CHAPTER- I

INTRODUCTION

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1.1. Introduction:

Irrigation is the application of water artificially to the land or soil. Irrigation is an important means for the crops to get water at right time. It is used to assist the growth of agricultural crops and in the maintenance of landscapes during the periods of inadequate rainfall. Irrigation means watering the fields by any means other than rain. Bhatty (1984) in his study has established that introduction of irrigation in a particular area not only increases farm production but also moulds the physical and the cultural environments in man's favour thereby increasing the per capita income. The system of irrigation practices varies in different parts of the world in general as in our country in particular. The state of West Bengal is no exception to this. Koch Bihar district is basically dependent on monsoon rainfall. The monsoon rainfall is not regular. As a consequence, the success of agriculture is influenced by the irrigation facilities. There are several types of irrigation practice. The major types of irrigation are as follows- I) Shallow Tube Well (STW), II) River Lift Irrigation (RLI), III) Deep Tube Well (DTW), IV) Dug Well, V) Canal Irrigation and VII) Tank Irrigation. In Koch Bihar District the irrigation is practiced mainly in the winter season.

India's total area under irrigation is 64.7 million hectares (Agricultural census 2010-11), the first Indian Irrigation Commission (1901-03) conducted a rather detailed enquiry into the problem and on the prospect of irrigation in the various regions of India. But in the states like West Bengal, the irrigation was recognized after India's independence in 1947 and stressed upon during the late 1960s with the implementation of New Agricultural Strategy. About 35% of the cultivable area is under irrigation in Koch Bihar District (West Bengal Agriculture Department, 2009). Among the various types of irrigation shallow tube well is the most viable and popular irrigation method among the farmers of this district. Ground water in the district is present in both water table and in confined conditions of the aquifers ranging in depth from about 2 metre(m) to 303 mbgl (metre below ground level).Dug wells and medium to heavy duty irrigation tube wells are in used to tap the ground water. They vary in depth from about 2 m to 8 mbgl (Field Survey 2016-17). During the field survey, it is observed that the different irrigation systems and agricultural practices

face several problems in the district. If the problems can be addressed properly, then the future development of irrigation system shall prosper in the district.

1.2. Scope of the Study:

The economy of Koch Bihar is agrarian at the same time the district is irrigation deficient. Koch Bihar belongs to poorly irrigated (<10 per cent) tract (Chatterjee,1995).There is no major irrigation scheme in the district. In Koch Bihar district 6 types of irrigation has been identified which are I) Shallow Tube Well (STW), II) River Lift Irrigation (RLI), III) Deep Tube Well (DTW), IV) Dug Well, V) Canal Irrigation and VII) Tank Irrigation. Except for STW irrigation all irrigation systems are either under-utilised or inadequetly functioning. STW (on Solar based) irrigation started just 3 years ago in only 4 blocks. Farmers of Koch Bihar district have been facing a number of problems concerning the irrigation water use which end to vary from season to season and region to region in the study area. Some of the major problems are related to mechanical malfunction of the motor pump, management and distribution of the government provided water, while the other issues are related to high pricing, electric problems, lack of government funding.

Based on field survey it is found that most of the RLI and DTW provided by the government were damaged because of miss management and ineffective co-operative system. Thus farmers encountering several problems, during their cultivation moved towards their own machinery system and consequently the RLI project was neglected by Government officials and the whole system transformed into a futile exercise. The Canal, Tank and Dug Well irrigation systems are fully or partially been damaged or have become non-functional. The district is, however, blessed with large numbers of perennial rivers and various wetlands (locally termed as *khal, beel, jheel, Chhara etc.)*. These resources are being utilized as a source of surface irrigation through a number of RLI and mini RLI schemes. However, most of these RLI often remain unutilized or underutilized due to fluvial activities like yearly floods, meandering courses, shifting nature, heavy siltation and also some socio-economic causes. The depth of water level varies with the topography and become steeper towards the northern side, ranging from 1.17 m to 6.7 mbgl.

A direct consequence of the progressive increase in population is the fragmentation of landholdings. About 2/3rd of the land holdings are less than 2 ha in size, being much less than the economic holding size of 2.5 ha. Majority of the farmers have neither the economic capacity nor the technical ability to adopt modern irrigation in their cultivation system.

Underutilization of irrigation potential adversely affects the cropping pattern, crop production and the economy of the farmer. In this district, the problems and causes of underutilization of irrigation have not been identified as well as their effects on agriculture were not quantified. For the sustainable solution of these problems, a detailed study and research are needed. Considering the above-mentioned issues, the present study on "Problems and Prospects of Irrigation in Koch Bihar District, West Bengal -A Geographical Analysis" has been taken up.

1.3. Location of the Study Area:

Koch Bihar district, located in the North Eastern part of West Bengal has been chosen as the study area. The latitudinal and longitudinal extension of the study area is approximately $25^0 57' 57''$ N to $26^0 32' 58''$ N and $88^0 45' 28''$ E to $89^0 51' 50''$ E respectively (Fig-1.1). Its geographical area is 3387 sq km, which occupies 128 Gram Panchayats with 1140 Mouzas. The western, south-western and southern parts of the district are bounded by Bangladesh, while the northern and eastern part is bounded by Jalpaiguri district and the Assam state, respectively. The Koch Bihar district is well drained by a number of perennial and ephemeral rivers, among them the most significant are Teesta, Torsa, Kaljani, Jaldhaka, Gadadhar, Raidak, and Sankosh. The study area with general elevation varying between 30-50 metres above mean sea level is essentially a flat region with a slight south-eastern slope along which the main rivers flow.

1.4. Objectives of the Study:

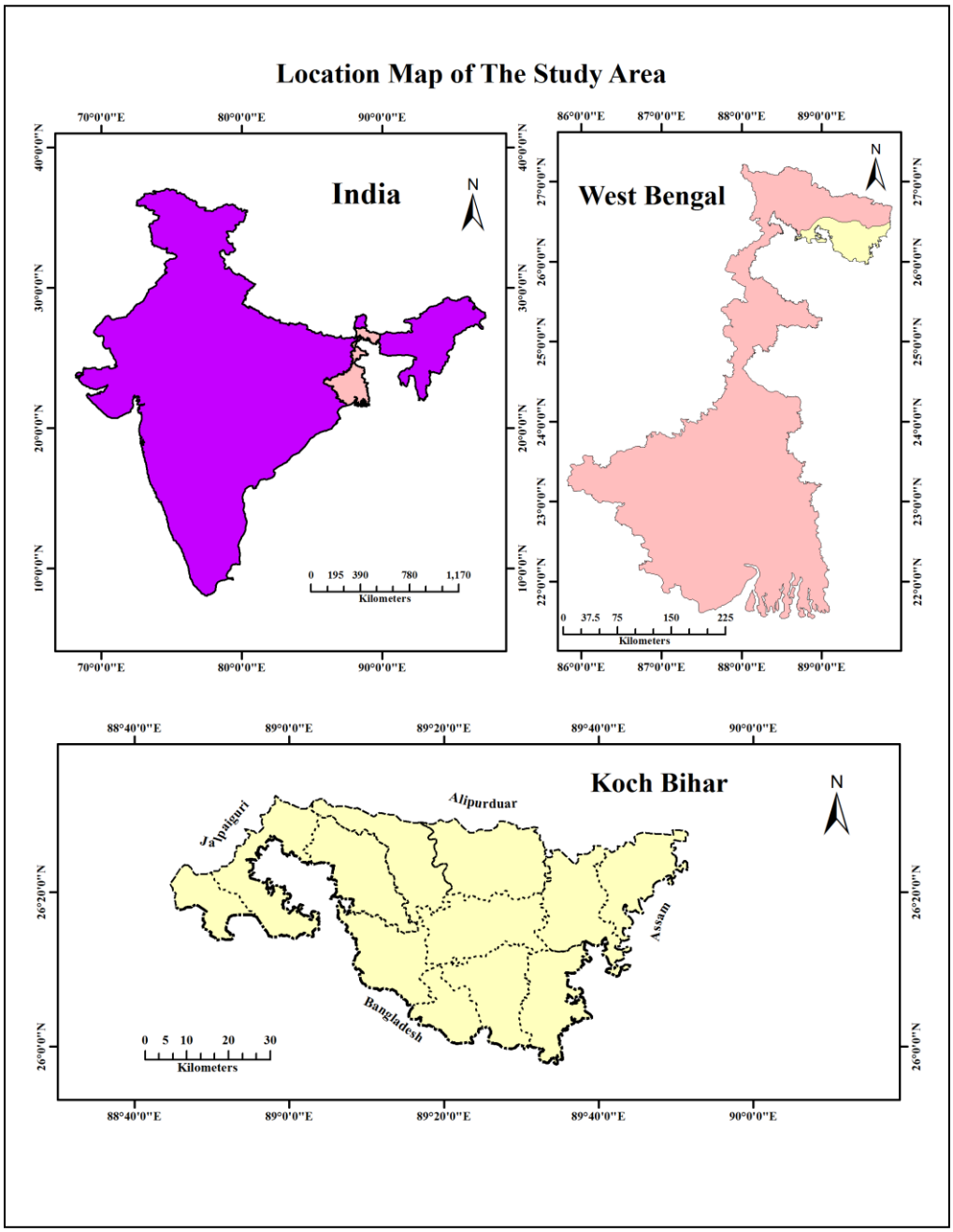
The objectives of the proposed study are as follows-

1. To study the determinants of irrigation in the district.
2. To analyse the spatio-temporal variation of irrigation practices between the period of 1990-91 to 2011-12 in the district.
3. To assess the impact of irrigation on agriculture and economic development of the farmer in the district.
4. To identify the problems related to irrigation in the district.
5. To study the irrigation availability both surface and ground water in the district.
6. To suggest measures for better utilization of irrigation potential in the district.

1.5. Hypotheses:

In order to study the problems and prospects of irrigation in Koch Bihar district, the following hypotheses have been considered.

1. Area under irrigation has changed over the decades in the district.
2. Potentiality of irrigation is underutilised in the district.
3. Irrigation practice in the district faces several problems.



Map-1.1. Study Area (Source: National Remote Sensing Centre, Hyderabad, India)

1.6. Methodology:

The methodology is the backbone of research work. The present study has been executed applying the following research methodologies-

1.6.1. Primary Data:

The primary data have been collected by using Stratified Random Sampling and size of the sample varies from to 1 percent to 10 percent. Questionnaire/schedules were prepared for the collection of field data. Six separate schedules have been prepared to interact with the farmers related to Shallow Tube Well (STW), Deep Tube Well (DTW), River Lift Irrigation (RLI), Dug Well, Tank Irrigation and Poorly Irrigated area also with Panchayet personnel, and other officials associated directly or indirectly with the subject concerned. During the pilot survey it was observed that, Canal irrigation is veryinsignificant in the District and has rarely been practised**.**

1.6.1.1. Choice and Selection of Sample Size and Sample Design:

1.6.1.1.1. Criterion Used in Selecting the Mouza:

STW is one of the important irrigation practices in the entire district. It is used more or less in all the Mouzas in the district. Thus, STW is the dominant irrigation practice throughout the district. For investigating the STW irrigation system the present researcher divided all the Mouzas (Total 1140) into two categories namely i) Well Irrigated Villages ii) Poorly irrigated village by using the following criterion.

$$\text{Selection of mouza as irrigated and poorly irrigated}$$
$$= \left(\frac{\text{No. of Shallow Tube Well}}{\text{Area of the each mouza}}\right) X \text{ Average area of total mouza of the Block}$$

For selecting the other irrigation systems, the researcher used purposive sampling technique. He identified the Mouzas having dominant in particular irrigation system viz. DTW, RLI, Dug well, and Tank irrigation system.

1.6.1.1.2. Sampling Method and Sample Size:

The present study has been carried out on farmers practicing irrigation in the Koch Bihar district which constitutes 12 blocks and 1140 mouzascovering an area of 3387 km^2 out of which 1284.12 km^2 (37.9%) area is an irrigated area. Samples were taken from the sampled mouza according to the irrigation system used by the farmers. To obtain the primary data at the household level, 58 mouzas have been selected from the 12 blocks of the district. Out of the 58 mouzas, 46 mouzas were selected based on different irrigation system practiced such

as 12 STW dominated mouzas, 12 DTW dominated mouzas, 12 RLI dominated mouzas, 6 Dug Well dominated mouzas, and 4 Tank dominated mouzas, while another 12 poorly irrigated mouzas have been selected (Fig-1.1). Dug Well and Tank irrigation system was found only in 6 blocks and 4 blocks respectively of the District thus one Dug Well and one Tank irrigation from each block was selected (Table-1.1). Total 1440 households have been selected.

Table-1.1. List of Sampled Mouza of Koch Bihar District, 2016-17

Name of the Block	STW (Name of the Mouza)	RLI (Name of the Mouza)	DTW (Name of the Mouza)	Dug Well (Name of the Mouza)	Tank Irrigation (Name of the Mouza)	Poorly Irrigated Village(Name of the Mouza)	Total
Koch Bihar - I	Haribhanga	Panisala	Baro Balasi	Nil	Nil	Paschim Haribhnaga	4
Koch Bihar - II	Bararangras	Gopalpur	Marichbari	Nil	Nil	Kalarayer Kuthi	4
Dinhata - I	Bhutkura	Bara Atiabari	Sakdal	Nil	Batrigach	Satkura	5
Dinhata - II	Kalamati	Gobrachara	Kismat Dasgram	Nil	Gobrachara	Kuchini-I	5
Haldibari	Baksiganj	Nagar Sahebganj	Baraidanga	Sarkar Para	Nil	Gach Para	5
Mathabhanga - I	Andaran Pakhihaga	Nendarpar	Kursamari	Bhogmari	Nil	Kursamari	5
Mathabhanga - II	Sikarpur	Akrahat Kharibari	Bhogmara	Choto Simulguri	Nil	Fulbari	5
Mekliganj	Uttar Bhotbari	Dakhsin Alokjhar	Bhottbari	Bajejama Kuchlibari	Nil	Testa Nadir Payasti	5
Sitai	Bharali	Dhumerkhata	Barathar	Nil	Nil	Chamta	4
Sitalkuchi	Kharija Sitalkuchi	Baro Koimari	Kharija Sitalkuchi	Nil	Nil	Nalgram	4
Tufanganj - I	Deochrai	Ghogarkuthi	Charaljani	Dhalpal	Balabhut	Dhalpal	6
Tufanganj - II	Basraja	Bagarkhata	Barokodali	Rampur	Salbari	Khagribari	6
Total	12	12	12	6	4	12	58

Source: District Census Hand Book, 2011 and compiled by Researcher.

1.6.1.1.3. Focus Group Discussion:

The main objective of focus group discussion is to provide an opportunity for the respondent to talk to one another about a specific area of study. It is one of the qualitative data collection methods in this study. Each focus group was within the range of 6 to 10 individuals inhabit the same mouza and employ the same irrigation system in the study area.

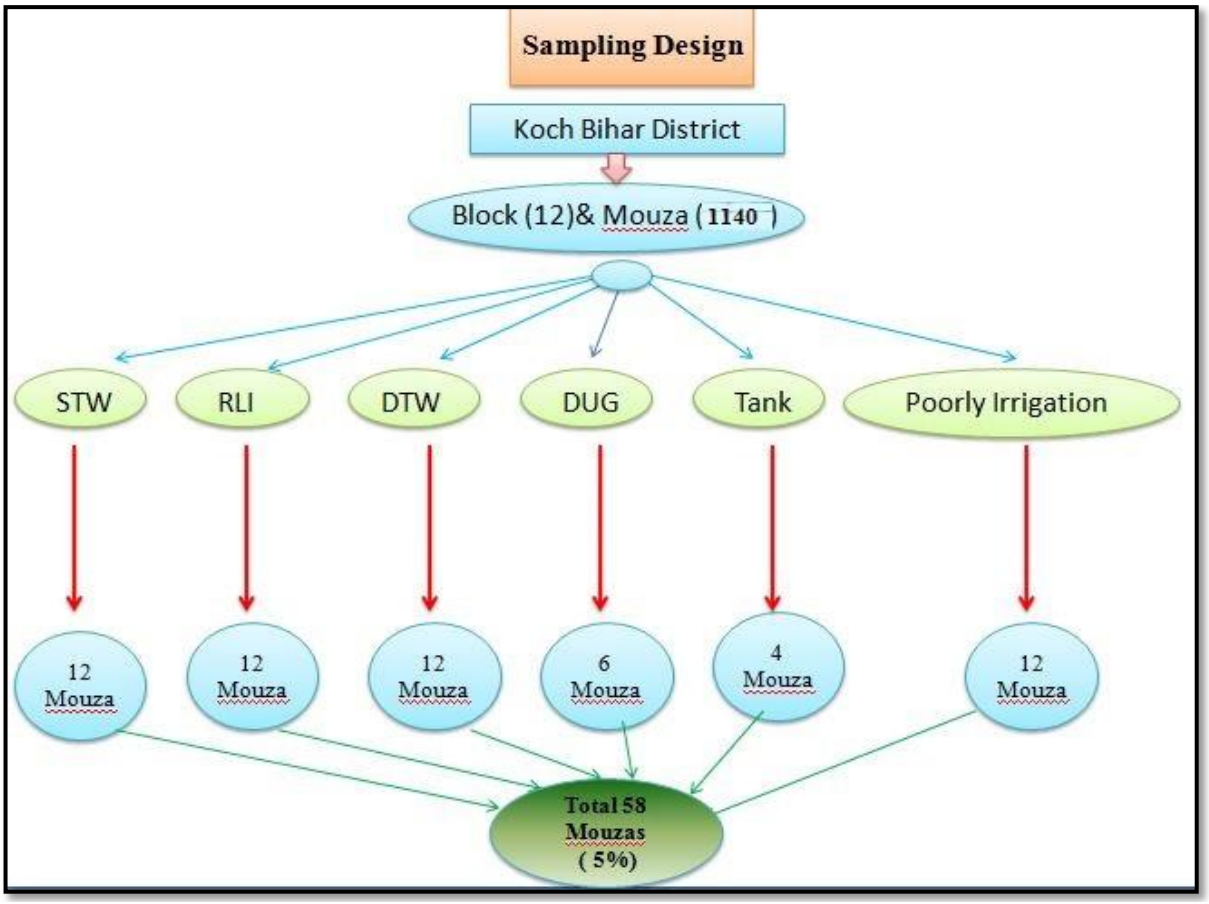


Fig-1.1. Sample design.

1.6.1.2. Water Table Measurement:

A field survey was conducted in 2014 and 42 shallow tube wells were selected taking 3 to 4 points in each block in the District for ground water depth measurement. The points were selected randomly throughout the district and the depth of water table was measured by opening the cover of shallow tube well/bore well with the measuring tape. Spatial coordinates of the sampled shallow tube wells were measured by using GPS (Garmin Oregon-eTrex-550) in 2014. Ground water depth of the sampled bore wells were measured during pre and post monsoon season in the year 2014. GIS map showing groundwater depth; level and fluctuation were developed and compared with surface relief map. The thematic layers were finally integrated using Arc GIS 10 to represent the ground water fluctuation map of the study area. The surface interpolation of the groundwater was carried out as a way of modelling of groundwater zone map within the study area.

1.6.1.3. Water Quality:

For determining the water quality in the study area, 48 sample sites have been selected on the basis of purposive random sampling in the year 2016. Out of 48 points, 24 were chosen

from ground water and 24 samples were chosen from surface water within 12 Blocks (Fig-1.2). Location of sample sites is tabulated and shown in the table-1.2.

Table-1.2: Sample site for ground water level, Koch Bihar District

Sl. No. of the Sample	Latitude	Longitude	Depth of water (mbgl), Pre-monsoon	Depth of water (mbgl), Post monsoon
1	26.207	89.498	2.01	0.91
2	26.175	89.47	2.8	1
3	26.025	89.474	2.9	0.78
4	26.078	89.608	3.79	1.32
5	26.134	89.576	3.45	0.95
6	26.35	89.454	1.77	0.89
7	26.33	89.454	3.91	1.65
8	26.415	89.438	3.85	1.67
9	26.473	89.369	3.3	1.76
10	26.439	89.346	2.3	1.89
11	26.392	89.385	2.1	1.65
12	26.289	89.416	2.75	1.54
13	26.258	89.254	1.3	0.56
14	26.281	89.216	3.8	0.89
15	26.283	89.163	3.9	0.97
16	26.197	89.214	2	0.45
17	26.15	89.24	1.85	0.56
18	26.145	89.276	2.1	0.67
19	26.065	89.317	1.9	0.54
20	26.026	89.369	2.2	0.67
21	26.358	89.706	2.65	0.96
22	26.215	89.693	2.95	0.76
23	26.306	89.701	2.8	0.55
24	26.33	89.731	4.15	0.77
25	26.385	89.748	2.6	0.89
26	26.376	89.637	2.6	1.2
27	26.257	89.644	3.55	0.68
28	26.456	89.022	4.3	1.3
29	26.456	89.022	4.09	1.45
30	26.342	88.767	1.83	0.83
31	26.34	88.768	2.74	1.2
32	26.461	89.241	3.6	0.78
33	26.38	88.158	3.05	1.2
34	26.548	89.104	3.79	1.34
35	26.548	89.104	6.8	1.54
36	26.222	88.774	6.5	1.63
37	26.222	88.774	4.5	1.2
38	26.45	89.528	3.9	1.35
39	26.291	89.799	2.8	0.86
40	26.29	89.799	2.61	0.79
41	26.158	89.719	2.89	0.66
42	26.987	89.567	2.88	0.47

Source- Field Survey, 2014-15

Table -1.3: Locations of Sample Sites for Water Quality Measurement

Name of the Block	Ground Water		Surface Water		Total
	Shallow Tube Well(Name of the Mouza)	Deep Tube Well(Name of the Mouza)	River(Name of the Mouza)	Natura lake/Pond(Name of the Mouza)	
Koch Bihar - I	Haribhanga	Baro Balasi	Panisala	Panisala	4
Koch Bihar - II	Bararangras	Marichbari	Gopalpur	Gopalpur	4
Dinhata - I	Bhutkura	Sakdal	Bara Atiabari	Bara Atiabari	4
Dinhata - II	Kalamati	Kismat Dasgram	Gobrachara	Gobrachara	4
Haldibari	Baksiganj	Baraidanga	Nagar Sahebganj	Nagar Sahebganj	4
Mathabhanga - I	Andaran Pakhihaga	Kursamari	Nendarpar	Nendarpar	4
Mathabhanga - II	Sikarpur	Bhogmara	Akrahat Kharibari	Akrahat Kharibari	4
Mekliganj	Uttar Bhotbari	Bhottbari	Dakhsin Alokjhar	Dakhsin Alokjhar	4
Sitai	Bharali	Barathar	Dhumerkhata	Dhumerkhata	4
Sitalkuchi	Kharija Sitalkuchi	Kharija Sitalkuchi	Baro Koimari	Baro Koimari	4
Tufanganj - I	Deochrai	Charaljani	Ghogarkuthi	Ghogarkuthi	4
Tufanganj - II	Basraja	Barokodali	Bagarkhata	Bagarkhata	4
Total	12	12	12	12	48

Source: Field Survey, 2016

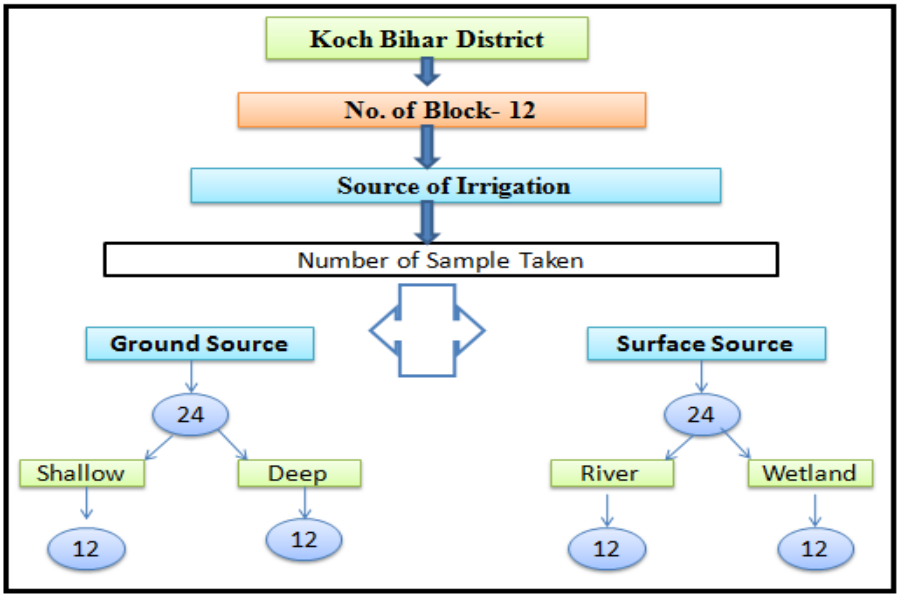


Fig- 1.2: Sample design for water quality

The water samples were collected during the Boro Cultivation (Winter Season). The Water Temperature, pH, Electrical Conductivity(EC) and Total Dissolved Solids (TDS) were

measured readily at the sample sites by HM Digital pH meter (Model pH-80), HM Digital EC meter (Model-AP-I) and HM Digital Aqua Pro TDS meter (Model-AP-I). The Result of the chemical analysis of the water samples has been analysed and discussed.

1.6.2. Secondary Data:

To represent and describe the study area on physical features, Topographical Maps, Satellite imageries, Land Use Map (Department of Science and Technology), are used as the secondary data which have been collected from various sources such as Central Ground Water Board, West Bengal, District Statistical Hand Book, Koch Bihar: Bureau of Economics & Statistics Government of W.B, District census handbook, Government of India, District Gazetteer, District Agricultural Annual Plan, Minor Irrigation Census, Agri-irrigation Census, B.L & R.O and D.L & R.O office have been used to describe the irrigation and agricultural scenario of the study area.

1.6.3. Method of Data Analysis:

Satellite imageries, Google earth, and Bhuban platform etc. were used to generate the maps. The thematic layers were finally integrated using Arc GIS 10.3. Collected data have been presented with different cartographic technique and a statistical method were used.

1.6.3.1. Growth Rate: The Growth rate of irrigated area and different irrigation system was measured with help of the following method-

$$\text{Growth Rate-} = \frac{\text{Present Irrigated Area} - \text{Previous Irrigated Area}}{\text{Present Irrigated Area}} \text{ X } 100$$

1.6.3.2. Density of Irrigation System:

The density of Shallow tube well was calculated and using the following formula.

$$\text{Density of Irrigation} = \frac{\text{No of irrigation system}}{\text{Net Area Shown}} / \text{Area in Hectare}$$

1.6.3.3. Standard Deviation:

The standard deviation concept was introduced by Karl Pearson in 1823. Standard deviation is the square root of the arithmetic average of the squares of all the deviations taken from mean. The standard deviation measures the absolute dispersion; the greater value of

standard deviation, for the greater will be the magnitude of the deviations of the values from their mean.

$$\sigma = \sqrt{(\frac{X^2}{N})}$$ where, σ= Standard deviation

$x^2 = X - \bar{X}$ (Deviation of the item from the mean)

N = Number of the observation

1.6.3.4. Estimation of Variability (CV):

It's a measure of relative dispersions. For each variable, mean and standard deviation values are computed first, from which variability can be found using the following formula –

$$CV = \frac{\sigma}{\mu} \times 100$$ Where, CV = Coefficient of Variation

σ = Standard Deviation

μ = Mean

1.6.3.5. Karl Pearson Co-efficient of Co-relation (1896):

The co-efficient of co-relation formulae according to Karl Pearson (1896) has been used to obtain the relationship between irrigation and cropping pattern.

$$r = \frac{\sum xy}{\sqrt{\sum X^2 \times \sum Y^2}}$$

X= Deviation from x seris, Y= Deviation from y seris.

1.6.3.6. Z Test:

Z score is the number of standard deviation (SD) from the population mean, it measures the how many SD below or above the population mean. It is also known as standard score and it can be represented on a normal distribution curve. Z scores value range from -3SD to +3SD. Zero value of Z score indicates the exact value of the population means.

$$Z = \frac{X - \bar{X}}{\sigma}$$

Where, Z= Z score, X= Population mean, $\bar{X}$= Sample mean, σ= Standard Deviation.

1.6.3.7. Kendall's Co-efficient of Concordance (Kendall's W):

To measure the degree of agreement between the rankings of constraints confronted by the farmers associated with irrigation, Kendall's Co-efficient of Concordance (Kendall's W) was applied. Kendall's test is a non-parametric statistical method used to measure a given set of constraints from the most affected to the least affected as well as to measure the

degree of willingness or concordance among the respondents. Kendall's W value ranges from 0 to 1. The value 0 means no agreement and 1 is complete agreement. The constraints were ranked on the basis of the most influenced to least influenced using numerals 1, 2,3…..n in order. The sum of the rank score for each constraint was computed and constraints with the lowest score were ranked as the most pressing constraint whereas the higher score was ranked as the least constraint. The total rank was used to determine the Kendall's 'W'. It measures the degree of agreement between respondents in ranking. The formula of Kendall's Co-efficient of Concordance (Kendall's W) is computed below-

$$W = \frac{12S}{m^2 n(n^2 - 1)}$$

Where W= Kendall's Co-efficient of Concordance, n=Total number of constraints being rank, m=No. of judges or respondents (farmer) ranking the object. The Coefficient of Concordance (W) has been tested for significance in terms of the Friedman's $\chi 2$.

Friedman's $\chi 2$ = m(n-1)W

Degree of freedom (df) = n-1

"W value ranges from 0 to1. If the W is 1, then all the respondents have been fully agreed, and each respondent has decided the same order to list of concerns. If W is 0, then there is no agreement among the respondent. In between the values of 0 to 1 indicate a higher or lower degree of unanimity among the respondent" (Legendre, 2005).

Null Hypothesis (H_0): The respondents do not agree about the constraints which lead them to change the cropping pattern.

Null Hypothesis (H_0): There is no agreement or consensus among the respondents over their rating or ranking of the problems in regard to irrigation.

The null hypothesis is rejected if the calculated $\chi 2$ value exceeds the tabulated $\chi 2$ value; it means that farmers agree with each other on the ranking of the constraints.

1.6.3.8. Dominant Distinctive Function: Dominant distinctive function has been applied for analysing the cropping pattern and their distributional characteristics in of the study area.

1.6.3.9. ANOVA:

Ronald Fisher has introduced the analysis of variance. ANOVA is also known as Fisher analysis of Variance, and it is the extension of the t- and z-test. The one-way ANOVA is used to analyse whether there is any statistically significant differences between the means

of the three or more independent groups. ANOVA has been done with the various irrigated water quality parameter of Koch Bihar District.

1.6.3.10. The χ^2 Square Test:

The χ^2 square test (pronounced as chi-square test) is one of the simplest and most widely used non-parametric tests in statistical work. The χ^2 test was first used by Karl Pearson in the year 1900. The quantity χ^2 describes the magnitude of the discrepancy between theory and observation. It is defined as-

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

Where O refers to the observed frequencies and E refers to the expected frequencies.

1.6.3.11. Sodium Adsorption Ratio (SAR):

Sodium adsorption ratio (SAR) was determined to study the sodicity hazard of the water; the SAR is used to predict the impact of sodium accumulation in soil. It is expressed in $(mmole/l)^{1/2}$.Excess sodium in water have produced the bad effects on soil and lowering the permeability and soil structure (Kelly, 1957). SAR is one of the basic indicators for determining the irrigation water quality. Generally, the water quality index is determined by SAR value (Ayers & Westcot, 1999). Richard (U.S. Salinity laboratory staff, 1954) has proposed the use of Sodium adsorption ratio (SAR) in use of irrigation water. Sodium Adsorption Ratio (SAR) –Shall be calculated from the formula-

$$SAR = \frac{Na^+}{\sqrt{(\frac{Ca^{2+} + Mg^{2+}}{2})}}$$

Where, SAR= Sodium adsorption ratio $\sqrt{(millimole/litre)}$

Na = Sodium ion concentration, me/l

Ca = Calcium ion concentration, me/l

Mg = magnesium ion concentration, me/l

1.6.3.12. Sampling Error:

Sampling error is the difference between the result of studying a sample and inferring a result about the population, and the result of the census o the whole population. King.L. was introduced the sampling error in 1964.

$$S.E\ (\dot{x}) = \frac{\sigma}{\sqrt{N}}$$

Where, $S.E\ (\dot{x})$= Sampling Erro, σ . =Standard Deviatio, N= Number of Observation

1.7. Limitation of the Study:

This research was undertaken to assess the problems and the prospects of irrigation in Koch Bihar District. It is not possible for a study such as this to accord with every aspect of irrigation, production of crops, farmers' income and their livelihoods. The household survey is a complex procedure and to get reliable data especially on income, land holding size, household items, assets as well as other variables which have close affinity to economic and social implications are not always free from bias. Most of the farmers easily imparted the recent information but it was not possible to get previous data easily. Socio-economic data were varying with landholding size and different irrigation systems. Another problem faced during the data gathering is that the farmers were not willing to spend the required time on the interview.

1.8. Literature Review:

Survey of available literature of a particular problem or study helps one to identify the research gap. It highlights the various aspects of a particular problem which will be carried out by the researchers as well as the academicians as it will provide meaningful solutions and help to formulate a general policy. It is a general overview that most of the events have existed in the earth and someone somewhere works on it. A researcher's task is to look into the matter in a different way and it requires an insightful thought about the problems. In the present study, the researcher has sought out some existing literature in agreement with the objectives taken by him. Thus, the present researcher has reviewed the following existing literature.

1. Alexander, K.C. (1982) in his article "Agricultural Development and Social Transformation" attempted to prepare a comparative framework for both the irrigated and non-irrigated area of the Ganga Nagar District, Rajasthan State. He observed that irrigation facilitated intensification of agricultural activity through the large use of labour, fertilizer, insecticides and other inputs, enable the farmers to use modern tools and machines which ensure the increase in the amount of per acre production & productivity and gross income. He also noticed that there are significant differences in sickness and health care behaviour among the two places i.e. command area and controlled area. He interviewed 900 persons of which 600 from the irrigated area (Ganganagar and Padampur tehsils of Kanpur) and 300 respondents from the non-irrigated area (Nauhar and Bhadra Tehsils)

2. Barrow, J. Christopher (1999) in his article "The promise of Runoff Agriculture" expressed runoff agriculture which is a form of agricultural irrigation. He stated how the use of surface & subsurface water often overlooked wasted that enables both small farmers & commercial agriculturists to improve yields & the security of harvest, even in harsh & remote environments. He expressed a number of techniques & strategies, as well as the challenges & the potential of the crucial approach, so much to reduce land degradation & improve conservation & sustainability of irrigation in this region.
3. Bharadwaja (1974) in his article "Production Conditions in Indian Agriculture - A Study Based on Farm Management Survey" has prepared a study based on farm management in the Indian context and its impact on productions. To him the irrigation can raise the productivity in three ways, i) by making possible multiple cropping ii) by increasing the yield per unit cost and iii) by allowing the production of more profitable crops. He stated that how irrigation influenced on the economy of the farmer in the study area.
4. Cantor (1967) in his book "A World Geography of Irrigation" discussed on the history of irrigation, sources and evolution of irrigation, different methods of irrigation, problems and prospect involved in it. Besides, he has also highlighted the impact of irrigation on agriculture in different parts of the world.
5. Chakraborty and Mistri (2017) in their article "Irrigation System and Pattern of Crop Combination, Concentration and Diversification Barddhaman District, West Bengal" studied the suitable cropping pattern in Badhaman district. The authors also argued that the type of irrigation and soil health control the choice of crop combination in the district.
6. Chatterjee (1995) in her book "Irrigated Agriculture; A case study of West Bengal" studied an overview of irrigation in West Bengal. He described physical, social, climatological as well as historical background of the development of irrigation in West Bengal. An assessment of underground as well surface water has been done the author. Different types of irrigation such as overflow irrigation, zamindary bank irrigation, canal irrigation, tank irrigation, poor irrigation, river lift irrigation and tube well irrigation have been described by the author. To her opinion, the about 36% of the cultivated land benefited by irrigation and about 20% underground water has been utilized for irrigation. Lastly, she highlighted various constraints for the development of irrigation.
7. Chowdhury (1971) in his book "Economics of tube well Irrigation in West Bengal", studied the economics of tube well irrigation in Nadia District of West Bengal. The

study was carried out in the irrigated area during Rabi crops in whole Nadia district except Krishnanagar-I. High cost involved in the installation of deep tube wells and excessive fragmentation of land compelled the medium and large farmers to turn towards shallow tube wells which can irrigate nearly 10 acres of land.

8. Dhawan (1988) in his book "Irrigation in India's Agricultural Development, Productivity, Stability, and Equity" examined the impact of irrigation on agricultural productivity and cropping pattern and on the basis of national level. He found that land productivity on irrigated lands was average 22 quintals per crop hectare in 1983-84 were as it was less than 9 quintals per crop hectare on un-irrigated lands. Also, the study indicated that productivity differential 5 years later was estimated 13.3 quintals during 1983-84. This was because of a firm upward character in the overall irrigated yield during the 14 year period from 1970-71 to 1983-84. This indicated that the production and productivity in agriculture had increased in nature.
9. Easter (1982) in a report on "Tank Development: The Experience of North Eastern Thailand" stated that the principal factors in determining the success of tank irrigation are land ownership patterns, legal status, the ability of farmers to organize, cost of construction and production potential. The author hypothesized that a small variation in farm size would foster better farmer cooperation in the distribution of water. Places where the variation is high; the large farmers use more water. He also observed that encroachment of the natural tanks by the promoters or land mafia is a serious problem in India. It causes the decline of tank irrigation.
10. Gadgil (1948) in his report "Economic Effects of Irrigation: A Report of a Survey of the Direct and Indirect Benefits of the Godavari and Pravara Canals" has evaluated the impact of irrigation on the economy with reference to Godavari and pravara canal irrigation. He highlighted the impact on the economy in non-irrigated area and agricultural production of the irrigated area. He opined that the agricultural activities of the irrigated area were labour intensive and demand of labour was high. It led to uplift of wages of the agricultural labourers. Irrigation practice played an important role in the development of the railway, road transport and trading establishment.
11. Ghosh (2012) in his research work "Impact of Mayurakhi irrigation canal system on the socio-economic aspects of its command area" explored that the Mayurakshi canal irrigation system determines the socio-economic aspect of the command area. The head area of the canal gains more water than the lower end area of the canal which adversely affect the production of crops and the economy. Sometimes the higher discharge of

water, failure of the embankment, water logging behind the canal embankment badly affect the producthe tion of crops and crop failure due to water born diseases in the crops. He suggested that scientific and systematically application of geological knowledge, proper training of the farmers and proper management of cropping pattern help to develop the agriculture as well as the economy of the farmers.

12. Gogoi, (1993) in his book chapter "Irrigation and Agricultural Development in Assamthe "described the impact of irrigation on agricultural development in Kamrup district of Assam. In her study, Gogoi made an attempt to compare between the farmers who are benefitted from irrigation and those who did not deprive of the irrigation facilities. The author did not find any change of cropping pattern in the irrigated area but HYV has been introduced in the irrigated area**. A**s a result of increased crop intensity and the introduction of HYV rice cultivation in the irrigated areas, the overall production of agricultural crops has been in increased.
13. Gthe arg et. al. (1971) in his paper "Income Disparity between Dry and Irrigated Farms in District Kanpur, Uttar Pradesh" presented a comparative analysis of income in dry and irrigated farms. He identified that in small land holdings the cropping intensity was 153.64 % and in comparatively large landholdings it was 158.53%. Whatever may be the size of land holdings, the differentiation of change of cropping intensity was very insignificant, they stated. The net income per hectare of dry land farms worked out at Rs. 413.77 as against Rs 1971.17 on irrigated farms. They concluded that the input-output relationship is more significant in irrigated farms as compared to the dry land.
14. Hitoshi (1976) in his book "Irrigation in the World Comprehensive Development" has attempted a comparative study of irrigation and drainage throughout the world. He also opined that the problems of irrigation are related to macro as well as micro level amongst them the micro level problems are related to the farmers and it creates trouble to the farmers. The micro level problems affect directly on cropping pattern and distribution of crops and economy of the farmers.
15. Hussain (1969) in his article "The Geographical Basis of Tube Well irrigation in the Upper Ganga- Yamuna, Doab the Geographical outlook" has attempted on the geographical point of view of the tube well irrigation in upper Ganga Yamuna Doab. In this study, he tries to present the impact of physical determinants on tubewell irrigation. He suggested to drill the tube wells and assessed the impact of tube wells in the cropping pattern and land use pattern in the study area. He has incorporated four maps which depict the relief of the study area, command area of the canal and tubewell

irrigation. The irrigated area under tube wells has also been revealed in a separate map. To him, this study will be helpful for further extension of canals the and the small irrigation system in the study area.

16. Ishaq and Javaid (2015) in their study "Quality assessment of tube well water for irrigation and impact on soil and crops in central Punjab Pakistan" revealed that in Tube Well irrigation (Sahiwal district) has poor water quality (EC 0.34- 5.17 dSm^{-1} and TDS ranges from 218 to 3309 mg $L-^{-1}$) for crop production. It increased the salinity of the soil. About 71 % of the Tube Well water was saline in nature which indicates that 71% Tube Well irrigation was not suitable for irrigation. The yield rates were decreased (3 to 15 %) where Tube Well were used compared to Canal irrigation
17. Kallur (1988)in his book "Irrigation and Economic Development" has attempted to show the impacts of irrigation on different categories of farmers in terms of crop rotation, cropping pattern, cropping intensity, input uses, production and productivity in the study area of left bank canal of Tungabhadra project in Karnataka. He discussed the cropping intensity between command area and controlled area. In command area where irrigation has been initiated there was cropping intensity of 199% and in the controlled area, the cropping intensity was 116%. He also showed that the modern mechanical inputs were more in command area than controlled area.
18. Karunakaran & Palanisami (1988) in their article "An Analysis of Impact of Irrigation on Cropping Intensity in Tamil Nadu" has attempted to reveal the impact of irrigation from different sources of irrigation on cropping intensity, to evaluate the cost of investment in major and minor irrigation systems and how to maximize the benefits of the existing resources by using secondary data from 1969-70 to 1993-94 in Tamil Nadu. For this, they used the regression model to estimate the relationship between irrigation development and intensity of cropping at the state level.
19. Mandal & Singh (2004) in their article "Impact of shallow tube well irrigation on farm economy in the lower Gangetic region of West Bengal" highlighted that West Bengal accounts nearly 10 per cent of shallow tubewell irrigation in India and serve 40 per cent of the gross irrigated area. STW has played a significant impact on the production of crops and cropping pattern. Good water management of STW increases the cropping intensity (295 %) as compared to without STW area (86 %). It is also revealed in their study that more diversified cropping pattern has been noticed in STW irrigated area.
20. Mondal & Saleh (2003) in their study "Evaluation of some deep and shallow tube well-irrigated schemes in Bangladesh using performance indicators" tried to explore, the

performance of DTW and STW in Rajbari district of central Bangladesh. The net benefit of boro paddy is higher in DTW scheme than STW scheme. The performance of STW and DTW were better than in the past. Production of crops has been increased in both schemes due to higher pumps discharges, frequently application of water.

21. Nadakarni (1979) in his article "Irrigation Development in Karnataka: An Impact of Irrigation by Tank, Well Canal" studied that a dry region having low production crops with unstable yields enjoys the privilege of a more stable and higher value of output with the utilization of irrigation.
22. Narayanamoorthy, Alli & Suresh (2015) in their article "Is the Role of Irrigation in Agricultural Output Declining in India?: A District-Wise Study at Six Time Points" tried to investigate tthe he role of irrigation for agricultural output. For this study, they have taken cross-sectional data for 235 districts of 13 states in six-time points such as 1962-65, 1970-73, 1980-83, 1990-93, 2003-05 and 2005-08. Descriptive as well as regression model (Univariate, Bi-variate and multivariate) were applied to assess the role of irrigation for the agricultural outputs.
23. Pal (1985) in his article "Contribution of Irrigation to Agricultural Production and Productivity" explained the contributions of irrigation to agricultural production and productivity. Different types of irrigation help agricultural productions in three ways, first, it raises yield per unit area by inducing the use of other complementary yield raising inputs namely, high yielding varieties of seeds, fertilizers and patricides secondary it leads to a development in the gross cropped area by making double and multiple cropping possible. Thirdly, for a given amount of output and input prices irrigation may raise the production by introducing farmers to allocate their lands to high yielding and high valued crops.
24. Patil et. al. (1978) in their study "Socio-Economic Survey of Girana Irrigation Projects Area in Jalgaon District (Maharashtra) observed that introduction of irrigation system enhances not only the economic condition of the farmers but also it encourages the social and cultural upliftment of the farmers in terms of education as well as health. In the selected 8 villages the authors observed that cropping pattern, the pattern of cultivation and cropping intensity have changed over time with the introduction of the irrigation system. This led to the secure agricultural activities and procure the more returns. They identified that the area without irrigation has practised traditional crops such as Bajra and Jowar whereas in the irrigated area the farmers produced cash crops such as cotton, sugarcane, banana, groundnut etc.

25. Phukan (1985) in his study with the title "A Study on the Impact of Deep Tube Well Irrigation on Crop Production in Jorhat District of Assam" tried to reveal the impact of deep tube irrigation on the production of crops in Jorhat District of Assam. He observed during his filed survey that irrigation potential is underutilised. About 55% of the potential created by the deep tube wells under study were utilized in the surveyed area. The author studied in the Jorhat district of Assam.
26. Phukan (1986) had undertaken a similar study on the title "A Study on the Impact of Deep Tube Well Irrigation on Crop Production in Kamrup District of Assam". In this study, he tried to explore the impact of irrigation on (i) cropping pattern, (ii) crop intensity, (iii) yield rates of irrigated crops and (iv) adoption of improved inputs and practices due to the introduction of irrigation in Kamrup district of Assam. The farmers utilize the irrigation water only autumn paddy *(ahu*) and wheat cultivation. He observed that there is a significant difference in crop yield in irrigated area and non-irrigated area. The extent of the double-cropped area in the beneficiary sample was 66.75% compared to 48.82% in the non-beneficiary sample.
27. Rao (1978) in his article "Linking Irrigation with Development Some Policy Issues," has identified the impact of different methods of irrigation in the southern part of Karnataka. He identified three major irrigation systems such as tanks, canals and wells in this region. He analysed that the proportion of irrigated land in the total cultivated land, is lower under tank the farms as compared to canals much lower under tanks, and it was less in large farms than small farms irrespective of mode of irrigation. The studies also explain low levels of yields, low fertilizer use and lower valued crops were practised under tanks as compared the to wells and canals. A greater prosperity with good urbanization took place in canal area as compared to tank irrigated areas.
28. Rawal (2001) in his paper "Expansion of Irrigation in West Bengal: Mid-1970s to Mid-1990s" has attempted to highlight the basic structure of irrigation in West Bengal. He also tried to identify the growth of irrigation in the post-land reform era. On the basis of secondary data, he identified the basic features of irrigation in West Bengal. He highlighted the pattern of irrigation, the growth of canal, ponds and RLI irrigation system. The author finally discussed the inter-district variation of irrigation in West Bengal.
29. Reddy (1997) in his book "Different Sources of Irrigation: A Case Study of Telengana Region "discussed the impact of various sources of irrigation on socio-economic condition of the Telengana region of Andhra Pradesh. In this area canal irrigation is

dominant in this region He showed that literacy level was higher in those families who used canal irrigation than the tank and dug well irrigation. Irrigation intensity was higher in canal irrigation followed by DTW and Tank irrigation. There was a strong positive relation between firm size and productivity in canal and tank irrigated areas. It is also revealed in this book that the more the investment in various modern inputs the more is the profit. The large farmers get this benefit as they provide more investment in irrigation in this region, the author stated.

30. Roy (2009) in his unpublished research "Changing pattern in agriculture: A case study of Koch Bihar District" explored that the district is dominated by Amon paddy (summer) and boro paddy (winter). Cropping area has changed over the decades in the district. The average size of the landholding was 0.62 hectare which is lower than the State average. The production of crops was remarkably low in comparison to another district of the state. About 70 per cent area under cultivation depends on summer rainfall but the gambling nature of monsoon rainfall affects the production of crops. In 2004-05 only 24.33% of the GCA were irrigated and 39 per cent of the NCA were irrigated which lower than the state average of 59.21 per cent. There was no major irrigation scheme has been identified and cultivators mainly depend on the minor irrigation scheme. The author identified the main sources of irrigation in the district are STW, DTW, RLI, Tank, Dug Well.
31. Sankhayan and Singh (1984) in their study "A Comparative Study of the Impact of Surface and Lift Irrigation Systems on the Cropping Pattern, Income Distribution and Economic Efficiency on the Punjab farms" highlighted the effect of the different method of irrigation on the cropping pattern income distribution and economic efficiency in Punjab. They had taken 200 the cultivators as sample size. They observed that the area under RLI has witnessed cereal crops as compared to canal irrigation systems.
32. Sarkar, A. (2012) in her study "Sustaining livelihoods in face of groundwater depletion: A case study of Punjab, India" focused on the sustainable livelihood patterns of farmers of the Punjab province in terms of the cropping pattern, production cost productivity I agriculture and profit generated through agriculture. She highlighted the use of groundwater and depletion of groundwater level for excessive withdrawal of groundwater. The farmers were unable to dig and deepen the existing tube wells. Thus, she opined that to provide government subsidies for setting up the tube as well as electricity.

33. Satpathy (1984) in his book **"**Irrigation and Economic Development" highlighted the impact of irrigation on economic development in Orissa. His study period was 1951 to 1981. His major thrusts were to study the impact of different policies for the development of irrigation in Orissa. He opined that the shift of cropping pattern from local variety crops to the high yielding variety (HYV) crops had resulted in a rise in yield rate but it consumes the higher amount of water. He has alsothe mentioned that the 'acerage effect' of irrigation which led to double to the multi-cropping system in Orissa.
34. Sawant (1986) in her article "Irrigation and Water Use" highlighted the impact of the duration of irrigation on crop productivity. She observed that irrigation facilitates the yield rates as well as encourages farmers to use modern inputs in agricultural practices which enhance the capacity of the land. It also imparts stability in yields per hectare and thereby reduces fluctuation in production levels. The author also identified that "if the supplies of irrigation are highly vulnerable in years of low rainfall when they are most badly needed - as is observed in the case of a state like Tamil Nadu, they may not induce desired stability in production levels".
35. Staub and Blase (1974) in their study "Induced Technological Change in Developing Agriculture: Implications for Income Distribution and Agricultural Development" have tried to examine the initial changes in income distribution which is very much coincident to new agricultural practices. The study was conducted by them among various regions and revealed on the impact of irrigation on the production of crops. They also highlighted the public and private investment helps to procure the surface and groundwater in Punjab region, especially on wheat cultivation.
36. Tak (1986) in his article "Impact of Puma Canal Irrigation Facilities of Cropping Pattern, Inputs Structure and Income at Farm Level, investigated the impact of canal irrigation on the pattern of crops, the intensity of cropping and use of modern inputs like seeds fertilizers and herbicide and pesticide. He showed the changing pattern of income among the irrigated and non- irrigated area. He also calculated the cost and benefit ratio under irrigated and non-irrigated area. He also showed that irrigated area has enriched in different household items than poor irrigated area.
37. Vidal, A. (2000) in his study "Remote Sensing and Geographic Information Systems in Irrigation and Drainage" explained on the satellite remote sensing & Geographic Information Systems (GIS) for the best irrigation system management. He proved that with the help of remote sensing satellite and imagery, the rock characters, groundwater

storage can easily be traced out. This attempt will highly help the irrigation system & control seepage losses. Also, it helps to a farmer for their better practised of different crops.

38. Willcocks, (1930) in his study "Lectures on the Ancient System of Irrigation in Bengal and its application to modern problems" explained the old irrigation system in ancient Bengal. He observed that the bad impact of the practice of overflow irrigation method of the Ganges & Damodar deltas at that time which has influences on health & wealth to Bengal. He regarded this system perfectly matches to meet the special needs of Bengal as to that of the basin irrigation of Egypt. He has explained the agricultural importance of muddy flood water. He also gives importance to build weirs at the heads of low deepened channels in order to raise the level of water surface. He stressed on wells & tanks for October irrigation & double cropping. He also put importance on the regular cleaning & desilting of the irrigation canals in order to carry more rain & flood water in the next rainy season.

39. Yadav. D (1987) in his article "Impact of Irrigation on the Crops of Haryana" discussed that the requirement of water differs according to the growth of different crops. Farmers depend on monsoon in Kharif season and for rabi crops, they depend on son irrigation. Maximum numbers of crops were practised in the irrigated area (such as wheat, barley, vegetables etc). The yield rate was increased (peas 45%, gram 50%, barley 125%) with the application of irrigation. Irrigation is the important limiting factors which influenced on cropping pattern as well as cropping intensity in the region.

40. Zhu, et.al. (2013) in their study "Agricultural irrigation in China" tried to explore the irrigation systems in China. They opined that China is the most populous country and hence faces challenges for food security as China has about 1.3 billion population and less than 10% arable land of the world. The authors presented the current status of agricultural irrigation. They also stated the agricultural water use and water shortage in and uneven distribution of water use. They suggested for adopting the potential methods to irrigation requirements.

1.9. Research Gaps

It is observed from the review of the above-mentioned literature that the domain of irrigation practice in different countries is approached differently by different scholars but there is still a necessity of more exploration and study. Certain research gaps identified by the present researcher are laid down as follows.

1. Most of the researchers highlighted the economic efficiency of cropping pattern under different sources of irrigation.
2. Studies which have documented the development of irrigation in India as well as in the individual states like Karnataka, Rajasthan, Karnataka and West Bengal.
3. Some of the studies were descriptive and exploratory in nature. In neither of the studies, the effort was taken to explore the variation in crop production in the different irrigation systems.
4. It has been documented that different types of irrigation determine the distinctiveness of the cropping pattern. But there is no literature that explores the individual irrigation system playing a vital role in the cropping pattern.
5. It is fact that the cropping pattern has changed over time. There are several reasons behind the change. Irrigation plays a dominant role in such changes. A very few literatureshave thrown light in this regard.
6. Rural out-migration is a serious concern in the present day context. But none of the scholars highlighted the matter that there is a relation between irrigation and rural out-migration.
7. A number of studies on the use of irrigation water in India and abroad have been carried out. No studies have been done on the impact water quality from different sources of irrigation.
8. Various indices such as NDVI, SAVI, MNDWI, NDMI, WRI, and SAVI are used for determining the surface water potential for irrigation. But there has been no study which has taken a comprehensive view of the surface as well as groundwater potential for irrigation.
9. Lastly, none of the available studies are conducted in the present area of study i.e. in Koch Bihar District.

Therefore there is a need to take a holistic view of this issue and view it from a policy perspective.

1.10. Conclusion:

The present chapter highlights the Scope of the study, location of the study area, hypothesis, objectives, methodology, Choice and Selection of Sample Size and Sample Design and limitations of the study. Also a brief selected review of literature directly or indirectly related with the study has been outlined.

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