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# Emerging Issues and Problems of Soil Salinity and Water Logging: A Case Study of Indira Gandhi Canal, Rajasthan

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## ABSTRACT

Soil salinity negatively affects plant growth and induces soil degradation. Saline soils indicate lower agricultural productivity and their impact on the livelihood security of farmers and the socio-economic status of the Indira Gandhi Canal region, Rajasthan. In the context of irrigation development, problems of rising groundwater levels and the development of salinity have arisen in the Indira Gandhi Nahar Priyojana (IGNP) area. The irrigation has recently decreased to about 1 meter, much higher than the specified value of 0.51 m in phase I. In phase I, severe inundation was observed. found in a variety of locations. It is anticipated that by the end of this century, roughly 49.6 percent of the region being studied will be at risk of experiencing flooding. The waterlogging, soil salinity, and alkalinity that plague India's agricultural landscape pose a challenge to the viability of irrigated farming. It has been determined that the most effective technique for halting the reduction in agricultural output is to use enhanced irrigation management in conjunction with a combination of surface and subsurface drainage. The method of reclaiming waterlogged lands by bio drainage is one that is efficient and economical. For the objectives of rehabilitation, species such as Salvador, Tamarix, Eucalyptus, and Prosopis Juliflora are among those that are recommended for planting in afflicted regions. The bio-drainage system helped in reducing the waterlogged areas and soil salinity by lowering the water table in the study area. Traditional knowledge and modern agricultural management good practices should be adopted for efficient and optimal use of water resources. This can be achieved by maintaining irrigation through the minimum pumping hours according to the minimum water requirements of the crop, as well as choosing more cost-effective planting methods. This research paper recommends policies to improve traditional and scientific knowledge into policies and improve mutual understanding, cooperation, and collaboration for better policy results for sustainable development and mitigate the emerging Issues and problems of soil Salinity and water logging in the area of Indira Gandhi Canal, Rajasthan.

***Keywords:*** *Groundwater, Irrigation, Resources, Soil Salinity, Water Logging, Sustainability*

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## INTRODUCTION

Water is one of nature's most precious gifts to humankind. Population growth and natural resource requirements are increasing at a fast pace, creating pressure on water and land resources. The development of water resources for the benefit of humankind is essential for

improving the quality of life. The temporal and spatial availability of these precious natural resources should be constantly and carefully monitored. The ability to leverage these precious resources for optimal use, system planning and development, operational maintenance, and prudent management of water resources is an ongoing requirement (Prasad et.al., 2021). Water is necessary for the existence of natural habitats. Water forms a living mass, together with the soil and air, representing living beings' environment Water is an important component of the geosystem (Pandey, 2021).

Due to ineffective management of water resources, the soil on about two billion million hectares of land throughout the world has deteriorated. Inundation and soil salinization together damage around 10–15 percent of the irrigated land across the world. It is well knowledge that irrigated agriculture in Mesopotamia has struggled with the twin challenges of waterlogging and soil salinization ever since the dawn of human civilisation in that region. The waterlogging and salinization of the land are said to be the factors that led to the downfall of this ancient civilisation (Rhoades, 1990). In his book "Desertification of the United States," David Shediden identifies the salinization of irrigated soils as one of the most perilous kinds of desertification (Shediden, 1981). There is no other place on Earth where irrigated agriculture can serve as a buffer against the effects of desertification like this one does. It is estimated that one-third of all irrigated land throughout the world is in danger due to the combined issues of waterlogging and soil salinization. This double problem in semi-arid and arid locations is extremely complicated, which poses major limits for the disposal and use of saline-drained water. These places are characterised by a lack of precipitation throughout the year. In order to solve the problem of disposal in a way that does not further complicate environmental factors, this calls for sophisticated and pricey technology. In India, 70 Per Cent of the cultivated area is in medium and low-rainfall areas. A major part of the arid zone in India (73.8Per Cent) falls in western Rajasthan, named Thar. Thar covers an area of about 19.84 million hectares, accounting for about 60 Per Cent of the area of Rajasthan and 6 Per Cent of the total geographical area of India. The Thar Desert is characterized by low and erratic rainfall, raindrops and salt-tolerant xerophytic plants. Formulation and implementation of canal irrigation in drier areas receiving scanty rainfall is a much-needed step (Datta et.al., 2000). However, the introduction of canals in such areas should be strictly according to the guidelines of government plans and proposals. It has been found that the introduction of the Indira Gandhi Canal without the provision of adequate drainage has led to

the problem of a rise in groundwater table leading to waterlogging due to seepage and increased level of salinization (Tewari et al. 1997).

Particularly in arid and semi-arid regions, soil salinity adversely impacts crop growth and yield and causes land degradation (Gerba and Pepper, 2019). By using irrigation water with a high salt content, humans can either naturally cause or contribute to soil salinity, which results from the weathering of rocks and fundamental minerals (Shahid et al., 2018). The connection between waterlogging, soil salinization, and plant yields has been the subject of numerous studies. Because waterlogged soils stop irrigation water's salt imports from leaching, soil salinization sometimes occurs in conjunction with waterlogging.

The natural topography does not allow excess water to be removed through the IGNP surface drainage system. Especially in Tibbi and Rawatsar command areas, there is no natural outlet, resulting in water being locked in these depressions, stagnant water in these depressions causing groundwater recharge in nearby areas. This raises the groundwater level, creating flooding problems in the area (Kumar, 2017). Rajasthan has a very low rural literacy rate. Due to their low literacy levels, farmers are unable to comprehend the nature of the problem in relation to its long-term effects on sustainability. They have a limited understanding of organic and inorganic fertilisers, as well as the ways in which specific crops make use of available water resources. They have persistently sought to produce crops with larger water requirements, which has made the situation worse, and there has been hesitation, totally based on ignorance, in adopting bio-drainage (Rhoades, 1990 and Maurya, 2017). By bringing the water table in the study region down, bio-drainage unquestionably assisted in the process of reducing the number of flooded places (Kumar, 2017).Both waterlogging and salinization are detrimental to plant development and yield. While waterlogging reduces soil aeration around the root zone, salinization affects crop development by raising the osmotic potential of the soil solution. In general, the decline in yield is linearly connected with the salinity level, and the harm to plant growth and production is more severe when these processes take place at the same time. Waterlogging causes plant roots to grow shallow, and salts accumulate in the soil profile because of capillary action, rendering the area unusable for agriculture.

Considering shifting temperature and precipitation patterns brought on by climate change, the study found that crop losses resulting from soil waterlogging are expected to rise (Singh, 2021). To lessen the stress caused by soil waterlogging, recommended management

approaches must be utilised, such as the adoption of flood-tolerant cultivars, better drainage, and the application of adaptive nutrient management techniques (Kaur et al., 2020).

Crop yield decline and farmland degradation are the results of improper management of waterlogging and lack of regular monitoring of irrigation water quality. As a result, efficient methods for measuring waterlogging are needed to aid in decision-making when it comes to monitoring waterlogging and farmland damage.

## ENTRY OF IGNP IN THAR DESERT

Soon after the attainment of independence in 1947 of India, the Indian government targeted to revive its shattered economy. Food crops were the prime need of the time since people were dying of hunger and starvation. The constitution of India was officially formulated, and the planning process began in India in a phased manner. The First Five-Year Plan was formulated in 1951 with a prime focus on agriculture and agricultural production. The areas reeling under the situation of drought were targeted to be covered with dense networks of Irrigation. The arid and semi-arid areas in north-western parts of India is no exception to this. It was decided to provide canal irrigation (Kumar, 2001). Canal irrigation should be provided for the rest of the Thar desert in Rajasthan. Prospective planning was initiated and water from three eastern rivers of the Indus basin (Ravi, Sutlej, and Beas) was allocated for use in Rajasthan. The building work of the Rajasthan Canal Project was ultimately opened on 30 March 1958 by Shri G.B. Pant, who was at the time the Minister of the Interior for the Government of India. This was after the project overcame all of the initial challenges. It was in order to supply the water that was commanded from the Harike barrage in Punjab area starting from its entry into Rajasthan near Hanumangarh and extending up to Jaisalmer including an area in intervening districts of Sriganganagar, Bikaner, Jodhpur, Churu, Hanumangarh and Bikaner. The entire planning and groundwork for this project were the handiwork of Shri Kanwer Sain the then Chief Engineer of the erstwhile state of Bikaner. Later this project was renamed Indira Gandhi Nahar Priyojana in 1984 and was the longest canal in the world. In the early phase, the command area showed a remarkable transformation in the cropping system and economy of this zone. This project is a dream to transform the vast desert, in the western part of India into the greenery. In the interstate agreement in 1981, the state of Rajasthan has a share of 8.6 MAF in the surplus water of the Ravi and Beas Rivers. This water is carried through IGMN and its distribution network for irrigation in an area of 19.6 lac. ha of northwest Rajasthan. The CCA of stage 1st GNP has an area of 5.46

lac ha, falling in Sriganganagar, Hanumangarh and Bikaner districts. The water allowance and irrigation intensity are 5.23 cases/000' acre and 110 Per Cent respectively. The construction was taken up in the year 1958 and water was first released in the Naurangdesar system, off-taking from masitawali head works on IGMN, in the year 1961. One of the major contributory factors to the success of the green revolution in India is the development of an extensive irrigation system after the independence, but the excess of everything is bad is a bitter truth. The same thing happened in the command area of Rajasthan. Coupled with all these developments, the area suffered from certain problems, which have arisen due to a disrupted equilibrium between the recharge and discharge of water. One of the main negative manifestations of this is an increase in the groundwater level which leads to waterlogging in the soil, high temperatures, and excessive presence of water-soluble salts in the soil (characteristics of the soil in savanna). this membrane) and a high rate of transpiration. caused the dual problem of secondary salinity and salt accumulation each year in the topsoil or the subsoil (Maurya,2017). This problem of water logging and soil salinity has been reported from all corners of the world but is more several and extensive in the arid and semi-arid regions. Canal irrigation areas of N-W Rajasthan particularly in the parts of Tibbi and Rawatsar area re facing this problem for quite some time (Chatterji and Sexena, 1988).

## THE STUDY AREA: INDIRA GANDHI CANAL, RAJASTHAN

The Indira Gandhi Canal is supposed to be one of the premiere projects launched and built in arid and semi-arid parts of India. It is in the northwest part of the country covering the culturally rich state of Rajasthan. The uniqueness of this project lies in the fact that it covers the part of “THAR DESERT” in India. The construction of this canal in such an inhospitable and perilous terrain has been challenging. By visiting the westernmost areas of Rajasthan, notably Bikaner, Jaisalmer, and Barmer, one acquires a fresh understanding of the phrase "Barren Land." These landscapes are characterised by the constant movement of sand dunes, which ultimately bury everything in their path.

The initial ground breaking for the IGCP took place on March 31st, 1958, and it now holds the position of being India's largest project. The breadth of this project is said to be 40 metres, while the depth is said to be 6.4 metres. The canal has a carrying capacity of about 18,000 cusecs when it comes to the headwaters. Due to the magnitude of the undertaking, its construction was broken up into two phases for the purposes of making its administration more manageable, maximising the utilisation of available resources, and realising early

advantages. It is important to take note that the Indira Gandhi Canal Command Area (IGCCA) encompasses around 4% of India's "dry zone" and over 10% of the state of Rajasthan.

## STAGE-1

A feeder canal spanning 204 kilometres in Punjab and Rajasthan, a main canal spanning 189 kilometres, and a Kanwar Sain lift channel spanning 151.5 kilometres make up Stages-1. They are linked to one another through a network of distribution networks as a whole. This stage irrigates a cultivable command area that is 5.25 million hectares in size, with a flow canal irrigating 4.79 million hectares and the Kanwar Sain Lift Canal irrigating 0.46 million hectares. The intended intensity of irrigation is 110%. It is anticipated that stage 1 will be finished, with the exception of a few supplementary tasks.

## STAGE-2

The length of the main canal in Stage-2 is 256 kilometres, which is somewhat longer than the length of the canal in Stage-1. It is helped along by 34 pumping stations that are connected to a broader network of a distribution system, as well as six lift schemes that have a maximum static lift of sixty metres. This stage of the project will cover an area of cultivable command area that is 10.12 lakh hectares in size (7.00 lakh hectares by flow and 3.12 lakh hectares by 06 Lifts canal), with an intensity of irrigation that is 80%. (Tewari, et.al., 1997). Up to the tail of the Main Canal, the construction projects are now considered finished (Fig.1).

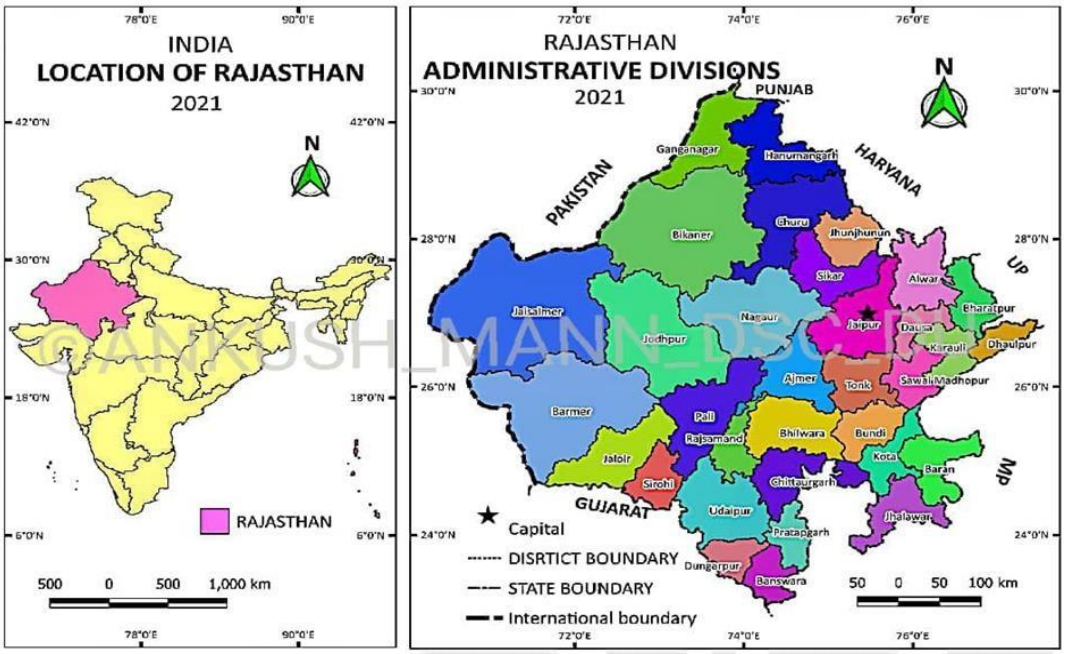

**Figure 1: Location of Rajasthan in India**

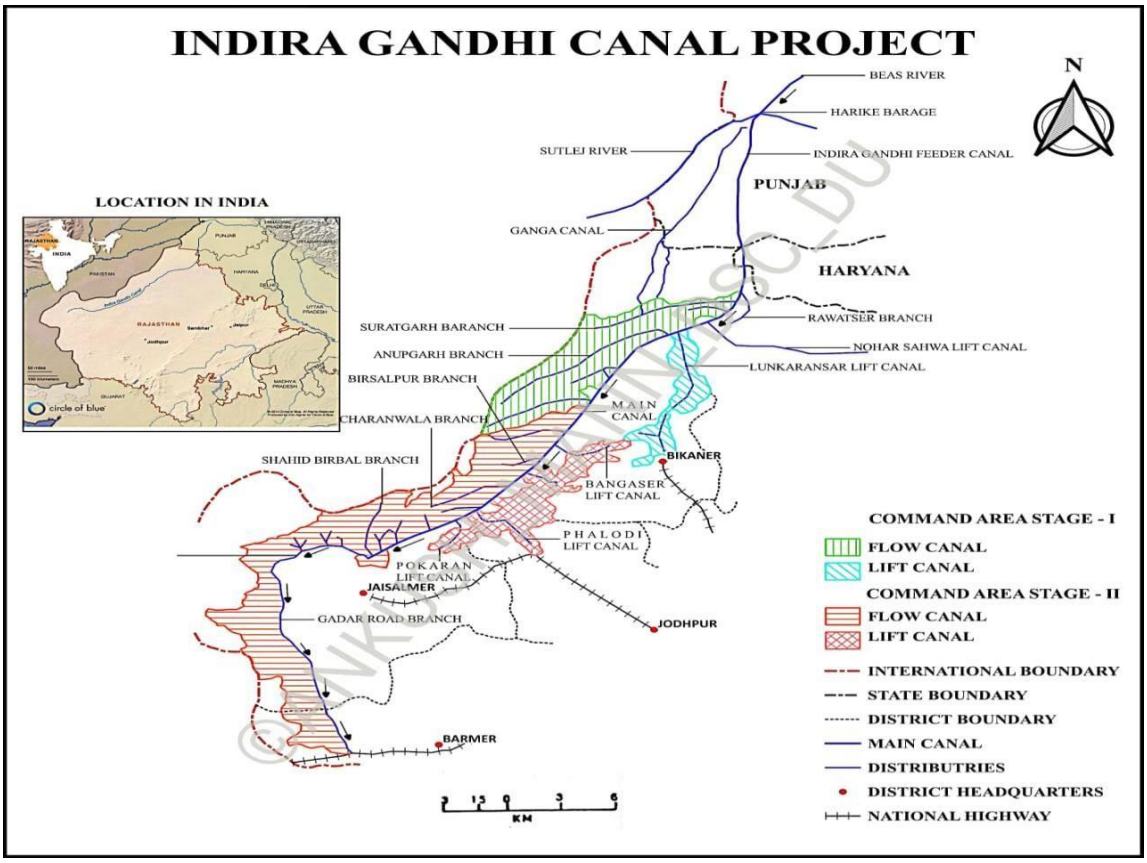


**Figure 1: Location of the Indira Gandhi Canal Project**

## EXPERIENCES OF IGCP

The major experiences of IGCP after the commencement of irrigation are as follows:

1. Availability of canal water for drinking and other domestic purposes.
2. The annual growth of Crops with the aid of canal water resulted in enhanced production.
3. Population growth will result in expanding new settlements, villages and mandies.
4. Enhanced socio-economic conditions and growth of all economic activities.
5. Improved household income with a decent expenditure structure.
6. Attitudinal and lifestyle changes result in understanding the need for education.
7. Increased mobility and communication.
8. Focus on population heterogeneity, improved interactions between communities and within communities, and faster diffusion and adoption of irrigated agricultural technology.
9. Knowledge of outbreak of drought conditions and techniques for its elimination.

10. Improvement and adjustment to micro-climate and reduction in the incidence of sandstorms.
11. The groundwater level is rising.

## OBJECTIVES OF THE STUDY

The present study has the following objectives:

- to explore and assess the main causes of waterlogging and salinization in the Indira Gandhi Canal, and
- to suggest ways to achieve hydrological sustainability by proposing remedial measures in waterlogged and saline sites in the study area.

## RESEARCH METHODOLOGY

Most of the data for this research project came from secondary sources. As a result, the present study effort is an output of that data. In addition to the work that was done by the Central Ground Water Board, the information was also obtained from secondary sources such as the Annual Progress Report of IGNP (Published by IGNP Head Office), Jaipur; Command Area Development, Rajasthan; the Ministry of Irrigation in New Delhi; the Department of Irrigation in Rajasthan in Jaipur; the Forest Department in Rajasthan; the District Census Handbook published in Jaipur, etc. The first and second stages of the canal command area are both accounted for in this analysis. The ensuing ecological alterations at a macro level were researched in order to investigate the effect that IGNP had on the surrounding ecosystem.

## RESULTS AND DISCUSSION

Waterlogging: - Any land is said to be water-logged when its productivity is affected or deteriorated due to a high and rising water table. The productivity of the soil can be largely affected when the root zone of aeration within the cross-section of the soil is filled with water showing signs of less aeration. Plant life depends on nutrients such as nitrates. Nitrification is a process of fixing the nitrates to the root nodules of the plants that are usually produced by bacteria. The growth of such micro-organisms providing food to the plants in the form of nitrates is retarded under the situation of water logging when the oxygen supply is cut off. This results not only in retarding the plant growth but production and crop yields are also hampered (Table 1).

**Table 1: Trends in the Area Sensitive to Waterlogging**

| Period | Area sensitive to water logging (Sq. Km) | Percentage of the observed Command |
|---|---|---|
| 1981 (September) | 742 | 9.3 |
| 1982 | 832 | 10.4 |
| 1983 | 928 | 11.6 |
| 1984 | 1234 | 15.5 |
| 1985 | 1311 | 16.4 |
| 1986 | 1456 | 18.2 |
| 1988 | 1795 | 22.5 |
| 1990 | 1980 | 24.8 |
| 2000 | 3960 | 49.6 |

**Source: (Saxena, 1993; Basic Statistics of Rajasthan, 1988, 1995, 1996, 2002)**

**Soil Salinity: -** Salinity in Soil refers to the amount of salt present. There is a tolerable limit to the presence of salt in every soil and it varies from region to region. Some soils are more tolerant to salt as compared to others. At times, a situation arises when the amount of salt present in the soil exceeds the tolerable limit and continues to increase. This entire process is called Salinization. The salt usually occurs naturally in soil and water through processes like weathering of minerals, volcanic eruption, higher rate of evaporation, global climate change etc. Anthropogenic processes like irrigation and road salting also contribute to its increasing concentration. Soils having a higher concentration of soil content are called Saline Soils and are usually unfit for the cultivation of crops and agricultural activities.

## Causes of Water Logging and Salinity in The IGNP Command Area

The absence of Natural Sub-Drainage and the non-presence of natural topography are the major factors responsible for the problem of water logging in the study area, especially in the Tibbi and Rawatsar Command Areas. The excess water does not have any innate outlet to be flushed out. Consequently, water gets stored in these depressions. Such stored and stagnant water results in increasing the groundwater level in the adjoining areas. This rise in the

groundwater level poses the problem of waterlogging. Under such circumstances of rising water levels, ease at its accessibility and more importantly, lack of assured and adequate water supply from canals, the farmers tend to utilise and apply an excess amount of water to the fields (ICAR, 1992). This over-utilization of water in the study area results in and aggravates the dire problem of waterlogging, salinity, and loss of production. Also, to be noted, it is a common practice to find that farmers rely on over-irrigation in surplus areas despite the water regulation schedule by the government. Most of them do not follow a crop pattern or a regional package irrigation schedule. The sparse use of groundwater due to its degraded quality (except in some reaches near Ghaggar Head plains) and even where groundwater quality is good, the reluctance of farmers to use ground water except in years of water scarcity in a canal, is to some extent responsible for waterlogging.

**Seepage from Canal Network and High-Water Allowance**

A large quantity of amount of water is lost through seepage from the network of canals which causes the waterlogging condition in areas adjoining the main canal, distributaries, and minors (Kumar 2001). It is due to construction defects. The higher water allowance of 5.23 cusecs/1000 acres compared to 3 cusecs in Stage II, and even lesser in the Ganga and Bhakra command, is contributing factor for waterlogging.

**Presence of a Thick Hard Pan of Gypsum at a very Shallow Depth**

The thick and sturdy layer of gypsum does not allow water to penetrate down the deeper layers of the soil, so it tends to get deposited over the hard surface. This also enhances salts in the soil and layers. The depth of the gypsum layer varies from 8-10 m. Without deep percolation, this water comes on the top layers of soil by the process of capillary movement with accumulated salt residuals on the surface. During summers, when the weather is dry, and the rate of evaporation is high this problem of salinity in the soil becomes acute with a salt content varying from 4-120 dS/m (Kumar, 2017).

**Seepage from the Ghaggar Depressions**

More than 18 depressions are in use to receive the water from this important river through Ghaggar Diversion Channel (GDC) during monsoon season when there is an overflow of water. These were constructed to check the flow of Ghaggar at the surface level outside the nation and mostly into Pakistan.

**Higher Temperature**

The temperature remains higher in the study area which has a mostly semi-arid climate and lies in the north-western part of Rajasthan. Temperature varies from 0 - 50^0 C.

**Excessive Water-Soluble Salts**

Water-soluble salts are present in abundance, and it is an inbuilt character of the soils of the Thar desert. During summers, when the temperature is dry, it results in a higher rate of evaporation. Due to an increased loss of water as water vapour, these dissolved salts come up to the surface of the soil through capillary action.

**Higher Rate of Evapotranspiration**

Salts get collected near the upper layer as the water table rises with high temperature. During periods of sunshine, the rate of evapotranspiration gets enhanced, and the salts get accumulate at or near the surface of the root zone. This accumulated salt proves to be detrimental to plant growth (Sen, 1993).

**Scanty Rainfall**

Rainfall in North-West Rajasthan is generally very low. Here Rainfed cropping pattern is common but excessive salt hampers crop growth. It is also to be noted that the annual rainfall is about 274 mm per year.

**No Natural Drainage**

The condition of drainage is very poor in 1st stage since it is devoid of any perennial source of a river. Topography is also uneven. The Ghaggar, which is a seasonal river, originates from the lower range of the Himalayas, enters Hanumangarh and flows westward through Suratgarh and Anoopgarh Tehsils. Finally, this river gets lost in the desert plain but its course can be easily traced and is demarcated up to Anoopgarh town. To, rejuvenate this natural and important drainage system, all the possible efforts should be taken otherwise waterlogging and salinity will remain as such. Man-made methods of drainage are also not properly managed and maintained.

**Ghaggar Diversion Channel (GDC)**

Due to the large amount of discharge from rivers during rainy days, there is a risk of flooding in the irrigated areas of the Nali belt along the Ghaggar River. To avoid such natural disasters in terms of flooding of fertile irrigated tracts, a diversion channel with a capacity of 12000 cumses was constructed to divert the head water to the depressions usually in the sand dunes

near Suratgarh. These dunes are very high and the seepage & recharging from a raised level of

### River Alignment Route

These depressions lie along the alignment route of the old Drishtawadi river- a tributary of river Saraswati. The level of bed along the banks of Drishtawadi is barely 15-20 feet lower than the bed of depressions. As a result, the impounded overtopped water makes an easy entry towards the adjoining bed of Drishtawadi, giving rise to the upliftment of groundwater level, causing a massive problem of water logging in Badopal, Jakhdawali & Manakthedi. In the early 1980s, it was noted that the groundwater level rose in the Badopal and Tibbi districts by around 0.8 metres each year, resulting in roughly 11,500 hectares of land being inundated by floodwaters. This phenomenon was attributed to a combination of factors. Even though the Ottu Dam has been reconstructed with a considerable reduction in the force it exerts, there has been no cessation in the encroachment of canals into the surrounding area. The erosional activities from winds have largely managed to bury the fertile and productive soils throughout the canal command area (Govt. Of Rajasthan, 1996). The tehsils of Tibbi, Hanumangarh, Pilibanga and Rawatsar within the purview of the Indira Gandhi Canal are reeling under the problems of environmental degradation in terms of frequent flooding, saline intrusion, and rising groundwater levels (Kitamura et.al., 1997; Raina, 2010).

## SUGGESTIONS AND REMEDIAL MEASURES IN WATER-LOGGED AND SALINE SITES OF IGNP

### Stage 1st Reduction in Water Allowances

Better, rational, and planned management of land and water resources is the prerequisite to solving the problems of water logging and salinity of Soil. There should be sound and conjunctive use of surface and groundwater to prevent its untimely and sudden rising trends. This will help save the further salinization of soils (Chouhan 1988). In addition to this, more areas can also be brought under irrigation, thus, providing a sense of relief and security to the poor farmers, who usually suffer in the canal command. Adopting the variations in allowances of water in the canal command may largely result in the reduction of waterlogging (Abrol et.al., 1988). For example, water allowances of 2 cusecs / 1000acres can be provided at places where a hard pan layer exists at a nearer surface area. Contrary to this, the water allowance could be increased up to 3 cusecs / 1000 acres where a hard pan layer does not exist near the surface.

## Excavation of an Open Drain

The drainage condition in Stage 1St is very poor. It does not have any perennial rivers. The Ghaggar, which is a seasonal river, originating from the Shivalik range of the Himalayas, enters the region of Hanumangarh from Sirsa to Birkali-Gandheli. This river is lost in sandy terrain, but its course is easily traceable up to Anupgarh Town. The Ghaggar river sometimes causes flash floods. The flood plain of this river is known as Nali Bed /neglected bed of the Saraswati River. Even today it can be rejuvenated or revived by excavating it as a somewhat reachable drain. The pathway for excavation may be followed as identified in Map on a river-like complete alignment (dark purple). By digging an open drain with proper alignment and natural gradient flow by using the route of a prevailing buried channel of the pre-historic river Saraswati. It will tackle the problem of the entire waterlogged area. Exact geographical coordinates (i.e., latitudes and longitudes) of the path may be followed as per the river-like identified pathway. Excavation of this drain from Birkali to Anupgarh Nali bed or extension up to Arabian sea (followed by a pathway up to Luni River to Rann of Kutch of Gujarat) is the best, safest and permanent solution although the cost might be staggering.

## Bio-Drainage

Plantation on both the sides of Indira Gandhi canal is a good technology to reduce the seepage of water. Growing Eucalyptus calmodulins is largely in practice since its high transpiration rate acts as bio-pump and thus, checks its seepage from canals. Also, species like, Acacia, Casuarina, Acadia stenophylla and Melaleuca are more tolerant to saline and flooded soils thus, providing a barrier to check the seepage of canals and their tributaries. Shesham Siresh, Poplar, Amaltash, Papdee & Imli (all are Hindi/local names) etc. trees are good for buffer plantation on both sides of canal banks in 2-4 rows. These plants not only check the seepage from the canals but also a source of income to the farmers in the form of fuel, fodder & timber wood. Apart from being salinity tolerant, these plants are also efficient in water extraction with deep roots. Planting buffer strips for Bio-Drainage between the Ghaggar depressions & low-lying areas in line with groundwater flow to prevent water logging from areas where the water table is still critical& in the rising trends is good to combat the problem with a preference to high-water requiring plants. The salinity of the plantation site is also very important, so it should be chosen as per the salinity tolerance limit (Hussain, 2019).

## Construction of Evaporation Pond

Construction of an evaporation pond followed by extraction of salts from severely saline and water-logged sites by solar evaporation systems. So that a substantial quantity of salts can be scrapped, and material can be used industrially leaving the soil with reduced salt content/salinity and water.

### Agriculture on Raised Sites

Transporting soil from dunes or other places and dumping over water-logged regions up to a height of around 1m to 1.5m above water-logged areas. Agriculture on these raised stretches can be done successfully for low water-requiring and salt-tolerant crops. Although, it is a costly and tedious method. Here salinity and water logging will remain under control for at least 2-3 years then again

### Reclamation of Soil by Leaching

The process of replacing sodium ions in the soil with calcium ions is one of the steps involved in the reclamation or rejuvenation of soil. After being diffused by water that is in excess beyond the root zone, the sodium ions that have been liberated are eventually carried away from the field and deposited in the drainage water. Gypsum, at a rate of 2-8 pints per hectare, is typically spread on the soil before it is tilled, as this method is the most popular. This gypsum will eventually dissolve in the water, releasing calcium ions, which will take the place of sodium ions in the water that is going downward. It is recommended that this method of reclaiming soil be carried out once every two to three years in order to avoid the problem from occuring again.

### Scraping of Salts from Top Soil

High rate of evaporation results in water loss and exposes the abundant salt present in some areas of the field. During the drier months, this salt reaches the topsoil of the fields; which can be scrapped and transported out of the field. For example, the upper soil of Luna Ki Dhani looks somewhat like a white blanket that needs to be removed away from the field. This will restore and enhance the fertility of the soil with a crop tolerance limit for 1-2 cropping seasons on one hand and will maintain a healthier growth of the plant on the other.

### Use of Good Quality Water during Pre-Sowing

The availability of good quality water when pre-sowing the seeds will help in flushing the salts away from the topsoil and make it suitable for a healthy crop. This helps promote better germination and seed formation especially fruitful for cotton cultivators.

## CONCLUSIONS

The analysis of the introduction of the Indira Gandhi Canal in the arid and semi-arid parts of the state of Rajasthan is highly significant for sustainability agricultural planning along with managing natural resources like land and soil. Therefore, this paper aimed to explore and assess the main causes of waterlogging and salinization in the Indira Gandhi Canal, and to suggest ways to achieve hydrological sustainability by proposing remedial measures in waterlogged and saline sites in the drier areas of Rajasthan. The above analysis clearly explained that the study area is frequently facing the problem of water logging and increased soil salinity. Such a pattern of hydrologically induced agricultural development can be explained by several indicators. The absence of natural sub-drainage, non-presence of the natural topography, seepage from canal network and high-water allowance, over-irrigation by farmers, presence of excessive water-soluble salts, higher rate of evaporation, scanty rainfall and river alignment route etc. are some of the aggravating factors.

The availability of water in drier areas in Rajasthan through canals resulted in both horizontal and vertical expansion in both the cropped areas as well as irrigated areas. Such a positive move in the area with the provision of adequate drainage, would no doubt change the very face of agriculture in the areas resulting in increased productivity and yield, improved socio-economic status of the farmers and more importantly noticeable positive changes in both hydrological scenarios and improved groundwater conditions.

The patterns of hydrological developmental can help the policy-makers to look into the issues and planning for the rural sustainability of the region. There are several suggestions and remedial measures proposed. The dependence of the population in the study area on agriculture is proportionately high. Therefore, the agriculture sector requires special attention from policymakers for its sustainability. The suggested ways to achieve agricultural sustainability like reduction in water allowances, provision of bio-drainage, reclamation of soil by leaching, scraping of salt from topsoil, creation of a favourable soil-balance condition at the root zone, etc. are important with reference to the Indira Gandhi Canal area in Rajasthan. Policy and institutional support on technology along with management of canal water supply and energy provision can go a long way in achieving the identified and

designated targets. It is anticipated that if sufficient measures are taken while making decisions about the area, rural sustainability keeping in mind the hydrological regime of the study area can be ensured with special reference to the water-logged and saline sites of Indira Gandhi Canal.

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