping basis. Sharecropping in the IGNP area is estimated to take place on 30–50% of the allotted lands (Ramanathan and Rathore 1991). Because of credit requirements, a large number of poorer cultivators in the initial phase had to borrow from the more affluent farmers and enter into exploitative labour contacts with their creditors (Sharma and Rathore 1990).

4. ***Provide drinking and industrial-use water to the inhabitants of the project area and adjoining regions:***

To understand the issues and problems specific to the stage II area, the IGNB and the office of the Commissioner for Area Development sponsored a host of studies. On the basis of these studies and their understanding, it appeared that the main needs were the following:

1. Organizational coordination among different agencies functioning in the IGNP area and strong motivation for government functionaries at various levels to act.
2. Meaningful participation of the settlers in management of the project.
3. Generation and extension of relevant hydrological and agronomic knowledge.
4. Creation and maintenance of basic infrastructure.

Government agencies failed to meet the challenge for several reasons. First, bureaucrats, in their role as agents of change, suffer from several handicaps. In this case, the bureaucrats' outlook was myopic, and their interaction with other important agents of change (for example, researchers, social activists, politicians) was minimal. When apparent, it was guided by no shared concerns or identified mutual interests. As resources are mainly controlled by the bureaucrats (in this type of development strategy), such behaviour marginalizes other sectors of the population, who lose the initiative to contribute to the growth of the economy or to society. Second, in government agencies, power is centralized in a hierarchical structure, and any initiative shown by functionaries at lower levels is viewed as suspect. As a consequence, bureaucrats on the lower rung hesitate to look beyond the implementation of orders received from above (Korten and Siy 1988). Third, bureaucrats lack accountability. Audits exist to ensure that inputs are used in the prescribed form and manner. However, hardly any system of accountability exists for the outcome of the efforts (Paul 1992). In bureaucracy-led development, it becomes extremely difficult to decide who is responsible for a decision — an individual or a group of individuals. Finally, bureaucrats have no long-term vision to guide their actions. At best, they may have far-sighted political

masters. But if their political masters are short-sighted too, the bureaucrats have nothing to guide their actions to achieve long-term objectives.

The markets and institutions in the region were thought to be one means to address these challenges. But markets failed to perform the job of allocating resources and rewards in support of the project's objectives. Similarly, the institutional backup was weak at different levels, so bureaucratic and non-bureaucratic players did not receive the correct guidance or signals.

Four interrelated factors may have contributed to the failure of the market in meeting the project's objectives: high transaction costs; interlocked markets; lack of information and the high cost of information that was available; and weak demand. Initially, sparse population and low household incomes limited the size of the market for goods and services. The absence of supportive services, such as marketing and credit, was a result of the limited market. Because of the small number of clients, the unit cost of delivery was, naturally, very high. The limitation imposed by the size of the market was compounded by the lack of infrastructure, especially roads. Limited access resulted in thwarted competition and rising costs of goods and services. The net result was that inputs required for agricultural development were never delivered to the settlers, and the farmers had no access to cheaper credit through formal institutions.

With the IGNP, all these handicaps were compounded by the harshness of the terrain and the extremely difficult living conditions. These conditions weakened the line of control from the central bureau to the local functionaries. The functionaries should have lived and worked on the site but had all the reasons for not doing so and, because of extraneous considerations, could not be disciplined or motivated to deliver goods to the settlers. Added to these various handicaps, frequent transfers of officials made the situation much more difficult. Together, these weaknesses impeded the bureaucracy's functioning as an effective development agency.

Along with effective bureaucratic accountability and quality control, local initiative was conspicuously absent. Several factors explained people's lack of involvement (Srivastava and Rathore 1992). Heterogeneity of the groups made cooperation difficult. The poverty of the people made them heavily discount future incomes and therefore discouraged their taking long-term development measures on their own. Absence of genuine people's organizations at the local level worsened the situation. Although formal chak samities (committees of the beneficiaries at the chak level) were set up in various parts of the region, they made hardly

any contribution. Above all, the approach taken to development tasks created a dependency syndrome.

4.7 Conclusion:

The economic position of the settlers will remain weak and their contribution to ecological sustainability, as well as agricultural development, will remain sub-optimal unless some measures are taken to strengthen the market forces and make bureaucratic interventions more effective and people's involvement genuine and extensive. Two prerequisites for successful operation of the markets in this region are the creation of necessary infrastructure and the far-reaching dissemination of information. The cooperative form of organization at the grass roots could probably impart such strength to the settlers.

However, we know enough about the preconditions for the formation and successful functioning of such groups to be swayed by the number of formally registered cooperatives in India: small groups of households with similar social and economic backgrounds have been able to increase the bargaining power of small producers. Some form of collective action by the settlers in buying and selling goods and services would be a precondition for proper functioning of the markets in the IGNP areas.

For bureaucracy to be effective, it is most important to strengthen the last link in the chain the state functionaries at the chak, or village, level. The government should give serious attention to motivating people at that level, both through financial incentives and nonfinancial benefits, together with effective deterrents for lapses of duty. However, a precondition for effective delivery of services to the settlers is that these functionaries reside or settle in the midst of the people they are supposed to serve. At the moment, all government services expected at the local level are provided by remote control. The functionaries live in nearby or not-so-nearby towns or cities. Unless the settlements have facilities for minimum levels of education, health, and housing, it is unrealistic to expect the functionaries to settle there. Government services could be organized in a hierarchical mode, with planning and coordination at the district level and delivery at the grass-roots level. Appropriate facilities would be available to the functionaries at different levels.

The three government agencies directly involved in the development of the IGNP area the IGNB, the Commissioner for Area Development, and the Commissioner for Colonization Development should have much better coordination. Coordination is equally important at the local level. The bureaucrats should become sensitive to the social and ecological aspects of

development. A coalition with the nongovernmental organizations (NGOs) functioning in the area would also be helpful. This coalition of the government organizations and NGOs should also involve the researchers working in hydrology, agronomy, and the social sciences.

At least an informal forum for periodic exchange of views on important development issues is needed. It is equally important to ensure follow-up of the decisions made at such a forum. In addition to supporting people's initiative and involvement in organizing small, homogeneous collectives for economic action, it is important to increase the political clout of the settlers. This should be possible with the strengthened Panchayati Raj institutions (local self-government institutions at the village, tahsil, and district levels), which were given statutory powers and resources through recently amended constitutional provisions. More responsibility should be devolved to these institutions.

The results of devolving authority for development tasks to the Panchayat level have been very encouraging. West Bengal is a good example, with its active Panchayat at the village level. Karnataka was another, during the brief time when a genuine Panchayati Raj system functioned there. The development tasks in the IGNP area are difficult, but the possibilities of meeting some of the important objectives of development and contributing to sustainable growth are also very real. The markets, bureaucracy, and people's cooperatives will have a distinct role in achieving these goals.

Chapter Five

Summary and Conclusion

The Indira Gandhi Canal is one of the biggest canal projects in India. The Indira Gandhi Canal Project was conceived in April, 1948 with the noble aim of improving the living condition of human being and to cater to the minimum needs of cattle populations in the region. It starts from the Harike Barrage at Sultanpur, a few kilometres below the confluence of the Sutlej and Beas rivers in Punjab state. It runs south-southwest in Punjab and Haryana but mainly in Rajasthan for a total of 650 kilometres and ends near at Ramgarh, near Jaisalmer, in Rajasthan. Its construction started on the 31st March, 1958, inaugurated by then Home Minister Govind Ballabh Pant. It was built with the aim of converting part of the Thar Desert from wasteland to agriculturally productive land. The project area is classified as arid. It is thinly populated and requires large scale effective settlement of people to realise the benefits of transfer irrigable water. The project was planned in two phases for the convenience of planning and construction. It was earlier known as the Rajasthan Canal. The name was changed on the 2nd Nov, 1984. It uses water released from the Pong dam and provides irrigation facilities to the north-western region of Rajasthan, a part of the Thar Desert. It consists of the Rajasthan feeder canal (with the first 167 km in Punjab and Haryana and the remaining 37 km in Rajasthan) and 445 km of the Rajasthan main canal which is entirely within Rajasthan. The IGNP traverses seven districts of Rajasthan: Barmer, Bikaner, Churu, Hanumangarh, Jaisalmer, Jodhpur, and Ganganagar.

The cropping pattern in the virgin IGNP command areas will experience gradual shift. The soils in the command area are presently deficient in nutrients and have low water holding capacity. During the initial period of about five years, the cultivators may raise traditional crops. Gradually with the improvement in water holding capacity and fertility of soil, microclimatic condition and effort of agriculture extensive services, the cropping pattern will change. Agriculture area is main indicator show to change due to Indira Gandhi canal area. Prior to 1995 Ganganagar & Hanumangarh was part of one district, for the sake of comparison these two districts have been considered as single district throughout all periods of analysis. Agriculture area & production is main tool of analysis for Bikaner, Ganganagar & Hanumangarh district. In Bikaner there is an increase in area under rice from 1980 to 1990, but this increase is small compared to that experienced by Ganganagar & Hanumangarh. This indicates area suitable for cultivation of water intensive crop like rice. Bikaner is characterised by sandy soil which is not suitable for rice cultivation. Jowar increased in terms

of its areal extent in Bikaner only for a few years; afterwards there is decline of this drought resistant crop. Ganganagar & Hanumangarh however did not show much change in area under this crop.

Bajra or Pearl millet (Pennisetum glaucum) is the most widely grown type of millet. Bikaner is major producer of Bajra in Rajasthan. There is increase in area afterward, but in year 2002-03 there is sudden fall in area due to drought condition prevails in western Rajasthan. While in Ganganagar & Hanumangarh there is continues increase of area, but compared to Bikaner this is low. Arhar, Moong, Urad, Moth & Kharif pulses are main crops under the category of pulses. Bikaner show remarkable changes area under pulses. This is the main crop group of Bikaner & this increasing trend continues till year 2000, but there is fall under this crop afterward. But in terms of its level, the proportion under this crop is still remains high in Bikaner district. In Ganganagar & Hanumangarh area under this crop group continues to increase, though in terms of its level, the area under this crop is lower than in Bikaner. There is contradiction in both districts in area under Groundnut. There is a continuous increase in area of oil seed in Bikaner district, while in Ganganagar & Hanumangarh there is a reduction in area even below 5000 hectare after year 2000

Cotton is mainly grown where water is available. It is clearly indicated that area under this crop in Bikaner increased after 1989, which is shows an increased availability of water for agriculture crop. This trend continues till 2002-03, but afterward there is a significant decline in area under this crop. Cotton is main crop for Ganganagar & Hanumangarh too. The increase of area under this crop has been visible 1980 onwards. The guar bean or cluster bean (Cyamopsis tetragonolobus) is an annual legume and the source of guar gum. It grows best under conditions with frequent rainfall, but tolerates arid conditions well. In Bikaner there is an increase in the area of this fodder crop after 2003. In another two districts show a good proportion under this crop. There is increase area under this crop afterward 1980.

The area under Kharif crops in Bikaner shows an increase in after 1980. However, this increase is not as sharp compared to Ganganagar & Hanumangarh, where there is sharp increase after introduction of canal. Bikaner shows steady increase in agricultural area, while other show remarkable changes in area under different crop. Indira Gandhi Canal irrigation benefits have been taken by mostly of northern districts of Rajasthan, namely Ganganagar & Hanumangarh.

In western part of Rajasthan cultivation of crops wàs primarily fed by rains, therefore, only summer (Kharif) crops were possible, but with the introduction of the project, winter (Rabi) wheat started growing (Imam, 2006). Ganganagar & Hanumangarh is main growing area of wheat. There is increase in the area of the crop afterward 1980. This shows that this area has been becoming one of the grain houses of Rajasthan. In Bikaner there is increase in area under this crop, but compared to other two districts, the level of share of this crop in the gross cropped area is very low. But given the aridity of western Rajasthan, such area changes are significant. Barley is a cereal grain derived from the annual grass Hordeum vulgare. Under barley there is increase in only in Ganganagar & Hanumangarh. In Bikaner there is very low proportion under this crop. This crop fluctuates in both districts, which show uncertain trend about this crop in this area. Gram is one of the main crop of Ganganagar & Hanumangarh, where it is show sudden increase in area of under this crop after1980. There is increase area until 2000, followed by a decline subsequently. In Bikaner, however, there is a relatively high area under this crop. There is increase in area continuously under this crop.

Mustard has emerged as one of the main Rabi crop for Ganganagar & Hanumangarh, and has had an appreciable increase afterward 1980. There is some reduction in area in 2001-02, where drought conditions prevailed. While Bikaner is also show a good proportion under this crop, but this is not high much as other two districts. Taramira is another oilseed crop in this area and this has had a somewhat fluctuating trend.

The gross cropped area for Rabi crops show that Bikaner under Rabi season three times increase in area starting from 1980, and increased until 2000, than sudden fall in area, but there increase in area afterward 2003. This is probably due to the 2000 drought that has affected the North Indian agriculture in a significant manner. In Ganganagar & Hanumangarh there is sudden increase in Rabi season area after 1980. This trend continues till date. The increase in area show remarkable changes in Rabi season in both districts.

In agriculture, crop yield (also known as "agricultural output") is a measure of the yield of crop per unit area of land under cultivation. Agriculture yield measures mainly in kg per hectare in all three districts. Rice is the main crop of Ganganagar & Hanumangarh district. There is yield around 2000 kg / hectare. There is an upward trend in yield in both two districts. But there is increase in yield after introduction of canal in this area. Jowar shows a declining trend in yield in Bikaner district, where Ganganagar & Hanumangarh show more or less a stagnant trend of agriculture yield for the crop. Bajra is the main crop in Bikaner

district. There yield is very low in Bikaner up to 1990, then increase in yield. In Ganganagar & Hanumangarh soon after introduction of canal, the yield remains low, but in recent years, there are signs of an upward direction. In Bikaner pulses' yield is also very low except for some years. In the other two districts there is a significantly increasing trend in pulses & it reach from below 200 kg per hectare to 1000 kg per hectare. In groundnut Bikaner show the changes in yield show is very remarkable. There is increase in production per hectare is increase is very high compared to other crops. Though the same trend is shown by Ganganagar & Hanumangarh, but increase in these two districts is lower compared to Bikaner.

Cotton is main crop for Ganganagar & Hanumangarh. There is no significant increase in the yield of this crop, but there is decline in the year 2002-03 due to drought condition. In Bikaner this crop experiences a very fluctuating trend due to uncertainty of rainfall. The impact of canal irrigation as observed through the increasing yields of crops is higher in Ganganagar & Hanumangarh as compared to Bikaner. Guar is mainly used as a fodder crop in these districts. But none of the three districts there was a substantial increase in productivity or production of the crop.

In Bikaner there is increase in yield after introduction of canal then a decline. From year 1992 there is increase in yield in wheat in Bikaner. In Ganganagar & Hanumangarh there is continuous increase in yield in wheat, which matches the yield to Punjab & Haryana. There is an increase in yield of Barley after introduction of canal in all the three districts. In Ganganagar & Hanumangarh show a significant increase in production. Gram is the only Rabi crop in all three districts which show a declining trend. In recent years, however, there is some increase in yield. In Rape & Mustard there is increase in yield in all three districts. In Ganganagar & Hanumangarh there is increase in yield continuously; while in Bikaner there is decline in yield during late eighties. Then after upward trend in yield in Bikaner district except drought year of 2002-03.

Land use & land cover is mainly shows the geographical phenomena of the area. Land use and land cover is of dynamics nature and need proper monitoring for the sake of optimum utilization of land resources. The land use & land cover pattern of a region is an outcome of the natural & socio-economic factor and their utilization by man in time & space. Land use & land cover for all three district show a distinctive trend during time period 1979-80 to 2005-06.

Bikaner comprises of 4 tahsils Bikaner, Lunkaransar, Nokha & Kolayat. Ganganagar & Hanumangarh comprise twelve tahsils. These land use & land cover category divided into nine main category namely Forests, Land put to non agricultural uses, Barren & wasteland, Area under permanent pasture and grazing lands, Area under miscellaneous tree crops and groves (not included in net sown area), Culturable waste land, Current fallow, Fallow other than current fallow & Net sown area.

During 1979-1982 to 1985-88 Lunkaransar tahsil which is situated in northern direction show maximum change in forest area in percentage (around 256 %). Compared to Lunkaransar tahsil the total area increased in Bikaner is more than Lunkaransar. While in western tahsil Kolayat, where canal is not reached in the area show less change in area of forest cover. Nokha exhibits very low influence of IGNP, which shows negative change in forest cover. Urban built up area there is maximum negative change in Kolayat tahsil, where it changes as much as 32%. Lunkaransar & Bikaner also show negative changes during this time period, but compare to previous it is low. While Nokha tahsil show slightly increases in this area. In barren & wasteland except Nokha tahsil there increase in all three tahsils. This is show the increase in desert area over time period. Area under permanent pasture show increase in percent very high, but compare to absolute area it is very low. Current fallow, in which fallow land less than one year & other than current fallow land which have fallow land more than one year but less than five year show increase trend over time period. Only Lunkaransar & Nokha show a negative change in other than current fallow. Net sown area of Bikaner district shows positive changes over the time period. Highest positive change in area in Bikaner tahsil followed by Nokha & Kolayat. But western tahsil of Lunkaransar slightly negative changes over time period. In this area there is not reach of Indira Gandhi canal at that time period.

During 1985-88 to 1995-1998, Indira Gandhi canal reach in interior part of tahsil. In land use pattern there is a distinct change over time period. In first category of forest the changes in forest area is very high. There is positive changes occur in all tahsil, except Bikaner tahsil show negative changes over time period. Land put to non agricultural changes also show increase trend over time period. This is increase in maximum in Lunkaransar tahsil followed by Bikaner, Nokha & Kolayat tahsil. Barren & wasteland show a mixed trend over this time period. There Bikaner & Lunkaransar where main canal go, there show negative changes of this category, while in other two tahsil show positive changes over time period. Except Bikaner there all three tahsil show a negative changes in permanent pasture & grazing

land. Culturable wasteland, current fallow land & other than current fallow land over the time period show negative changes. This shows the impact of IGNP over the area. There is a decline in wasteland & fallow land with a corresponding increase in net sown area over the time period. Maximum changes occur in Bikaner tahsil, followed by Kolayat, Nokha & Lunkaransar. Than impact of Indira Gandhi canal clearly visible on desert land of Bikaner.

During 1995-98 to 2003-06 Indira Gandhi canal show clear cut impact on the desert land of Bikaner. In forest category the changes are positive. The forest cover has increased particularly in the canal area. Highest changes occurred in the area of Nokha tahsil. In second category of land put for non agricultural show a slightly increase in all tahsil. Barren & wasteland also show increase trend in area over time period in Nokha & Lunkaransar tahsil, while Bikaner & Kolayat tahsils show a decline in this category. Permanent pasture & grazing land also show a mixed trend over this time period, but decline in overall is predominate. Culturable wasteland in Nokha tahsil show increase in very high over this time period, while all three tahsil show decline in this category. Current fallow land has increased in this time period in all three tahsil except Nokha. But in Nokha this is also very low changes over time period. Highest increase Kolayat tahsil followed by Lunkaransar & Bikaner. Kolayat shows an increase over time in long term fallow, i.e. fallow other than current fallow. The net sown area in Kolayat tahsil show maximum decline over this time period, While Nokha & Lunkaransar tahsil show decline in area other than current fallow land. There was a slight decrease in net sown in Lunkaransar tahsil. While increase in Bikaner (3.39%) & Nokha (.70%) show increase but compared to previous time period it is very low.

Ganganagar & Hanumangarh comprises 12 tahsils namely Anupgarh, Bhadra, Ganganagar, Hanumangarh, Karanpur, Nohar, Padampur, Raisinghnagar, Sadulsahar, Sangaria, Suratgarh & Tibbi. During 1979-1982 to 1985-88 in Ganganagar & Hanumangarh district there is increase in the forest area over time period. Highest changes in Bhadra tahsil followed by Nohar & Raisinghnagar, while other tahsils, though showing an increase in forest cover, has experienced a low increase compared to above three tahsils. Land put to non agricultural use show an increase in all tahsils in Ganganagar & Hanumangarh district. Highest increase in Suratgarh which is 20.41% than followed by Anupgarh & Nohar, while in other tahsil there is not so much change that occurred during this period. In this time period there is impact of Indira Gandhi canal show a clear impact. There is a decrease in barren & wasteland in the tahsils where Indira Gandhi canal flow. Maximum changes occur in the

region of the Hanumangarh, Suratgarh, Anupgarh & Nohar. Permanent pasture in Ganganagar & Hanumangarh is also very low. It increased only in Suratgarh & Anupgarh tahsil, while other tahsils show no changes in this category. Area under miscellaneous tree, crops & groves shows increase in many tahsil namely Raisinghnagar, Suratgarh & Sangaria have prominent changes. There are negative changes in the Tibbi & Padampur tahsil, while other tahsils show positive changes during time period. Culturable wasteland show negative changes in the all tahsils, except three tahsil namely Ganganagar, Bhadra & Sangaria, which show positive changes Karanpur & Anupgarh show increase in area of current fallow land, while remaining 10 tahsil show decrease in the same. Fallows other than current fallow land also show negative changes in all tahsils, this is one of the clear and visible impacts of the Indira Gandhi canal in this region. There is an increase in area of net sown area in all tahsil over the time period. Highest changes occur in the Anupgarh tahsil (25.90%) followed by Suratgarh, Nohar, Raisinghnagar & Bhadra.

During 1985-88 to 1995-98 forest area continuously increased over time period. Maximum changes occurred in Suratgarh, Tibbi, Raisinghnagar & Bhadra. Ganganagar, Karanpur, Padampur, Sadulsahar & Sangria show no changes in forest canopy. Land put use for non agricultural land area show increase over time period except Suratgarh, Padampur & Tibbi tahsil where maximum negative changes occur. Anupgarh & Nohar show increase in this category. Barren & wasteland show highest increase in Suratgarh followed by Nohar, while maximum reduction in area of Anupgarh. Remaining tahsil has no sign changes in his area. Area under permanent tree reduced over the time period mainly in tahsils of Raisinghnagar, Anupgarh & Nohar, while in category of miscellaneous tree crops and groves, there has been both a reduction & an increase in area over the time period. Culturable wasteland shows reduction in many tahsil mainly in Anupgarh, Bhadra, Hanumangarh, Sangaria & Raisinghnagar. Increase in mainly area near canal region in this time period. Current fallow land shows reduction over the time period. The canal irrigated area comprising Bhadra Hanumangarh, Tibbi & Suratgarh area show increase in this category. There is increase in salinity adjacent to canal area and this is indicated by an increase in fallows other than current fallow land. It clearly shows than negative impact of Indira Gandhi canal over the region. Also, net sown area during this time period has very less growth rate & in some tahsil it registered a negative rate of growth. Only in Anupgarh tahsil there is a high increase in net sown area.

In time period 1995-98 to 2003-06 forest area increased in area maximum in Bhadra & Nohar, while other tahsils show very less or no changes over the time period. Land use put for non agricultural purpose show increase in area over time period, but in Anupgarh &Tibbi there are negative changes. Barren & wasteland reduced in Anupgarh, Nohar & Suratgarh, while it is slightly increase in Tibbi tahsil. Remaining tahsils have no sign of increase or decrease over time period. Area under permanent pasture shows reduction in many tahsils, namely Anupgarh, Bhadra, Nohar & Suratgarh. While it increases only in Hanumangarh tahsil, it is around 20%. Area under miscellaneous tree, crops & groves shows a reduction pattern in all tahsils. Culturable wasteland increase in area during this time period. In this time period there are maximum changes occur in the area near canal region. Reduction in area mainly in the Bhadra, Nohar & Anupgarh tahsil. Current fallow & other than current fallow land show increase in area over time period. All tahsils show positive increase in area of these 2 categories. Nohar, Padampur, Raisinghnagar, Sadulsahar & Ganganagar show the maximum changes over the time period. There is an adverse impact that is seen on net sown area well over this time period. It is surprising to note that all tahsils in Ganganagar & Hanumangarh district show a negative change over this time period, means that these two districts have had an absolute decline in net sown area. Suratgarh & Karanpur tahsils shows maximum reduction in net sown area over this time period. Padampur, Raisinghnagar, Sadulsahar & Anupgarh tahsils also show a high reduction in net sown area. Tibbi show minimum reduction in area over the time period.

Land cover is distinct from land use despite the two terms often being used interchangeably. Land use is a description of how people utilize the land and socio-economic activity - urban and agricultural land uses are two of the most commonly known land use classes. Remote Sensing (RS) and Geographic Information System (GIS) are now providing new tools for advanced ecosystem management. Use of remote sensing & GIS there all three districts categorized into five land use & land cover classes, namely forests, urban built up area, agriculture area, canal area, barren & wasteland. The land use and land cover map prepared from the Landsat imagery of 1977, 1989, 1999 and 2008 has revealed the spatial distribution, and dynamic nature of different classes in the area which results into formation of complex physiographic features.

Ganganagar land use & land cover by using GIS show a distinctive trend. In 1977 barren land occupy 17.63 % which decrease over time period. It reduced 14.47 % & 13.16 % in 1989 & 1999 respectively. It shows clear cut impact of Indira Gandhi canal & Gang canal

on barren land of Ganganagar. But due to water logging & salinity there increase in barren land in year 2008. Area under agriculture increase from 1977 to 1999. It changes from 71.09 % in 1977 to 72.16 % in 1999. But in year 2008 there drastic change in area, it reduced up to 67.78 %. Settlement (urban built up area) increase over time period, which is 5.71 % in 1977 increase to 6.97 % in year 2008. In Ganganagar many agriculture related industry have been established, which leads to increase in settlement area. Forest area in Ganganagar is very low; it was low as only 4 % in 1977. It slightly increased to 7.48 % to total area in 2008. It coincides with the increase in the canal area. Surrounding of canal area there water logging problems increase, which leads to problems of development of Sam problem in this area. Salinity in Ganganagar increase over the time period. This spotted as blue spotted in the unsupervised classification of Gnagaganagar map surrounding to canal irrigate area.

In Hanumangarh barren land in 1977 was 52310 hectare, which composes 5.94 % of total area. Barren land reduced in year 1989 & 1999 respectively 3.74 % & 2.91 %. This is show impact of Indira Gandhi canal in Hanumangarh district. Similar to Ganganagar district Hanumangarh also show increase in barren land. This barren land as form of saline land, hard pan & water logged area. In this area this problem mainly known as 'Sam'. In recent years this problems increase very rapidly. Agriculture area in Hanumangarh is 87.51 % in 1977, which highest in year 1989 is 89.04 %. Than it decrease to 87.71 in next time period. Than it considerably reduced in year 2008 is 83.76 %. Agriculture area near canal area has changed into barren & saline land as is indicated from the tahsil level data. Nohar & Bhadra show highest barren land changes during this time period. Barren land shows increase the land degradation problems in area. Agriculture area in Hanumangarh is 87.51 % in 1977, which highest in year 1989 is 89.04 %. Than it decrease to 87.71 in next time period. Than it considerably reduced in year 2008 is 83.76 %. Agriculture area near canal area change in barren & saline land. Nohar & Bhadra show highest barren land changes during this time period. Barren land shows increase the land degradation problems in area.

Before introduction to Indira Gandhi canal there barren land found in most of part of Bikaner. In year 1977 there is barren land as high as 50 % in Bikaner district. Which is highest than other two study area. After introduction of Indira Gandhi canal area, the landscape changed from barren land to agriculture area. Indira Gandhi canal reached up to middle of Bikaner district in year 1977. Indira Gandhi canal water use for mainly drinking & irrigation purposes. In 1977 there mainly water reached in two tahsils namely Lunkaransar & Bikaner. Afterward it reaches all four tahsils. Agriculture is low in year 1977 which consist

only 42.76 % of total geographical land area. In year 1989 there was not much increases in agriculture land area. It went up to 43.57 % of total geographical area. Impact of Indira Gandhi canal is now clearly visible on deserted land of Bikaner in recent decades. There barren land reduced from 45.98 % in 1977 to 30.94 % in 1989. First time in year 1989 agriculture land area surpasses barren land. It increases up to 56.50 % to total geographical area. In next time period the increase is not very high, it reaches only 57.58 % in year 2008. Bikaner district is main centre of industrial activities in colonial time period. Area under built up area is much higher in Bikaner compared to the other two districts. It increased progressively through the entire time period under study. Chaudhary (1996) examined the settlement development in Indira Gandhi canal command area in Thar Desert. It was expected that the canal irrigation would put the economy of desert area on new footing by enabling intensive cultivation. Forest area in Bikaner is high compared to two other district of Indira Gandhi canal areas. Alongside Indira Gandhi canal area there are increases in forest cover over time period under consideration. In 1977 it was 88367 hectare, which increased to 145685 hectare in year 2008. Canal area is also increased over time period. Main canals, branches, sub branches increased over the said time period. Some area of stage 1 show increase in problem of water logging & salinity. But it is mainly confined to the northern side of district. Barren land reduced over time period. This barren land converted into agriculture land use of water from Indira Gandhi canal. Than Bikaner is now converted into a green pasture in deserted land of western Rajasthan.

Water logging & salinity is main problem around Indira Gandhi canal area. According to Ram & Chauhan (2002), with the introduction of canal irrigation in 1958 about 33% district area in Hanumangarh have been brought under irrigated farming with 179% irrigation intensity. On the other hand the emergence of water logging & salinisation hazard turned about 11,000 ha irrigated double cropped land into wasteland. Further 15,300 ha area is under critical limit of water logging. A number of village settlements are deserted and people have moved to nearly safer sites. After two decades of the introduction of canal irrigation, the problem of water logging and soil Salinisation started in the IGNP command. The twin problem not only adversely affected crop production in canal command but also created ecological problems. Water scarcity due to adoption of high water requiring crops was noted in the command. Attempt has been made to assess the problem of land and water management on the one hand and high production of quality crops on the other. It is apparent that an optimal policy to control the problems associated with water logging will include:

1. More careful irrigation water management, lower water allowance for the farmers, and encouragement to move towards low volume, high efficiency irrigation methods and increased use of groundwater wherever the quality of water is adequate.
2. Increased use of trees to transpire groundwater.
3. Selective use of artificial drainage in areas of particular need.
4. Recognition that it is impractical and uneconomical to attempt to reclaim all affected areas, when plenty of alternative land is available. The cost of environmentally sound, sustainable means of reclaiming all affected land is potentially enormous.

IGNP achieved task of halt the process of desertification, develop agriculture in the command area, create human settlements in the sparsely populated area & Provide drinking and industrial-use water to the inhabitants of the project area and adjoining regions. But this task is not fully achieved in all command area. The three government agencies directly involved in the development of the IGNP area — the IGNB, the Commissioner for Area Development, and the Commissioner for Colonization Development — should have much better coordination. Coordination is equally important at the local level. The bureaucrats should become sensitive to the social and ecological aspects of development. A coalition with the nongovernmental organizations (NGOs) functioning in the area would also be helpful. This coalition of the government organizations and NGOs should also involve the researchers working in hydrology, agronomy, and the social sciences. The development tasks in the IGNP area are difficult, but the possibilities of meeting some of the important objectives of development and contributing to sustainable growth are also very real. The markets, bureaucracy, and people's cooperatives will have a distinct role in achieving these goals.

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