REVIEW OF RESEARCH
IMPACT FACTOR : 5.7631(UIF) UGC APPROVED JOURNAL NO. 48514 ISSN: 2249-894X
VOLUME - 8 | ISSUE - 2 | NOVEMBER - 2018

SPATIO-TEMPORAL ANALYSIS OF AGRICULTURAL PRODUCTIVITY AND IRRIGATION PATTERN IN RAMPURHAT SUBDIVISION OF BIRBHUM DISTRICT, WEST BENGAL

Amit Kumar Mandal[1] and Sutapa Mukhopadhyay[2]
[1]Research Scholar, Department of Geography, Visva Bharati, Santiniketan, India.
[2]Professor and Head, Department of Geography, Visva Bharati, Santiniketan, India.

ABSTRACT

In this paper, attempts have been made to analyse spatio-temporal variation of agricultural productivity within different blocks of Rampurhat subdivision of Birbhum district since 1993 to 2011. Spatio-temporal variation of irrigation schemes have also been studied to find out relationship between crop productivity and irrigation pattern of the study area. Results from this study unveil great disparity in crop productivity within different blocks of the subdivision. Temporal analysis regarding percentage contribution of surface water based irrigation systems to total irrigated area is showing a gradual declining trend whereas groundwater based irrigation systems is showing a gradual increasing trend. Besides positive relationships are found between groundwater based irrigation system and crop concentration and crop yield. Whereas negative relationships are identified between surface water based irrigation system and crop concentration and crop yield. From this it can be remarked that in comparison to surface water based irrigation system groundwater based irrigation system plays more effective role to determine agricultural productivity.

KEYWORDS: *Crop Productivity, Crop Concentration, Crop Yield, Groundwater Irrigation, Surface Water Irrigation.*

INTRODUCTION

Agriculture is a human activity involving planned utilization of land or soil and water for the growth of plants and animals to meet the basic requirements of food and clothing (Roy, 1992). Cropping system of a region is decided by large number of physiographic, pedological, hydrological, climatic, socio-economic, institutional and technological parameter that determines overall agro-ecological setting for nourishment or appropriateness of a crop or set of crops for cultivation (Bhattacharyya, 2013). In India where most of rainfall occurs in rainy season due to south west monsoon wind, irrigation plays a key role to decide agricultural landscape (Khullar, 1999). The canal irrigated area was larger than groundwater irrigated area until 1972-73, but now groundwater irrigated area is nearly double than that of canal irrigated area and the ground water factor as a source of irrigation contributes more in explaining the interstate variation of agricultural production (yield) and overall productivity among all inputs use (Bhattarai et.al, 2003). Thus groundwater irrigation has played a crucial role in expanding agricultural production to meet the food needs of the rapidly growing population. As Robert Repetto comments, "The Green Revolution has often been called a wheat revolution; it might also be called a tubewell revolution" (Repetto, 1994). From this contexts crop productivity and irrigation pattern of the study area have been analysed for last twenty years to find out interrelation among them. The results have disclosed the important crisis facing by the state for implication of sustainable agricultural planning.

OBJECTIVES:

- To examine the spatial pattern of crop productivity of the study area
- To detect the temporal changes of crop productivity of the study area
- To detect the temporal changes of irrigation schemes of the study area
- To find out relationship between crop productivity and irrigation pattern of the study area

ABOUT THE STUDY AREA:

Rampurhat, the most populous subdivision (Census of India, 2001) of the Birbhum district of West Bengal is situated in the northern part of Birbhum district and constituted with eight Community Development Blocks namely Murarai-I, Murarai-II, Nalhati-I, Nalhati-II, Rampurhat-I, Rampurhat-II, Mayureswar-I and Mayureswar-II with sixty two Gram Panchayats.

Geomorphologically, this area can be subdivided into four major subdivisions i.e. flood plain in the south eastern part, upper mature deltaic plain and paradeltaic fan surface in the northern and eastern part, pedeplain or peneplain in the western and southern part and hills and valleys in the minor areas of south western part (Krishnanunni., 2001). The thickness of aquifer is lesser in the hard rock areas of the western part which increases towards eastern soft rock areas resulting the eastern part as highly potential for groundwater resources and western part as poorly potential (Govt. of India, 2007).

Except two municipalities, this area is characterised by rural population where agriculture is the main economic activity and 60.69% of the total main workers are engaged in agricultural related activity (Census of India, 2001). This area is also very much backward from industrial developmental point of view (Govt. of West Bengal, 2011). So, here groundwater is withdrawn mainly to serve the agricultural sector and domestic needs.

MATERIALS AND METHODOLOGY:

Agricultural landscape of the study area is analysed using secondary sources of data. All the data have been collected from District Statistical Handbook of Birbhum, published by West Bengal Government Applied Economics and Statistics Department in different time period. For the convenience of the study agricultural data of 1993, 2000 and 2011 have been used to maintain ten years interval. As statistical handbook of 1991 and 2001 is unavailable so data of its nearest year is applied i.e. 1993 and 2000.

The production and productivity effects of an area can be evaluated by considering both the rate of output in terms of area and yield of various crop groups as well as the relative contributions of area and yield to overall output of the region. The study of agricultural productivity is a fruitful technique for agricultural planning and showing efficiency of region in comparison to neighbouring region. So crop yield and crop concentration indices ranking coefficient technique (Singh et al., 2005) has been selected to demarcate spatial as well as temporal change in agricultural productivity.

The crop yield and concentration indices ranking coefficient procedure is –

$$Yi=Yae/Yar\times100 \quad \text{- - - - - - - - - - - - - (I)}$$

Where, Yi= the crop yield index.
Yae= the average yield per hectare of crop in “a” in the component enumeration unit.
Yar= the average yield of the crop “a” in the entire region or country.

$$Ci=Pae/Par\times100 \quad \text{- - - - - - - - - - -- - - - (II)}$$

Where, Ci= the crop concentration index.
Pae= the percentage strength of crop “a” in the total harvested area in the component enumeration unit.
Par= the percentage strength of crop “a” in total harvested area in the entire region.

The crop yield and concentration indices are thus derived for all the crops and ranked separately. Yield and concentration ranks are added and thereafter divided by two.

Crop yield and concentration indices ranking coefficient for crop "a"=(Crop yield index ranking of crop a + Crop concentration index ranking of crop a)/2 - - - - - - - - - - - - - - (III)

Lastly, for the drawing of choropleth maps of two different years ranks of crop yield and concentration indices of five crops of particular year are added and then divided by five. And average ranks of crop yield and concentration of five crops are grouped into three categories namely (I) High Productive Zone (II) Moderate productive Zone (III) Low Productive Zone.

Concentration of surface water based irrigation systems and concentration of groundwater based irrigation system within eight blocks of this subdivision is analysed by applying Location Quotient Index. This is calculated using following formula.

$$LQ = \frac{Cij}{Ci} \Big/ \frac{Cj}{C}$$

Where, Cij = Area under jth water based irrigation in ith sub region, Ci = Total irrigated area of that unit, Cj = Area under jth water based irrigation a region, C Total irrigated area of the region.

From the Location Quotient values choropleth map is prepared and three concentration zones are identified for surface and ground water based irrigation.

Relationship between irrigation system and agricultural productivity is identified by applying Pearson's Product Movement Correlation Technique. As agricultural productivity is the combined output of crop concentration and crop yield, so four block level variables have applied to obtain the extent of this relationship i.e. percentage of surface water based irrigated area to total irrigated area, percentage of ground water based irrigated area to total irrigated area, average score of crop concentration of all five major crops and average yield of all five major crops.

SPATIO-TEMPORAL ANALYSIS OF AGRICULTURAL PRODUCTIVITY:

Crop productivity indicates total amount of production of different crops per unit of area (acre/hector). On the basis of which the level of agricultural development can be marked. Hypothetically higher the productivity value of crops higher will be agricultural development.

From spatio-temporal analysis of agricultural productivity (Table 1-6), it can be generalised that high crop productivity is observed in the northern part of this subdivision particularly in the blocks of Murarai-I, Nalhati-II and Nalhati-I throughout the time period and low productivity is found in southern part particularly in the blocks of Mayureswar-I and Mayureswar-II. Though the nature of crop productivity in the blocks of Rampurhat-I, Mayureswar-II varies from time to time.

Table-1: Crop Concentration and Yield Index, 1993

Sl. No.	Name of the Block	Paddy		Wheat		Potato		Pulses		Oilseeds	
		ci	yi	ci	yi	ci	yi	ci	yi	ci	yi
1	Nalhati-I	1.01	0.97	1.05	0.98	0.62	1.01	0.20	0.94	0.84	1.04
2	Nalhati-II	0.96	1.14	0.90	1.12	4.36	1.18	0.00	0.00	0.87	1.01
3	Murarai-I	1.09	0.98	0.95	0.97	0.34	1.01	3.17	0.84	0.78	0.59
4	Murarai-II	0.98	1.15	1.02	1.17	0.48	1.00	2.58	0.86	1.04	1.01
5	Mayureswar-I	1.04	0.86	1.07	0.85	0.23	0.96	0.30	1.12	0.65	0.81
6	Mayureswar-II	1.01	0.93	0.80	0.89	3.92	1.18	1.60	1.24	1.13	1.80
7	Rampurhat-I	0.97	0.95	1.06	0.96	0.16	1.03	0.21	1.05	1.17	0.90
8	Rampurhat-II	0.94	1.03	1.01	1.05	0.39	0.61	0.24	0.94	1.52	0.83

Source: District Statistical Handbook, 1993-94

Table-2: Crop Productivity status, 1993

Productivity Zone	Range Value	Name of Blocks
High	3.65-4.23	Mayureswar-II, Murarai-II
Moderate	4.24-4.81	Nalhati-I, Nalhati-II, Rampurhat-I
Low	4.82-5.40	Rampurhat-II, Murarai-I, Mayureswar-I

Source: Computed by the Researcher

Table-3: Crop Concentration and Yield Index, 2000

Sl. No.	Name of the Block	Paddy		Wheat		Potato		Pulses		Oilseeds	
		ci	yi	ci	yi	ci	yi	ci	yi	ci	yi
1	Nalhati-I	0.95	0.94	1.26	1.10	1.88	1.27	0.95	0.87	0.95	1.24
2	Nalhati-II	0.97	1.19	1.28	0.91	0.05	1.26	0.58	0.85	1.47	0.97
3	Murarai-I	1.04	0.87	0.59	1.11	0.50	0.73	3.25	1.06	0.77	1.11
4	Murarai-II	0.91	0.67	1.89	1.13	0.30	0.84	2.61	0.87	1.16	0.77
5	Mayureswar-I	1.11	0.98	0.51	0.85	0.85	0.93	0.47	0.81	0.50	0.74
6	Mayureswar-II	1.00	1.08	0.33	0.76	3.77	1.22	0.92	0.81	0.52	1.06
7	Rampurhat-I	1.13	1.08	0.42	1.15	0.18	0.87	0.11	0.75	0.70	1.16
8	Rampurhat-II	0.86	1.20	1.77	0.98	0.43	0.89	0.17	1.00	1.97	0.95

Source: District Statistical Handbook, 1999-00

Table-4: Crop Productivity Status, 2000

Productivity Zone	Range Value	Name of Blocks
High	3.50-4.16	Nalhati-I, Murarai-I,
Moderate	4.17-4.83	Rampurhat-II, Nalhati-II, Murarai-II
Low	4.84-5.50	Rampurhat-I, Mayureswar-II, Mayureswar-I

Source: Computed by the Researcher

Table-5: Crop Concentration and Yield Index, 2011

Sl. No.	Name of the Block	Paddy		Wheat		Potato		Pulses		Oilseeds	
		ci	yi	ci	yi	ci	yi	ci	yi	ci	yi
1	Nalhati-I	0.93	1.10	1.43	1.05	1.45	1.31	0.90	0.80	0.78	0.77
2	Nalhati-II	1.04	1.16	1.03	1.07	0.41	1.03	0.17	1.06	1.50	0.98
3	Murarai-I	0.89	1.06	1.01	1.04	0.46	1.21	2.38	1.19	1.06	1.10
4	Murarai-II	1.01	0.93	1.06	1.01	0.53	1.14	1.35	1.03	0.88	1.04
5	Mayureswar-I	1.14	0.99	0.61	0.76	0.98	0.86	0.52	0.52	0.94	0.81
6	Mayureswar-II	0.94	0.93	0.46	1.06	4.00	0.47	0.77	1.32	0.70	1.03
7	Rampurhat-I	1.05	0.93	0.98	1.00	0.23	0.99	1.01	1.07	1.09	1.22
8	Rampurhat-II	1.00	0.91	1.22	1.01	0.51	1.00	0.75	1.01	1.12	1.05

Source: District Statistical Handbook, 2010-11

Table-5: Crop Productivity Status, 2011

Productivity Zone	Range Value	Name of Blocks
High	3.70-4.36	Murarai-I, Nalhati-II, Nalhati-I
Moderate	4.37-5.03	Murarai-II, Rampurhat-I, Rampurhat-II, Mayureswar-II
Low	5.04-5.70	Mayureswar-I

Source: Computed by the Researcher

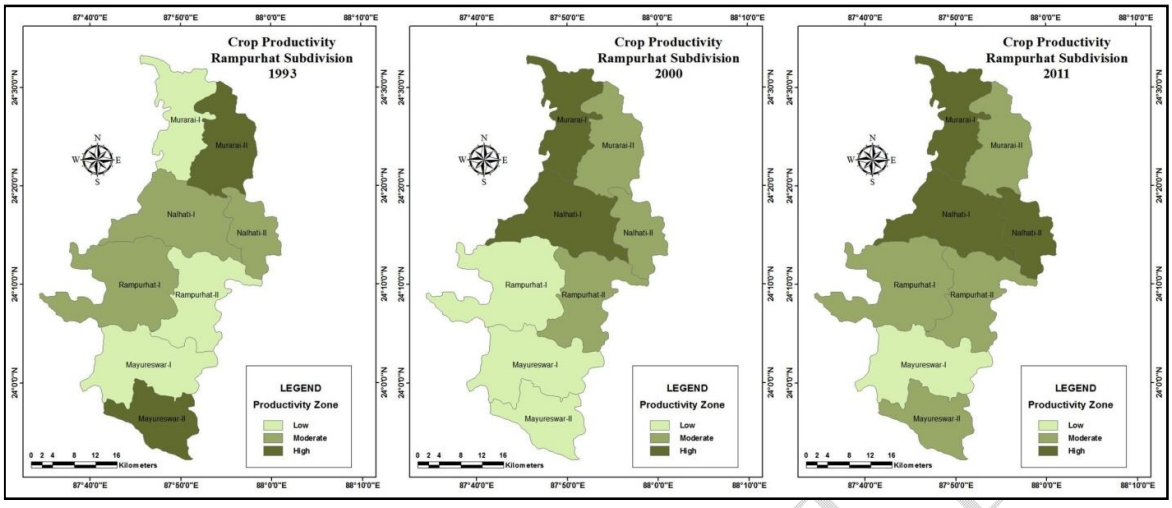

Fig.-1: Spatio-Temporal Variations in Crop Productivity Irrigation Pattern:

Water is an important input for successful agriculture. Water may be available to crops in the natural course by rainfall but the process of supplying water to crops by artificial means such as canals, wells, tubewells, tanks etc from the sources of water such as rivers, tanks, ponds or underground water is called irrigation (Khullar, D.R., 1999). Unfortunately rainfall in India is uncertain, unreliable, irregular, variable, seasonal and unevenly distributed due to mysterious behaviour of south west monsoon wind. So, proper irrigation facility is indispensable for sustainable agricultural development. Both surface water and groundwater is used for irrigation purposes in the form of canal, tanks, tubewells etc. Blockwise pattern of irrigation facilities is identified from 1993-94 to 2010-11 to detect changes in agricultural landscape.

SURFACE WATER BASED IRRIGATION SYSTEM:

In this Subdivision surface water based irrigation systems i.e. Canal, Tank and River Lifting Irrigation schemes have dominancy to supply water in the agricultural field in terms of areal coverage. Mayurakshi-Darkeswar Main and Branch Canals and Brahmani North Main and Branch Canals have formed the canal networks in this area which operates from Tilpara Barrage and Haridaspur sluice gate respectively. Tank irrigation is functioned from different natural and manmade ponds and wetlands of the study area, human labour and machine are used to supply water to the field from reservoirs. River lifting irrigation schemes are operated by West Bengal Government Irrigation Department which supply water to the agricultural field from rivers of the area i.e. Mayurakshi, Brahmani, Dwarka, Pagla, and Bansloi using high power pumpsets. Blockwise areal coverage of these surface water based irrigation schemes is given in Table-7.

High concentration of surface water based irrigation are found in the blocks of Rampurhat-I and Mayureswar-I and Low concentration are found in the blocks of Nalhati-II, Murarai-I, Murarai-II and Mayureswar-II whereas rest of the blocks maintain parity with subdivisional averages. So surface water based irrigation system is dense in the middle portion of the subdivision over which most of the river flows.

Temporal analysis regarding percentage contribution of surface water based irrigation system to total irrigated area is showing a gradual declining trend. In 1993, 93.27% percent area of this subdivision is irrigated by surface water whereas in 2011, its contribution reduced to 70.91% area only. In the blocks of Murarai-I, Nalhati-II and Mayureswar-II this trend is very much acute. Whereas Mayureswar-I and Rampurhat-I blocks have not experienced greater change in terms of dependency on surface water in irrigation purposes. So there is a negative relationship between concentration of surface water based irrigation system and declining trend of contribution of surface water based irrigation system to total irrigated area.

Table-7: Surface Water based Irrigation System

Name of Block	Irrigated Area in hect. (1993)					Irrigated Area in hect. (2000)					Irrigated Area in hect. (2011)				
	Canal	Tank	R.L.I.	Total	% to total irrigated area	Canal	Tank	R.L.I.	Total	% to total irrigated area	Canal	Tank	R.L.I.	Total	% to total irrigated area
Nalhati-I	7720	3400	560	11680	93.44	8646	1560	176	10382	76.37	4400	1750	800	6950	71.72
Nalhati-II	7720	3900	560	12180	93.69	7717	1150	7	8874	75.61	7717	778	100	8595	57.82
Murarai-I	5612	2800	240	8652	91.54	7790	1300	253	9343	85.01	0	1800	1000	2800	50.96
Murarai-II	8826	2200	120	11146	91.02	10864	600	86	11550	92.38	1500	1900	500	3900	61.83
Mayureswar-I	15000	8500	**210**	23710	93.85	15800	4100	116	20016	84.08	15000	550	**0**	15550	93.16
Mayureswar-II	14930	4500	70	19500	90.02	5571	2010	16	7597	63.57	10705	2710	40	13455	58.86
Rampurhat-I	1720	8800	300	10820	96.52	12006	3600	59	15665	94.57	1800	7500	750	10050	88.00
Rampurhat-II	12390	5900	30	18320	96.17	14437	3050	8	17495	87.14	14000	100	1	14101	74.21
Subdivision	**73918**	**40000**	**2090**	**116008**	**93.27**	**82831**	**17370**	**721**	**1E+05**	**83.25**	**55122**	**17088**	**3191**	**75401**	**70.91**

Source: District Statistical Handbook, 1993, 2000, 2011

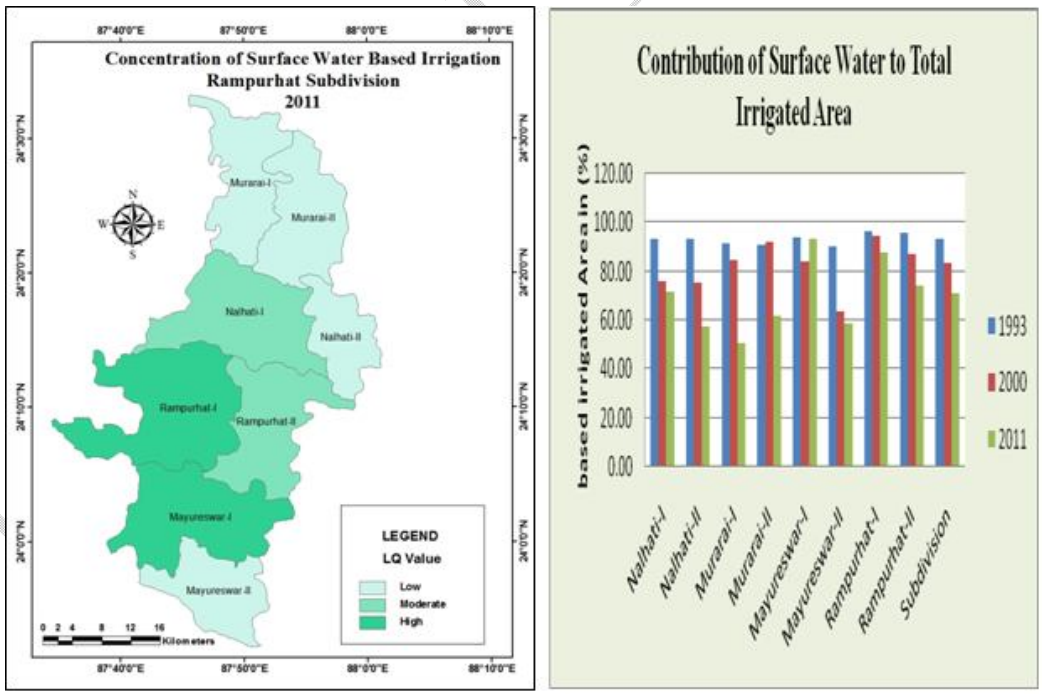

Fig.-2: Spatio-Temporal Variation in Surface Water Based Irrigation System

Groundwater Based Irrigation System:

Groundwater based Irrigation system i.e. deep Tubewells and shallow Tubewells are emerging as an important ways to supply water to the agricultural field due to its flexibility and reliability. In deep tubewells groundwater is lifted from deep aquifer with the help of pumping set operated by mainly electric motor. In case of shallow tubewells groundwater is lifted from shallow aquifer with the help of pumping set operated by electric motor or diesel engine. Blockwise areal coverage of these groundwater based irrigation schemes is given in Table-8.

From the table it is evident that during 1991 and 2000 shallow tubewells were the main source of groundwater based irrigation but in 2011 deep tubewells becomes the most important part of groundwater based irrigation system. From this it can be inferred that as groundwater level is lowering, farmers are shifting to deeper sources to get uninterrupted water supply in the field.

High concentration of ground water based irrigation are found in the blocks of Mayureswar-II, Nalhati-II, Murarai-I and Murarai-II, and Low concentration are found in the blocks of Nalhati-I and Mayureswar-I whereas rest of the blocks maintain parity with subdivisional averages. So groundwater utilisation is higher in the eastern part of this subdivision which is characterised by alluvium aquifer from which groundwater extraction is easier and profitable.

Temporal analysis regarding percentage contribution of groundwater based irrigation system to total irrigated area is showing a gradual increasing trend. In 1991, 6.73% percent area of this subdivision is irrigated by groundwater whereas in 2011, its contribution amplified to 29.09% area. In the blocks of Murarai-I, Nalhati-II and Mayureswar-II this trend is very much acute. Whereas Mayureswar-I and Rampurhat-I blocks have not experienced greater change in terms of dependency on surface water in irrigation purposes. So there is a positive relationship between concentration of groundwater based irrigation system and increasing trend of contribution of groundwater based irrigation system to total irrigated area.

Table-8: Groundwater based Water System

Name of Block	Irrigated Area in hect. (1993)					Irrigated Area in hect. (2000)					Irrigated Area in hect. (2011)				
	D.T.W.	S.T.W.	Others	Total	% to total irrigated area	D.T.W.	S.T.W.	Others	Total	% to total irrigated area	D.T.W.	S.T.W.	Others	Total	% to total irrigated area
Nalhati-I	60	760	0	820	6.56	21	3171	21	3213	23.63	2533	200	7	2740	28.28
Nalhati-II	60	760	0	820	6.31	38	2815	9	2862	24.39	4580	650	1039	6269	42.18
Murarai-I	0	800	0	800	8.46	10	1625	12	1647	14.99	2280	0	415	2695	49.04
Murarai-II	0	1100	0	1100	8.98	25	920	8	953	7.62	2400	0	8	2408	38.17
Mayureswar-I	35	1518	0	1553	6.15	35	3734	20	3789	15.92	90	1027	25	1142	6.84
Mayureswar-II	63	2100	0	2163	9.98	25	4325	4	4354	36.43	7810	1360	235	9405	41.14
Rampurhat-I	30	360	0	390	3.48	47	824	28	899	5.43	350	950	70	1370	12.00
Rampurhat-II	70	660	0	730	3.83	35	2532	16	2583	12.86	4000	900	0	4900	25.79
Subdivision	**318**	**8058**	**0**	**8376**	**6.73**	**236**	**19946**	**118**	**20300**	**16.75**	**24043**	**5087**	**1799**	**30929**	**29.09**

Source: District Statistical Handbook, 1993, 2000, 2011

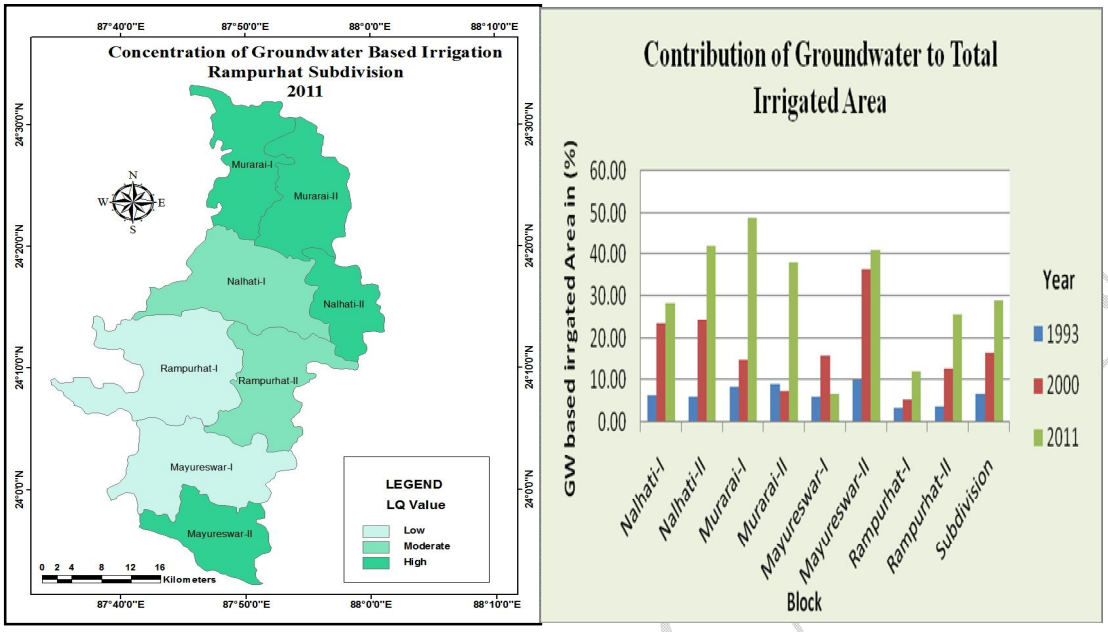

Fig.-3: Spatio-Temporal Variation in Ground Water Based Irrigation System

Relationship among Agricultural Variables:

Pearson's Product Moment Correlation value provides indication about nature of association and interdependence among variables. In this section variable like boro paddy concentration, paddy concentration, boro paddy yield index, paddy yield index, % of surface water irrigation to total irrigated area and % of groundwater irrigation to total irrigated area is incorporated to assess relationship among agricultural landscape and irrigation pattern. As paddy and boro paddy is the predominant crop of the study area, crop concentration index and crop yield index is used only for these crop to assess the generalized facts of the study area. From Table-9, positive relationships are found between groundwater based irrigation system and concentration of paddy and boro paddy and yield of paddy and boro paddy. Whereas negative relationships are identified between surface water based irrigation systems and concentration of paddy and boro paddy and yield of paddy and boro paddy. From this it can be remarked that in comparison to surface water based irrigation system groundwater based irrigation system plays more effective role to determine agricultural productivity. From negative relationship between surface water based irrigation system and agricultural productivity, it can be inferred that though Canal, R.L.I. and Tank irrigation schemes are present in government record book but in reality these schemes are almost in defunct state with minimum functionality. Temporal trend is also showing that gradually the efficiency of groundwater based irrigation schemes is increasing where as surface water based irrigation schemes are experiencing reverse situation.

Table-9: Pearson's Product Moment Correlation value

	CP	CBP	YIP	YIBP	LQSWI	LQGWI
Concentration of Paddy	1	-.403	-.506	.118	-.201	.201
Concentration of Boro Paddy		1	.505	.392	-.378	.478
Yield Index of Paddy			1	.197	-.549	.549
Yield Index of Boro Paddy				1	-.065	.065
LQI of Surface Water Irrigation					1	-1
LQI of Groundwater Irrigation						1

Source: Computed by the Researcher

MAJOR FINDINGS:

- Productivity of crop is higher in the northern part of this subdivision particularly in the blocks of Murarai-I, Nalhati-I and Nalhati-II. Low crop productivity is found in the blocks of Mayureswar-I which is located in middle portion of the subdivision. In rest of the blocks moderate crop productivity is observed.
- In most of blocks nature of productivity remains almost same throughout time period but fluctuating pattern in crop productivity is noticeable in the blocks of Rampurhat-I and Mayureswar-II.
- High concentration of surface water based irrigation are found in the middle portions of this subdivisions particularly in the blocks of Rampurhat-I and Mayureswar-I and Low concentration are found in the blocks of Nalhati-II, Murarai-I, Murarai-II which is located in northern portion of the subdivision.
- Temporal analysis regarding percentage contribution of surface water based irrigation system to total irrigated area is showing a gradual declining trend. In 1993, 93.27% percent area of this subdivision is irrigated by surface water whereas in 2011, its contribution reduced to 70.91% area only.
- High concentration of ground water based irrigation are found in the blocks of Mayureswar-II, Nalhati-II, Murarai-I and Murarai-II, and Low concentration are found in the blocks of Nalhati-I and Mayureswar-I whereas rest of the blocks maintain parity with subdivisional averages.
- Temporal analysis regarding percentage contribution of groundwater based irrigation system to total irrigated area is showing a gradual increasing trend. In 1993, 6.73% percent area of this subdivision is irrigated by groundwater whereas in 2011, its contribution amplified to 29.09% area.
- Positive relationships are found between groundwater based irrigation system and crop concentration and crop yield. Whereas negative relationships are identified between surface water based irrigation system and crop concentration and crop yield.

CONCLUSION:

From the study it is evident that agricultural productivity is significantly influenced by the function of groundwater based irrigation system. Whereas surface water based irrigation system is gradually becoming ineffective to serve agricultural field. Thus pressure on groundwater resources is escalating in an alarming way. So for the sustainability of agricultural productions and groundwater resources, drastic reforms in existing surface water based irrigation schemes should be initiated in a planned way. Combined effectiveness of both the irrigation types will make the agricultural field highly productive and sustainable. This type of study is relevant in context to present scenario of the state which is facing the crisis of groundwater level declination, drying up of surface water sources, health hazards as consequent factors.

REFERENCE:

Bhattacharyya A (2013). Evaluation of Hydro-Geonomic Characteristics of Flood in The Mayurakshi River Basin Of Eastern India. Unpublished doctoral thesis of Visva-Bharati, Santiniketan, India.

Bhattarai, M. and Narayanamoorthy, A. (2003). Irrigation Impacts and other Factors Contribution to the Agricultural Productivity Growth and Development in India: A Cross-State Panel Data Analysis for 1970 to 94. presented at the IWMI- TATA annual workshop in Anand, Gujarat, India.

Census of India (2001). District Census Handbook, 2001, Birbhum District. West Bengal: Directorate of Census Operation.

Government of India (2007). Groundwater Information Booklet, Birbhum District, West Bengal. Ministry of Water Resources: Central Ground Water Board.

Government of West Bengal (2010-11). District Statistical Hand Book, 2010-11, Birbhum. Department of Statistics & Programme: Bureau of Applied Economics & Statistics.

Krishnanunni, K. (2001). District Resource Map. Geological Survey of India.

Kullar, D.R. (1999). India: A Comprehensive Geography. pp-494-95. New Delhi: Kalyani Publisher.

Repetto, R. (1994). The 'Second India' Revisited: Population, Poverty and Environmental Stress Over Two Decades. Washington, DC: World Resources Institute.

Roy, P. (1992). Economic Geography A Study of Resources. pp- 147-48. Kolkata: New Central Book Agency (P) Ltd.

Singh, J. and Dhillon, S. S. (2005). Agricultural Geography. pp-297-98, New Delhi: Tata McGraw Hill Publishing Company Limited.