CHAPTER I

INTRODUCTION, GEOGRAPHICAL PERSONALITY
OF THE STUDY AREA AND METHODOLOGY

Introduction

Soil moisture is the most crucial factor for crop production in the tropical and subtropical regions, where other climatic factors such as photo-period is adequate and temperature is not an inhibiting element. In India photo-period is not a limiting factor in agricultural development except in Himalayan region where temperature remains low throughout the year. North-western parts of Indian plain also occasionally experience cold waves and frost conditions in the months of December and January which are harmful for rabi crops. "Of the major weather elements affecting crops production, such as temperature, sunlight, moisture and wind, moisture is by far the most important single factor in Indian agro-climatology".

Success and failure of Indian agriculture has been closely associated with the success and failure of southwest Monsoon, the main source of soil moisture in Indian subcontinent. Southwest monsoon rainfall is characterised by high spatial and temporal variations, uncertainty in
onset and withdrawal, prolongation of dry and wet spells and frequent occurrence of droughts and floods. These parameters of rainfall are mainly responsible for the instability and fluctuations in agricultural output and productivity. The frequency of crop failures and the incidence of low level of agricultural productivity are comparatively higher in arid and semi-arid areas of western and southern parts of the country. This region has low rainfall (less than 100 cm.) and very high variability of annual and seasonal rainfall (ranging between 25 to 80 percent). This region is termed as 'drought prone area' and generally experiences a severe drought once in a period of three years. Drought prone areas have persistent soil moisture deficiency. Besides, even the humid regions of the country experience prolonged dry spells causing droughts occasionally. But, it does not hinder the agricultural production as much as in arid and semi-arid areas.

Irrigation, a method of meeting the soil moisture deficiency for growing crops by diverting river or stream water and lifting groundwater for application in the crop fields, is known to the farmers of Indian subcontinent for a long period of time. However, it had been recognised as an effective mean of increasing agricultural production and countering the adverse effects of droughts and dryspells on crop production since the Mughal period. British period
also witnessed the development of surface irrigation in some areas of the country such as Punjab, Doab land of western Uttar Pradesh, Narmada valley in Gujarat and Godavari delta. These areas recorded an impressive growth in the production of wheat, rice, sugarcane, and cotton during the later half of nineteenth century to first quarter of twentieth century. But, Britishers were never curious about the tapping of water resources and thereby providing a technological breakthrough for the development of the stagnant agricultural economy of the country and protecting the crops from the vagaries of weather. Concerted efforts for providing irrigation development began only after the independence.

At the time of independence, created irrigation potential of the country was sufficient to irrigate an area of 22.60 million hectares. First Five Year Plan emphasised on development of irrigation resources through the construction of major and medium irrigation projects. During this period, irrigation potential increased at the rate of 0.7 million hectares per annum. The policy of irrigation development during the Second and Third Five year Plans also continued to be the same as in the First Five Year Plan. Irrigation potential during these plan periods increased at the rate of 0.6 and 0.9 million hectares per annum
TABLE 1.1

Development of Irrigation Potential in India Since 1947
(Million ha.)

<table>
<thead>
<tr>
<th>Year</th>
<th>Major and Medium Projects</th>
<th>Minor projects</th>
<th>Total irrigation potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre Plan (upto 1949-50)</td>
<td>9.70</td>
<td>12.90</td>
<td>22.60</td>
</tr>
<tr>
<td>First Plan</td>
<td>12.20</td>
<td>14.00</td>
<td>26.20</td>
</tr>
<tr>
<td>Second Plan</td>
<td>14.30</td>
<td>14.80</td>
<td>29.10</td>
</tr>
<tr>
<td>Third Plan</td>
<td>16.60</td>
<td>17.00</td>
<td>33.60</td>
</tr>
<tr>
<td>Annual Plans</td>
<td>18.10</td>
<td>19.00</td>
<td>37.10</td>
</tr>
<tr>
<td>Fourth Plan</td>
<td>20.70</td>
<td>23.50</td>
<td>44.20</td>
</tr>
<tr>
<td>Fifth Plan</td>
<td>24.77</td>
<td>27.30</td>
<td>52.25</td>
</tr>
<tr>
<td>Sixth Plant target</td>
<td>32.60</td>
<td>38.00</td>
<td>70.60</td>
</tr>
<tr>
<td>1988-89*</td>
<td></td>
<td></td>
<td>76.36</td>
</tr>
</tbody>
</table>

Source: Central Water Commission, New Delhi.

* Govt. of India, Economic Survey, 1989-90.
respectively. Till mid-sixties Indian planners had the impression that providing irrigational facilities, particularly through major and medium irrigation projects, would help in reducing weather induced risk and uncertainty in agricultural sector and achieving the target of food self-sufficiency. However, two consecutive droughts of mid-sixties showed the vulnerability of Indian agriculture to adverse weather. Foodgrains production saw a decline from 89.37 million tonnes in 1964-65 to 74.0 and 74.23 million tonnes in the following two years, 1965-66 and 1966-67.

Beside other factors, the failure of the strategy of agricultural development owed to the lack of technological breakthrough and a large gap between the creation and utilisation of irrigation potential in the command areas of major and medium irrigation projects. Period after the drought in mid-sixties witnessed the review of old policy and adoption of a new strategy of agricultural development. The introduction of package technology during this period marked the beginning of 'Green Revolution'. The launching pad of green revolution was irrigation. It formed an integral component of package technology along with HYV of seeds, chemical fertilizers and insecticides and pesticides. Green revolution has been most successful in irrigated areas of northwest India and coastal plain in Andhra Pradesh and Tamil Nadu. Despite its effects, in increasing...
interpersonal and inter regional disparities, green revolution steered through the campaign of gaining self-sufficiency in foodgrains production. Foodgrains production after mid-sixties increased at the modest rate of 3.3 percent per annum over the period 1964-65 – 1970-71 and 2.8 percent per annum over the period 1964-65 – 1978-79.

The strategy for irrigation development witnessed a marked change after the drought in mid-sixties. By the end of Third Five Year Plan, only about 80 percent of the irrigation potential, created through major and medium irrigation during the post independence period, was utilised. It was a major cause of concern for the irrigation planners as this amounted to the wastage of a scarce resource like water. Moreover, development of irrigation resources also involved a very heavy investment by the government. Consequently, the Fourth Five Year Plan laid the emphasis on narrowing the gap between creation and utilisation of irrigation potential. Moreover, this plan also laid emphasis on increasing the benefits from all types of irrigation and registering a high growth rate (5 to 6 percent per annum) in agricultural production. During the Fifth and Sixth Five Year Plan periods, irrigation potential increased at the rate of 1.6 and 2.2 million hectares per annum respectively. Seventh Five Year Plan had the target
of creating irrigation potential of about 2.5 million hectares per annum.

Narrowing the gap between the potential and utilisation of irrigation resources of major and medium works has been one of the main objectives of the strategy of irrigation development in all the Five Year Plans in 70s and 80s. The Fifth Five Year Plan adopted an integrated approach towards irrigation development in the command areas of major and medium irrigation projects. This new approach for full utilisation of irrigation potential and land resources, and realising optimum agricultural productivity in the command areas of major and medium irrigation works was termed as 'Command Area Development' programme. It is an area development approach and envisages onfarm development (water course lining, levelling and shaping of land), development of infrastructural and credit facilities, development of drainage facilities, ensuring equity in the distribution of water below outlet through the implementation of Warabandi system and evolving of suitable cropping pattern. But, even adoption of this approach has not been able to plug the gap between potential and utilisation of irrigation resources. In 1988-89, only about 85 percent of the created potential of irrigation was utilised in the command areas of major and medium irrigation works of the country.
The Fifth Five Year Plan marked another significant change in the strategy of irrigation development. It laid emphasis on conjunctive use of surface and groundwater resources and providing larger irrigation coverage to the chronically drought affected areas. Sixth and Seventh Five Year Plans also emphasised the above mentioned aspects of irrigation development. The need of providing irrigation facilities to drought affected areas, however, was realised by Second Irrigation Commission (1972). Irrigation Commission recommended that a irrigation project with a Benefit-Cost ratio of greater than 1.5 may be considered as economically feasible project. The commission further recommended that the irrigation project located in the drought affected area should be acceptable for execution even if its Benefit-Cost ratio is as low as 1.0. The commission identified following goals of the irrigation policy - (i) maximising agricultural production per unit of land in the Brahmaputra Valley, Kerala and Indo-Gangetic Plain, (ii) maximising the production per unit of water in the regions of medium and low rainfall, and (iii) providing irrigational facilities to maximum area in the drought affected areas.

The command area of Indira Gandhi canal is located in chronically drought affected area of northwestern
INDIRA GANDHI CANAL
COMMAND AREA

BOUNDARIES
- International
- Interstate
- Interdistrict
- Command Area

HARIKE BARRAGE
Sutlej R.
Sutlej R.
(Punjab
Ganganagar
Main Canal-
Head
Haryana
Lunkaransar
Churu
Bikaner
Main Canal Tail
Jaisalmer
Barmer

COMMAND AREA

- Under Flow
- Under Lift

Stage I

Stage II

Source: Dept. of Irrigation, CAD, IGCP, Bikaner.
Rajasthan. This irrigation project was launched in 1958 and envisages for providing protective irrigation. The strategy of irrigation development for this project in the lower command area has been revised and aims at providing irrigation facility to larger arid land in western Rajasthan.

**Indira Gandhi Canal Project**

Indira Gandhi canal is one of the largest canal systems of the world and one of the most ambitious irrigation project of the country. This irrigation project promises to transform one of the backward economies in the country, i.e. the Thar Desert in northwestern Rajasthan. This project was conceived by an engineer, Kanwar Sain, in 1948 in his study "Water Requirements of Bikaner State". The project proposal was submitted to Central Government for its consideration. Central Government accepted the feasibility of the project in 1957 and it was formally launched on March 31, 1958. Indira Gandhi canal, previously known as Rajasthan canal, originates at Harîke barrage, the confluence of Sutlej and Beas in Ferozepur district of Punjab. This canal project envisages the use of 7.6 million acre feet of water out of 8.6 million acre feet of surplus water of Ravi-Beas rivers allocated to Rajasthan as per the proposal of Central
### TABLE 1.2

**Some Salient Features of the Irrigation Project**

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Particulars</th>
<th>Unit</th>
<th>Stage I (1980 plan)</th>
<th>Stage II (1985 plan)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Length of canal</td>
<td>Km.</td>
<td>204</td>
<td>-</td>
<td>204</td>
</tr>
<tr>
<td>i)</td>
<td>Feeder</td>
<td></td>
<td>204</td>
<td>-</td>
<td>204</td>
</tr>
<tr>
<td>ii)</td>
<td>Main Canal</td>
<td></td>
<td>189</td>
<td>256</td>
<td>445</td>
</tr>
<tr>
<td>iii)</td>
<td>Distributories</td>
<td></td>
<td>2950</td>
<td>5826</td>
<td>8776</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td>3343</td>
<td>6082</td>
<td>9425</td>
</tr>
<tr>
<td>2.</td>
<td>Culturable Command Area</td>
<td>Lakh.ha.</td>
<td>4.81</td>
<td>7.00</td>
<td>11.81</td>
</tr>
<tr>
<td>i)</td>
<td>Under Flow Irrigation</td>
<td></td>
<td>4.81</td>
<td>7.00</td>
<td>11.81</td>
</tr>
<tr>
<td>ii)</td>
<td>Under Lift Irrigation</td>
<td></td>
<td>0.49</td>
<td>3.12</td>
<td>3.61</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td></td>
<td>5.30</td>
<td>10.12</td>
<td>15.42</td>
</tr>
<tr>
<td>3.</td>
<td>Irrigation Potential</td>
<td>Lakh.ha</td>
<td>5.84</td>
<td>8.10</td>
<td>13.94</td>
</tr>
<tr>
<td>4.</td>
<td>Irrigation Intensity</td>
<td>%</td>
<td>110</td>
<td>80</td>
<td>90</td>
</tr>
<tr>
<td>5.</td>
<td>Water Allowance</td>
<td>cusecs</td>
<td>5.23</td>
<td>3.5</td>
<td>NA</td>
</tr>
<tr>
<td>6.</td>
<td>Water Requirement</td>
<td>Million acre feet</td>
<td>3.59</td>
<td>4.0</td>
<td>7.59</td>
</tr>
<tr>
<td>7.</td>
<td>Drinking and Industrial use</td>
<td>cusecs</td>
<td>300</td>
<td>1500</td>
<td>1800</td>
</tr>
<tr>
<td>8.</td>
<td>Cost</td>
<td>Crore Rs</td>
<td>246</td>
<td>1420</td>
<td>1666</td>
</tr>
<tr>
<td>9.</td>
<td>Annual Food Production</td>
<td>Lakh. tonnes</td>
<td>14.50</td>
<td>22.50</td>
<td>37.00</td>
</tr>
</tbody>
</table>
Above (1.1) A View of Indira Gandhi Feeder Canal from Masitanwali Head. Below (1.2) A View of Indira Gandhi Main Canal at its Head, (Masitanwali)
Government in 1981. This canal in 40 metres wide at bottom and 6.4 metres deep and has a capacity to carry 18,500 cusecs water at the head.

Indira Gandhi Canal is feeder channel up to a length of 204 km. and traverses for a length of about 159 km. in Punjab and 19 km. in Haryana before entering Rajasthan. Indira Gandhi main canal takes off from feeder channel near Masitanwali in Hanumangarh tehsil of Ganganagar district and has a length of 445 km. Main canal runs almost parallel to the Pakistan border in Rajasthan at an average distance of 38 km. west of the canal. The slope of the land is towards south and therefore, all the branches and distribution systems on the right bank of the main canal flow along the gradient. However, east of the main canal land surface is very undulating and slopes down towards the canal. Therefore, all the branches and distribution systems taking off from the left bank of the main canal, except Rawatsar branch, are lift channels.

Construction of the canal started in 1958 and was expected to be completed in 1978. However, it has not been completed till now. Construction is being carried out in two stages for administrative conveniences. While construction of the stage I of the canal was completed in 1983, it is in progress for Stage II. Water was released in
the canal on October 11, 1961 and reached the tail of the main canal on January 1, 1987. In stage II, lining of the main canal is completed but work is in progress for construction of distribution systems. Length of the distribution systems in the entire command area of the canal is 8776 km. Total length of the canal system including feeder and main canal is 9425 km. Culturable command area of Indira Gandhi canal as per revised plan of 1985 is 15.42 lakh hectares. Of the culturable command area, 11.81 lakh hectares is under flow channels and 3.61 lakh hectares is under lift channels. Irrigation potential of the project is 13.94 lakh hectares with an irrigation intensity of 90 percent. After realising full irrigation potential command area of the canal is visualised to produce about 37 lakh tonnes foodgrains every year. Strategy of irrigation and economic development is different in the two stages of the command area.

Stage I

Stage I of the canal included the construction of feeder channel, main canal up to the length of 189 km. and distributories having the length of about 2950 km. Culturable command area of Stage I is 5.3 lakh hectares including 0.49 lakhs hectares under Lunkaransar - Bikaner lift canal. Command area of Stage I lies in south and south western parts of Ganganagar and northern part of Bikaner.
Above (1.3) A view of Sheopura Distributory (flow channel) near village 8SHPD (Suratgarh tehsil). Below (1.4) Anupgarh Distributory (flow channel) near Village 1LSM (Anupgarh tehsil).
districts. Canal systems of Stage I has the potential to irrigate an area of 5.84 lakh hectares every year with an irrigation intensity of 110 percent and water allowance of 5.23 cusecs. Command area of this stage in divided into 15 colonisation tehsils which are consolidated into 5 extension districts.

Stage II

Command area of State II covers partially the districts of Bikaner, Jaisalmer, Barmer, Jodhpur and Nagaur. Construction work in Stage II includes the lining of main canal from 189 km. to its tail and distributaries for a length of 5826 km. Construction of the distribution systems in Stage II is delayed far behind the scheduled time. Plan of irrigation development in the command area of Stage II has been revised eight times. Strategy of irrigation development in this stage is to provide extensive irrigation and also cater to the development of pastures and sand dune stabilisation. Its objective is eco-development and developing animal husbandry apart from agricultural development. Irrigation plan of Stage II proposes to irrigate about 3.66 lakh hectares of area for pasture development. As per revised plan of 1985 culturable command area of stage II has been increased to 10.12 lakh hectares which include 3.12 lakh hectares of area under lift
Above (1.5) A view of Lunkaransar-Bikaner Lifting Canal from above Water Lift Station at Hassanpur. Below (1.6) Hassanpur Water Lifting Station at Lunkaransar-Bikaner Lift Canal.
channels. Irrigation potential of this stage is 8.10 lakh hectares with an irrigation intensity of 80 percent. Water allowance in this stage has been reduced to 3.5 cusecs in order to provide the irrigational facilities to the larger area in the desert.

Geographical Personality of the Study Area

The study area is comprised of Stage I command area of Indira Gandhi canal as irrigation was introduced in Stage II command area after mid-eighties and it has not made much impact in terms of influence on environmental and socio-economic conditions. However, command area of both stages are taken into account while discussing geographical personality of study area. Command area of Indira Gandhi canal lies in the northwestern arid tract of Rajasthan, partly spread over Ganganagar, Barmer, Bikaner, Jaisalmer, Jodhpur, Nagaur and Churu districts. It approximately covers an area of about 24525 square kilometers.

Geological Formations

Command area of Indira Gandhi canal has land formations of recent geologic times. It is evident from fig. 1.2 that most parts of the command area consist of alluvium and blown sand. Stage I command area comprises of
IGC COMMAND AREA

GEOLOGY

the alluvium laid down by Ghaggar river and overlain by sand dunes. Thickness and expanse of wind blown sand dunes overlaying alluvium is more in Stage II command area. Some areas in lower command area of Stage II have rock outcrops of the older origin. These land formations are sandstone and conglomerates of Pleistocene age, Jurassic formations, Eocene formations, Abur beds and Bap beds.

There are contradictory views about time and process of origin of Thar desert. "The origin of Indian desert is attributed, in the first instance, to a long continued and extreme degree of aridity of the region, combined with the sanddrifting action of the southwest monsoon winds, which sweep through Rajasthan for several months of the year without precipitating any part of their contained moisture. These winds transport inland clouds of dust and sand particles, derived in a great measure from the Rann of Kutch and from the sea-coast, and in part also from the basin the lower Indus... A certain portion of the desert sand is derived from the weathered debris of the rocky prominences of this tract, which are subject to the great diurnal as well as seasonal alternations of temperature characteristics of all arid regions". However, some scholars, particularly the geomorphologists of Central Arid Zone Research Institute, Jodhpur, argue that
desert sand of western Rajasthan is primarily a product of weathering of rock material.

Controversy regarding time of origin of Thar desert also remains unresolved. Some scholars date the origin of the desert in recent past. "There is evidence that the region north of Kutch and south of Punjab was a fertile and forested tract of country, supporting well populated cities, even so late as the time of invasion by Alexander the Great". The sub-recent conglomerates in the Aravali region and archeological evidences also suggest that desert conditions in western Rajasthan were accentuated during last 5000 years. While some other scholars date its origin between the end of Pliocene and beginning of last glaciation when most parts of northern India experienced repeated fluctuations in terms of temperature and precipitations.

Relief

Relief of Indira Gandhi Canal command area characterised by relief features of alluvial plains, sandy plains, interdunal depressions or deflation basins and sand dunes. Upper part of the command area in Ganganagar district is an extension of Punjab plain, which consists of the alluvium laid down by Ghaggar river. Flood plain of
IGC COMMAND AREA
EXTENT AND DEGREE OF SAND DUNES

Source: Agricultural Atlas of Rajasthan, 1972
Ghaggar is a fertile and recently deposited alluvium and the adjoining old alluvium is overlain by scattered small sand dunes and blown sandy soils. Fig.1.3 shows that intensity of sand dunes increases as moving from upper parts to lower parts in the command area. In Jaisalmer and Barmer districts about 80 to 100 percent of land surface of command area is covered by continuous longitudinal ridges of the sand dunes rising upto the height of about 60 metres above the surface. In Bikaner district command area of Indira Gandhi canal is severely affected by sand dunes which account for about 60 to 80 percent of surface area. In Stage II command area and lower part of Stage I command area sand dunes are generally longitudinal while in upper part of Stage I command area they are transverse. Extensive sandy plains and interdunal depressions also exist in Stage II command area, in Bikaner and Jaisalmer districts. Interdunal depressions embody palayás, pans and dry salt lakes locally termed as Ranns.

As evident from fig. 1.4 command area of Indira Gandhi canal slopes westward and contours are almost parallel to main canal. Height of the command area near the head of main canal is about 200 metres above the mean sea level. It lowers down to about 100 metres in the western part of Jaisalmer district. West of the main canal land slopes gently towards Pakistan border. It is
quite difficult to represent the slopes of the desert accurately because of transitory nature of dunes and difficulties involved in mapping narrow interdune plains at 1:2 million scale. Fig. 1.5 depicts that slope of interdunal plains and Ranns is very low, up to 1 percent. Sandy plains and alluvial plains of upper command area of Stage I also have low slope, ranging between 1 to 5 percent. Command area of Stage II, severely and very severely affected by sand dune infestations in Jaisalmer, Bikaner and Barmer districts, has very high slope ranging between 10 to 20 percent.

**Drainage**

This region does not have any perennial river. Ghaggar, which is a seasonal river and originates from Shivalik range of Himalayas, enters the region in Ganganagar district near Hanumangarh and flows westward through Suratgarh and Anupgarh tehsils. This river is lost in sandy plains but its course is easily traceable up to Anupgarh town. Ghaggar river causes occasional flash floods. Floodplain of the river is very narrow and known as Nalli land. It is very fertile and rice is produced in flooded areas. Some scholars are of the view that Ghaggar was a perennial stream and carried a large volume of water till early historic times. The hydrographic changes in river
Ghaggar along with climatic changes were responsible for shifting or decline of proto-historic culture in this region. The hydrographic changes were more likely to have occurred due to new tectonic movements both in the Himalayan catchment and basin of Ghaggar river. "During Sub-Recent times some interchange took place between the easterly affluents of the Indus and the westerly tributaries of Yamuna by minor shiftings of watershed. The river Yamuna during early historic times discharged into Indus system through now neglected bed of the Saraswati river". However, this view regarding change in hydrologic and climatic conditions in the basin of Ghaggar river has been contested by some scholars. "From the configuration of the sites in the area, particularly those on the river Saraswati and from the results of scientific studies, it appears that the climatic and hydrological conditions during the past three thousand years have not undergone any major changes. The conditions (with some variations of a minor nature) in the area covered by the Saraswati and the Drishadvati-represented by Ghaggar, Hakra and Chautang - were not radically different from those prevailing in the recent times. The behaviour of these rivers may have been the same as it is now".

Command area of Stage II and lower parts of Stage
I command area do not have even seasonal streams. This region has internal or closed drainage systems where seasonal torrents last only for few kilometers or even metres. This is because of enclosed sandy basins, scanty rainfall and very high percolation rate of water in the sandy soils. These physiographic and climatic conditions along with very high rate of evapotranspiration have resulted in the formation of brackish water lakes, Ranns, and evolution of calcareous and clay pans on or near the surface of depression basins and sandy plains in this region.

Soils

Soils of Indira Gandhi canal command area are generally sandy except in some parts in Stage I, where they are alluvial. Fig 1.6 shows that most parts of the command area, except near the head of main canal and commands of Suratgarh and Anupgarh branches, have recent sandy soils which do not have much structural development. In the upper command area near the head of main canal soils are Psammments - Fluvents i.e sandy soils of recent origin are mixed up with recent alluvium. In the command area of Suratgarh branch sandy soils with some structural development are blended with recent alluvium. While in the command area of Anupgarh branch soil combination consists of Fluvents-Orthid soils. Recent alluvium or Fluvents in this
area is laid down by Ghaggar river. In the lower command area of Stage II in Jaisalmer and Barmer districts both Psamments (recent sandy soils) and Orthids (soils of arid origin with some development) are found both separately and mixed.

Given the nature of terrain, soil classification of Indira Gandhi canal command area requires a detailed soil survey. This task is being carried out under CAD programme in the area. Sand dunes have light textured and structureless sandy soils. Sandy plains are also light textured and have sandy and sandy loams. "The dunes are highly sandy and contain only 1.8 to 4.5 percent clay and 0.4 to 1.3 percent silt. The interdunal and associated plains are also light textured". Soils of depressions and Ranns are generally sandy loam and loam. These soils have greater concentration of salts and are alkaline in nature. Soils of depression basins and Ranns are generally underlay a pan of calcium carbonates, clay and silt at a depth of few cms. to few metres. There are contrary views about the development of saline soils in the region. One hypothesis holds the view that soil salinity in the region is because of the marine origin of the sand which overlays the alluvial plain. This has been contradicted by the geomorphologists of Central Arid Zone Research Institute,
Jodhpur. According to them, the distribution of salt lakes and salinity are linked with the courses of prior drainage systems. Salt basins are relics of prior drainages as along with the sediments of various composition, mineral salts detached in soluble form from the parent material were also carried down by the channels and precipitated on low land according to their solubility.

Natural Vegetation

This region has very sparse vegetal cover because of soil moisture deficiency and aridity. Natural vegetation in the command area comprises of thorny scrubs and bushes which withstand high rate of evaporation from the surface of leaves. Command area of Stage I has plants of *Acacia Senegal* type while command area of Stage II has *Prosopis-Acacia Senegal* type of plants and *Elyonurus-Cymbopogen Jwarancusa* type of grass cover. This region does not have forest cover and degraded forests are visible only in very few areas. Infact, vegetal cover in the region disappears after the rainy season.

Climate

Climate of this region is hot desert type which is not conducive not only for crop cultivation and raising livestock but also for human inhabitation. This region has very high range of seasonal and diurnal temperature. In
IGC COMMAND AREA
MEAN ANNUAL TEMPERATURE

20 0 20 40 60 KM

27°C
28°C
29°C
30°C
31°C
summer mercury sores up to 49°C and in winter it drops down to 2°C frequently. Hot waves (Loo) and dust storms sweep this region in summer and cold waves occur occasionally during the winter.

Temperature - Mean annual temperature in the area varies between 25°C to 28°C. As evident from fig. 1.7, mean annual temperature is slightly higher in the command area of Stage II of the canal, (26°C to 28°C). Mean maximum temperature in the region is about 40°C during summer while mean minimum temperature during winter varies between 4°C to 6°C. Mean diurnal temperature range is 12°C to 17°C.

Rainfall - Command area of Indira Gandhi canal has scanty and erratic rainfall. Fig 1.8 shows that average annual rainfall in the region varies from about 25 cm in upper command area to less than 15 cm near the tail of the main canal. About 90 percent of total annual rainfall occurs during southwest Monsoon season. During this season mean relative humidity varies between 68 percent to 78 percent in the morning and 36 percent to 50 percent in the afternoon.

Because of high temperature and windspeed, and longer duration of sunshine rate of evapotranspiration is very high and exceeds the precipitation even during rainy season. The mean evaporation during summer exceeds 10 mm per day. The potential evapotranspiration values during summer (April-
IGC COMMAND AREA
AVERAGE ANNUAL RAINFALL

Fig 1-8

Scale: 20 0 20 40 60 KM

Rainfall Contours:
- 15 cm
- 20 cm
- 25 cm
- 30 cm
IGC COMMAND AREA

AVERAGE NUMBER OF RAINY DAYS

20  0  20  40  60 KM
IGC COMMAND AREA

VARIABILITY OF ANNUAL RAINFALL
(Percent)
Bajra is a monoculture in Jaisalmer and Barmer districts. However, in Bikaner and southwestern parts of Ganganagar district along with bajra kharif pulses (moth) and fodder crop (guar) were main crops before the introduction of canal irrigation. These crops are hardy and drought resistant. Paucity of soil moisture does not allow double cropping under rainfed conditions in the region. However, in upper part of the command area (in Ghaggar basin) gram and wheat are sown under rainfed conditions in rabi season by preserving soil moisture through dry farming techniques, i.e. preparatory tillage. Yield level of the crops under rainfed conditions remains very low. In the eventuality of severe droughts and prolonged dry spells these crops completely wither away.

Livestock raising or pastoralism is main occupation of a large number of people in lower parts of the command area (in Jaisalmer, Barmer and Bikaner districts). It is a supplementary source of income of the people in the upper and middle parts of the command area also. Persistent risk in the agriculture and insufficient and unreliable rainfall had forced the sedentary cultivators to adopt pastoralism as a subsidiary occupation in the region."But continuous droughts and famines encouraged abandonment of agricultural pursuits and concentration upon the flocks as
the major subsistence source. Availability of grazing land in abundance and growth of one of the most nutritious grasses in the world, Sewan, are other factors which have encouraged the people to take up pastoralism in this region. According to 1977 statistics of Livestock Census of India, in Jaisalmer and Bikaner district grazing area available per head of livestock population was 2.35 and 1.00 hectare respectively. While in Barmer and Ganganagar districts 0.22 and 0.18 hectare grazing area was available per head of livestock. Apart from permanent pastures, grazing is done on culturable waste lands. Proportion of culturable wasteland is very high in Jaisalmer and Bikaner districts. But fodder and drinking water in the region do not last for beyond rainy season. This forces the pastoral nomads to resort to the migration along with their herds to the places as far as Uttar Pradesh, Madhya Pradesh, Punjab, Haryana and Gujarat. Most of these nomads do not have any property at home and return back to their original place during next rainy season only. Besides, occurrence of severe droughts also compels these nomads to migrate out even during rainy season.

Livestock mainly comprise of cattle, sheep and goats. Sheep and goats constituted more than three fourth of total livestock in Jaisalmer, Barmer and Bikaner districts in 1977. But in Ganganagar district sheep and
goats constituted about 45 percent and bovines constituted more than half of total livestock. Number of cattle had declined in Jaisalmer and Barmer districts over the period 1956 to 1977. Cattle population is also on decline in Bikaner district after 1966. However, cattle and buffalow population had increased continuously in Ganganagar district. Contrarily, number of sheep and goats had registered an increase of more than 70 percent in Jaisalmer, Bikaner and Barmer districts over the period 1956 to 1977. While in Ganganagar district number of sheep and goats had increased by 46.7 percent during above mentioned period of time. Livestock population is on the rise in all the four districts of western Rajasthan over the period 1956 to 1977. However, growth in the number of total livestock in Jaisalmer and Barmer districts was not impressive during the period 1966 to 1977. Infact, during this period total livestock population had slightly declined in Barmer district.

Scope of the Present Study

Introduction of irrigation in drought affected and soil moisture deficient region of western Rajasthan has obviously led to the transformation of subsistence agricultural and livestock economy. Besides, irrigation induced development has also affected the social and economic conditions of the people. Availability of
irrigation water has also made both positive and negative impacts on environmental conditions. The present study attempts to have a comprehensive view of the irrigation induced socio-economic and environmental transformations in the agriculturally backward and arid region of western Rajasthan.

Objectives

Objectives of the present study are -

(i) To evaluate the progress of irrigation development, identify the causes of underutilisation of created irrigation potentials in the command area and examine the influence of implementation of Command Area Development (CAD) programme on levels of utilisation of irrigation potentials;

(ii) To examine the influence of irrigation on some parameters of physical environment, i.e.
(a) Subsoil water table,
(b) soil salinity and alkalinity,
(c) vegetal cover and structure of sandy soils and
(d) afforestation and its role in restoration of ecological balance;
(iii) To examine the impact of irrigation in inducing agricultural development in terms of
(a) Landuse pattern,
(b) cropping pattern,
(c) structure of animal husbandry,
(d) use of modern agricultural inputs and
(e) levels of agricultural productivity.

(iv) To examine the process of land allotment and colonisation in the project region and influence of irrigation development and land allotment on some parameters of socio-economic conditions of the people in terms of
(a) migration and redistribution of population,
(b) shift in the occupational structure,
(c) change in the relationship of means of production, i.e. land ownership and
(d) change in the tenancy structure.

Hypotheses

Following are the research hypotheses to be tested is the proposed study.

(i) Implementation of Command Area Development programme has helped in increasing the utilisation levels of created irrigation potential.
(ii) Intensive irrigation has led to sharp rise in subsoil water table and caused the environmental problems, waterlogging and soil salinity and alkalinity.

(iii) Availability of irrigational facilities has helped in change in the landuse pattern in favour of cultivation and led to efficient utilisation of land resources, i.e. increase in net sown area and cropping intensity.

(iv) Assured supply of soil moisture through surface irrigation has led to replacement of the drought resistant and low yielding crops by commercial and remunerative crops.

(v) Irrigation along with modern agricultural inputs is responsible for rapid increase in agricultural output and productivity.

(vi) Priority in land allotment to landless and economically and socially backward section of the society has led to equitable distribution and access to land resources.

(vii) Land allotment and agricultural development following introduction of canal irrigation in the region have resulted in large scale immigration in the pursuit of employment and shift in the occupation pattern.
Data Base of the Study

The present study has utilised both primary and secondary informations and data. The primary data has been generated through the field survey in the area during the period December 1988 to April 1989. The primary data and informations regarding agricultural inputs, outputs and cropping pattern refer to the agricultural year 1987-88. The informations were collected in the questionnaire form through a household schedule and a village schedule.

Most of the secondary information and data have been collected from the Office of Commissioner, CAD, Indira Gandhi Canal Project, Bikaner and various departments of CAD-

(i) Agriculture Research and Soil Survey Wing, Command Area Development, Krishi Bhawan, Bikaner.
(ii) Department of Colonisation, Indira Gandhi Canal Project, Bikaner.
(iii) Agricultural Extension, Command Area Development, IGCP, Bikaner.
(iv) Forest Department, IGCP, Bikaner
(v) Status Report on Waterlogging in Ghaggar Basin and IGCP, Stage I in Ganganagar District, April 1987, Govt. of Rajasthan, Groundwater Department, Jodhpur.
Besides, landuse data for Ganganagar and Bikaner districts was collected from Statistical Abstracts and Season and Crop Reports, Directorate of Economics and Statistics, Rajasthan. Data and informations pertaining to livestock were collected from the Report on the Livestock Census of Rajasthan, 1977, Board of Revenue, Ajmer. Data regarding population and migration was collected from Census of India, Series-18, Rajasthan - District census Handbooks Ganagnagar and Bikaner districts and Migration Tables, Part V - A & B.

Sample Design

The command area of Stage I of Indira Gandhi canal exhibits spatial variations in terms of physical environment. Moreover, the level of the utilisation of irrigation potential, generally, declines as moving downwards from the head of main canal. Hence, systematic area sampling technique has been utilised to select the sample villages. Three revenue tehsils of Ganganagar district - Hanumangarh, Suratgarh and Anupgarh, and Bikaner tehsil in Bikaner district are major beneficiaries of the canal irrigation in the command area of Stage I. Hence, four villages, one each from the above mentioned tehsils, have been randomly selected for the present study. These villages are located at increasing distance from the head of
main canal and get irrigation water through different distributaries of the canal. Sample villages 9MND, 8SHPD, 1LSM and Jagdevwala are located in Hanumangarh, Suratgarh, Anupgarh, and Bikaner revenue tehsils respectively. Jagdevwala is irrigated by Lunkaransar - Bikaner lift canal whereas other three villages are irrigated by flow channels. Moreover, 9MND and Jagdevwala are old revenue villages and 8 SHPD and 1LSM are newly colonised settlements. Fig 1.11 shows that village 9MND is located in upper command area, villages 8SHPD and 1LSM are located in the middle command area and village Jagdevwala is located in the lower command area of Stage I.

All the households of these villages are taken into account while conducting the field survey. The cultivating households in village 9MND belong to 6MND-A, 6 MND-B and 9MND Chaks. The cultivating households in village 8SHPD belong to 10SHPD-A, 10SHPD-B, 11SHPD, 8SHPD and ISWM chaks. In village 1LSM operational holdings of the households are located in the chaks 1LSM, 3LSM, 23APD and 20APD. While the area of Jagdevwala falls under four chaks. Detailed particulars of the sample villages and households are mentioned in table 1.3.
Table 1.3

Particulars of Sample Villages

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Particulars</th>
<th>Unit</th>
<th>Sample Villages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>9MND</td>
</tr>
<tr>
<td>1.</td>
<td>Sample households</td>
<td>No</td>
<td>90</td>
</tr>
<tr>
<td>2.</td>
<td>Ownership holdings</td>
<td>No</td>
<td>73</td>
</tr>
<tr>
<td>3.</td>
<td>Operational holdings</td>
<td>No</td>
<td>65</td>
</tr>
<tr>
<td>4.</td>
<td>Average size of ownership holdings</td>
<td>ha</td>
<td>22.51</td>
</tr>
<tr>
<td>5.</td>
<td>Average Size of operational holdings</td>
<td>ha</td>
<td>25.98</td>
</tr>
<tr>
<td>6.</td>
<td>Average fragments of operational holdings</td>
<td>No</td>
<td>1.60</td>
</tr>
<tr>
<td>7.</td>
<td>Proportion of NSA in operational holdings</td>
<td>%</td>
<td>97.22</td>
</tr>
<tr>
<td>8.</td>
<td>Proportion of NAI to NSA</td>
<td>%</td>
<td>89.92</td>
</tr>
<tr>
<td>9.</td>
<td>Proportion of area under sand dunes in operational holdings</td>
<td>%</td>
<td>8.38</td>
</tr>
</tbody>
</table>

Definition of Concepts and Terms Related to Irrigation:

Utilisation Level of Irrigation Potential - It is expressed as a ratio between gross area irrigated and created irrigation potential (GAI/potential of irrigation x 100). Values of this ratio, expressed in percentage, less than 100
percent and more than 100 percent mark underutilisation and overutilisation of irrigation potentials respectively.

Water Allowance - Water allowance or design factor is volume of water allocated per 1000 acres of culturable command area.

Irrigation intensity - It conveys different meanings to agricultural scientists and engineers. It is ratio between gross area irrigated and net area irrigated (GAI/NAI X 100) for the former. Whereas, Irrigation engineers define irrigation intensity as a ratio between gross area irrigated and culturable command area (GAI/CCA X100). The later concept of irrigation intensity has been used in Chapter II and III while the former has been used in Chapter IV.

Gross command Area (GCA) - It is total area which can be irrigated by an irrigation project. It also includes uncultivable area.

Culturable Command Area (CCA) - It is Culturable area of GCA. CCA is equal to GCA minus uncultivable land.

Calcareous of Kankar Pan - A hard layer of calcareous material or clay near the surface of land.
Methodology and Organisation of Study:

Most of the studies concerned with the impact of irrigation are, in fact, techno-economic evaluation and analysis of the irrigation projects. These studies, generally, analyse the impact of irrigation in the framework of Benefit – Cost (B/C) ratio and its modified form, Social Benefit – Cost Analysis (SBCA). Central Water Commission has also identified both direct and indirect benefits accrued from the irrigation projects and has issued guidelines for conducting such a study. However, the present study does not fit in any of the above mentioned methodological framework.

The present study is an attempt to have a comprehensive view of the irrigation induced changes in the arid region of northwestern Rajasthan. Beside the irrigation induced transformation in agricultural economy, it also evaluates the utilisation pattern of irrigation resources and its impact on the physical environment of the command area. Furthermore, the present study also addresses to the policy of land allotment and the impact of land allotment and irrigation induced agricultural development on the socio-economic conditions of the people.

Chapter II evaluates the progress in development and utilisation of irrigation potential in the command area
of Stage I. Statistical tables and chloropleth maps have been used to depict temporal and spatial variations in utilisation level of irrigation potential and intensity of irrigation. Impact of the implementation of CAD programme, particularly water course lining, on the utilisation of irrigation potentials is borne out by comparing the levels of the utilisation of irrigation potential in the command areas of the lined and unlined water courses.

Chapter III analyses both positive and negative impact of the introduction of irrigation on the environment of the command area of StageI. Waterlogging and soil salinity are identified as two major negative influence of irrigation on the physical environment of the region. Development and spatial dimension of the waterlogging is assessed with the help of statistical table showing the level of water table at the time of introduction of irrigation and at present. Spatial dimension of this environmental problem is also depicted with the help of the statistical table and a map based on the informations provided by a project, 'Monitoring of Water Table' of the Ground water Department. The influence of irrigation on physical environment in terms of causing soil salinity and alkalinity is borne out by the difference in pH values of soil samples belonging to irrigated and unirrigated areas of
four sample villages. The spatial dimension of irrigation induced soil salinity and alkalinity is shown with the help of a table and a choropleth map representing percentage of soil samples affected by salinity and alkalinity in extension district. The positive impact of irrigation on the physical environment is assessed in terms of the progress made in afforestation, sand dune stabilisation and pasture development in the command area.

Chapter IV analyses the impact of irrigation on landuse and cropping pattern. The temporal change in the proportion of area under various landuse categories is represented by the statistical tables while the spatial variation in landuse pattern is depicted with the help of choropleth maps. The influence of irrigation on the landuse is also borne out by the correlation coefficients between the intensity of irrigation (GAI/NAI X 100) and percentage of area under various landuse categories for available time series data. Change in the cropping pattern following the introduction of irrigation is analyzed in terms of change in the percentage of gross cropped area under individual crops depicted with the help of trend line graphs. Trend line are drawn with the help of the regression equation \( Y = a + bx \). \( Y \) is a dependent variable (proportion of area under individual crop) whereas \( X \) denotes time (years). Choropleth technique has been used to depict spatial variations in
proportion of area under foodgrains, cereals, pulses, oilseeds and individual crops. Crop combination analysis is done using Doi's technique of combinational analysis. It is a modified form of Weaver's technique of crop combination. Weaver's formula of crop combination is based on the technique of least deviation of actual percentages of area under crops from the theoretical curve. Doi has modified this formula because sometimes it includes even minor crops in the combination in the eventuality of continuity in the proportion of area under secondary and minor crops. Doi has applied the least square technique to overcome this drawback of Weaver's formula. As per this modification, the crop combination which has minimum sum of squares ($\sum d^2$) between the actual proportion and theoretical base curve is regarded as the crop combination. Triennium average of data has also been taken wherever required.

Chapter V evaluates the trends in the output of major crops, spatial variations in the level of agricultural productivity and correlates of agricultural productivity. Trends in the levels of output and yields of major crops is analyzed with the help of trend line graphs and computing compound growth rates. Formula used for the computation of compound growth rate is mentioned below:
\[
R = \left(\frac{\log x - \log x}{2^1 - 1^1}\right) - 1 \times 100
\]

Where \( R \) is compound growth rate, \( x_1 \) is the figure during earlier period, \( x_2 \) is the figure during later period and \( i \) is the difference between two periods.

Spatial variation in the levels of agricultural productivity in the command area is analysed in terms of differentials in the agricultural productivity of four sample villages. Sample villages are located in different parts of the command area and have difference in the utilisation of irrigation potential and physical environment. Agricultural productivity (Rs. per ha) is, in fact, gross output per hectare of net sown area. Agricultural productivity for the households is obtained by multiplying the outputs of all the crops by farm harvest prices and dividing the gross output by net sown area as given in the formula:

\[
Y = \frac{\sum (X_{P1} + X_{P2} + X_{P3} + \ldots + X_{Pn})}{\text{Net sown Area}}
\]

Where \( X \) is crop output and \( P \) is the farm harvest price of the crop.

Stepwise multiple linear regression technique has been used to analyse interfarm variations in the levels of agricultural productivity. There are five different
regression equations and correlation matrices, one each for four sample villages and total sample households. There are twelve explanatory variables but only seven have been included in the regression analysis because of the problem of multicollinearity. Details of the explanatory variables are mentioned in the chapter. Explanatory variables are explicit in their meaning except that of average numbers of waterings. It is an approximate indicator of volume of water applied per unit of irrigated area and computed as:

$$\sum (C_{W1} + C_{W2} + C_{W3} + \ldots \ldots + C_{Wn})$$

Net Area Irrigated

Where C is area irrigated under the crops and W is number of waterings.

Chapter VI discusses the process of colonisation and land allotment; and the impact of land allotment policy and irrigation induced agricultural development on the socio-economic conditions of the people in terms of migration and redistribution of population, occupational pattern and change in the relationship of the means of production, i.e land ownership and tenancy structure. The process and progress of land allotment in the command area is analysed in the light of land allotment policy of the Colonisation Department. This analysis is based on both
primary and secondary informations. Analysis of the other aspects of socio-economic conditions is based on the primary data. The sample households have been categorised into four social groups - (i) scheduled castes and tribes, (ii) backward castes, (iii) cultivating castes and (iv) higher castes, to analyse the distribution pattern of the fruits of irrigation induced economic development among various social stratas of the society. Higher castes include Brahman, Rajput, Vaishya, and Khatri whereas cultivating castes have agriculture as their traditional occupation and include Jat, Jat Sikh, Ahir, Gurjar, Kamboj, Nath, Bairagi and Bishnoi. Scheduled castes and tribes belong to lowest social strata and include Meghwal, Nayak, MajhabiSikh, Balmiki, Bawari and Sansi castes. Scheduled tribes do not reside in the sample villages. The traditional occupation of most of the backward castes is artisanship. Backward castes include Kumhar, Suthar or Khati, Chhipa, Nai, Bhat and Oad.

Chapter VII presents the summary of conclusion of the present study.

Overview of Literature:

Irrigation has been assigned a key role in the strategy of agricultural development in India. Despite various problems faced in the development of irrigation resources, it has emerged as an effective mean of countering
adverse effects of weather on the agricultural production and increasing foodgrains production which is very crucial for the developing economy of the country. Irrigation has played three fold role in agricultural development - (i) providing protection against adverse weather, (ii) bringing in stability in agricultural production and increasing production. It has attracted the attention of scholars belonging to various disciplines of knowledge, ranging from economics to engineers. The literature related to this subject also ranges from the aspects of utilisation and development of irrigation resources and water management to the benefit - cost evaluation of irrigation projects and influence of irrigation on environment. A brief review of available literature related to irrigation is presented as below.

Kumar (1977) evaluates the impact of the construction of field channels on the cropping pattern, cropping intensity, proportion of irrigated area, farm income, farm inputs and outputs and labour in the command area of Hirakud canal system. Field channel irrigation was unknown to the farmers of this region before 1966-67, when a pilot demonstration programme of providing field channels was undertaken under intensive Agricultural District Programme (IADP). It is a comparative analysis between the villages with and without irrigation. Pandey (1979)
studies the impact of irrigation on rural development in Kiul-Badua-Chandam Command Area in Bihar. This study is a comparative analysis of some selected households of three irrigated and three unirrigated villages. The author has selected occupation, educational level, land holdings characteristics, level of irrigation, cropping pattern, employment, income and indebtedness as indicator of socio-economic development. Wade (1980) studies the problems of underutilisation of irrigation potentials of canal systems in India. He argues that irrigation intensity in the country is very low (120-125 percent). Underutilisation of irrigation potential is linked to heavy loss of water through seepage. The author says that heavy loss of water in transmission has also led to the problems of waterlogging and soil salinity. He stresses the need of the implementation of CAD programme and on farm development, and conducting socio-economic research of the command areas. Patel (1981) analysis the impact of irrigation on employment in the command areas of 24 medium irrigation projects located in Gujarat. The study is based on the data collected from 100 farm households from each project. The study reveals that there is a remarkable increase in the employment in the irrigated areas. Although, employment of labour per one rupee of investment falls but, the employment of labour per unit of land increases. It leads to ultimate
increase in overall employment on irrigated farms. Stepperdson (1981) discusses the environmental and socio-economic consequences of the development of irrigation in the Indus River Basin in Pakistan. The author says that heavy conveyance loss of water (estimated to be 30 to 50 percent) has led to extensive waterlogging in the region. Increase in the cultivated land has led to depletion of forest cover. Population pressure on the land has also increased rapidly. George and Raju (1981) evaluates the influence of irrigation on employment in the command area of Nagarjunsagar left canal. Sample households for the study are categorised into three stratas, unirrigated, receiving irrigation for last two years and receiving irrigation for more than five years. The study analyses inter-strata differences in employment level and its correlates. Irrigation has led to higher level of labour absorption in onfarm activities, particularly in crop production. But, level of labour absorption in non-farm economic activities continues to be very low even in the areas where irrigation has been introduced more than five years ago. Chopra (1982) analysis the influence of irrigation, in particular quality of irrigation, on the farmers' decision about the allocation of level at various crops and cropping intensity. The author has used linear regression model for two periods of time (1970-74 and 1974-78) to explain the increase in the
proportion of area under rice and cropping intensity. The independent variables are volume of canal water, volume of tubewell water, composite index of level of irrigation, number of tubewells, sowing period rainfall, profitability of rice cultivation compared to cultivation of competing crop, cultivated area per agricultural worker and relative average of harvesting period wage rate. Shift in the cropping pattern in favour of rice is explained by quality of irrigation (proportion of tubewell irrigated area in total cropped area under Kharif crops) and relative profitability index. Whereas, change in cropping intensity is explained by tubewell irrigation and cumulative irrigation index. Verma (1983) examines the policy issues about wateruse in the command area of Rajasthan Canal. The author advocates for the policy of acquiring high irrigation technology and intensive in order to maximise the profit and production per unit of water and land. Dandikar (1983) also examines the policy issues 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 more profitable but it definitely leads to uneven distribution of resources in the space and society. It may also lead to the problem of soil salinity. The author advocates for providing extensive irrigation and development of pastures
to boost the traditional livestock economy of the region. Dhir (1983) points out that the soil characteristics and environmental conditions in the lower parts of the command area of Stage I and the proposed command area of Stage II are different from those in the upper parts of Stage I. Hence, this area requires a different policy of irrigation development and technology than that adopted for the command area of Stage I. Bithu (1983) also discusses that introduction of intensive irrigation in arid areas overlooking their fragile environmental conditions has let to environmental deterioration. The command area of Stage I of Indira Gandhi canal has already developed waterlogging and soil salinity on an extensive scale. The author suggests that irrigation planning and practices for the command area of Stage II should be different from that of Stage I. Roy (1983) studies the impact of irrigation on social, economic and environmental conditions. This study is based on primary data collected from a sample of 820 households belonging to 68 villages of the command area of Indira Gandhi canal. The author has followed the guidelines suggested by Central Water Commission in conducting the field survey with some modifications. The impact of irrigation is borne out by comparison of the households with and without irrigation. This study has analysed both direct and indirect effects of irrigation. Palanisami (1984)
analyses the pattern of water allocation and use; impact of water availability on cropping pattern, input used and crop yield; identifies organisational and management weaknesses in the project management and suggests measures to improve the performance of water distribution in the command area of Lower Bhavani Project. This study is based on the survey of 150 farmers, located at 10th, 66th and 120 miles from the head of canal. Sathpathi (1984) evaluates the impact of irrigation on the farm economy, deficiencies in irrigation policy, problem of underutilisation of irrigation potential and water rates in Orissa. The author has used curvilinear regression analysis for production function. Jha (1984) examines the role of irrigation in agricultural development with special reference to Bihar. The study also draws comparison between planned and unplanned irrigation development, discusses and evaluates various methods of wateruse, reviews present irrigation policy and evaluates nature of floods and flood control. Pant (1984) edits the proceedings and papers of the workshop on "Productivity and Equity in Irrigation Systems" organised by Giri Institute of Development Studies (Sept. 1982). This book deals with theory, concept and issues; empirical case studies of irrigation management and administrative experience in Andhra Pradesh and Gujarat. Gupta (1987) evaluates the irrigation induced environmental degradation (waterlogging
and soil salinity) and has suggested certain measures for its amelioration. The author estimates that about 12 million hectares of land in India is affected by waterlogging and soil alkalinity and salinity. Dhawan (1988) has done an extensive work on the impact of irrigation on agricultural development in India. The study is mainly based on secondary data and covers a wide range of the influence of irrigation on agricultural development in the country. The empirical enquiry mainly focusses on protective, productive and stabilising role of irrigation in Indian agriculture. The study also analyses inter-source differences in productivity of irrigated agriculture, income generation through irrigation and equity in sharing gains from irrigation. Dhawan (1989) discusses various issues involved in water resource management in the country. This article covers wide ranging aspects of water management including waterlogging and drainage, wastage of irrigation water, prevention of groundwater depletion, conjunctive use of irrigation water, improvement in the level of irrigation utilisation and achieving economy in wateruse.
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