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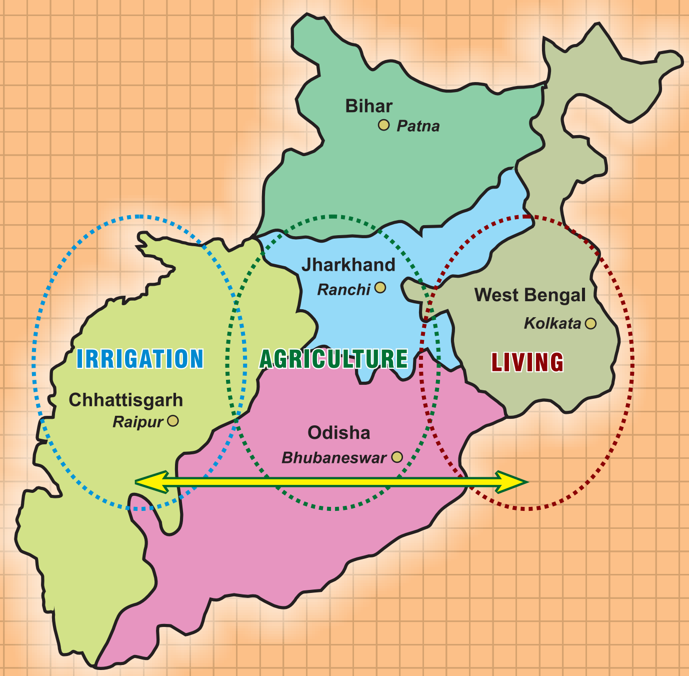

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CONTENT

1. INTRODUCTION

Over the last four decades the policy agenda of agriculture has evolved significantly from an initial focus on increasing food production to concerns for the environmental sustainability, poverty alleviation and diversified living options. It has been recognized that irrigation resources have played a major role historically in poverty alleviation by ensuring agricultural development, expanding living opportunities and employment both on and off the farm. In agricultural dependent settings, irrigation contributes significantly to improving livings and reducing poverty (Hussain and Hanjra, 2004). Recent multi-country studies provide further evidence that there are strong linkages between irrigation and poverty alleviation, and that the anti-poverty impacts of irrigation vary widely across settings (Saleth *et al.*, 2003; Sivamohan, *et al.*, 2004; Hussain, 2004).

Development of irrigated agriculture has been a major engine for economic growth and poverty reduction. But the growing scarcity and competition for water are putting the poor in irrigated areas at great risk (Barker *et al.*, 2000). Poverty alleviation has always been an important aim of the governments of developing countries when investing in the construction of irrigation infrastructure (van Koppen, 2002). Between the mid 1970s and 1990, the number of people below the poverty line in India fell from over 50 percent to approximately 35 percent (Datt, 1998); however, the absolute number of people below the poverty line increased. An important factor to poverty alleviation was the growth in public sector funded canal irrigation and in largely private sector-funded tube well irrigation. Identification of analytical, methodological and policy issues are crucial for understanding and promoting the overall poverty alleviation impacts of irrigation (Saleth *et al.*, 2003). During the 3rd annual partners meet of the International Water Management Institute (IWMI) – Tata Water Policy Research Programme on February 2004 it was mentioned that (a) irrigation development promotes non-farm employment (b) the impact of irrigation was relatively higher with temporal and spatial variations in rural poverty (c) groundwater irrigation explained variations in rural poverty even better than canal irrigation and (d) irrigation availability (measured as irrigated area per worker) has a positive impact on real farm wage rates. The smaller the systems with well managed infrastructure, relatively equitable water distribution and diversified cropping patterns supported with market infrastructure, the greater the poverty reducing impacts of irrigation. Improving the performance of irrigation systems by enhancing land and water productivity, diversifying cropping patterns and improving water distribution across locations would help reducing poverty in presently low productivity-high poverty parts of the systems (Hussain *et al.*, 2006).

If irrigation has the potential to produce such profound impacts on agrarian dynamism, why such impacts are not visible in eastern India, where it is needed and has the water resources to sustain intensive irrigation (Shah, 2004). Rural eastern India is still poverty stricken with narrow living options inspite of plentiful water resources. This kind of mismatch demands an analysis of irrigation, agriculture, living and poverty linkages in eastern region of India. It will delineate the missing link between poverty and level of living scenario and growth of irrigation and agriculture sector. In this context, present study was conducted to analyse links between irrigation, agriculture and living scenario in five eastern Indian states *viz.* Orissa, West Bengal, Chhattisgarh, Jharkhand and Bihar.

2. METHODOLOGY

Different indexes were constructed for assessment of district wise scenario of irrigation, agriculture, living and poverty, *viz.* Groundwater Development Index (GWDI), Irrigation Coverage Index (ICI), Composite Irrigation Index (CII), Agricultural Development Index (ADI), Poverty Ration Index (PRI), and Level of Living Index (LLI). Brief account of these indexes are given below:

GWDI included utilisable groundwater resource (ha-m) and gross annual draft (ha-m).

$GWDI_j = [(GWD_j - \text{min. } GWD_j) / (\text{max. } GWD_j - \text{min. } GWD_j)]$

Where, GWD_j = (gross annual draft of jth district / utilisable groundwater resource of jth district)

ICI was calculated on the basis of gross irrigated area out of gross cultivated area.

$ICI_j = [(IC_j - \text{min. } IC_j) / (\text{max. } IC_j - \text{min. } IC_j)]$

Where, IC_j = (gross irrigated area of jth district / gross sown area of jth district)

CII was calculated averaging GWDI and ICI giving equal weight.

ADI included seven indicators *viz.* % of cultivable land to total land area, % of net sown area to total cultivable area, % of gross irrigated area to gross cropped area, cropping intensity, yield of major crop, food grain productivity and per ha fertilizer consumption. Composite agricultural development index was calculated as:

$$ADI_j = \frac{\sum_{i=1}^{n} I_{ij}}{\sum_{i=1}^{n} i}$$

Where, ADI_j is the index of j^{th} district and equal weight to all the indicators

$I_{ij} = (X_{ij} - \min X_{ij}) / (\max X_{ij} - \min X_{ij})$

Where, X_{ij} is the actual value of i^{th} variable for j^{th} district

min X_{ij} and max X_{ij} are the minimum and maximum value of i^{th} variable

PRI was calculated on the basis of rural families below poverty line (BPL) to total number of rural families

$PRI = [(max.\ PR_j - PR_j) / (max.\ PR_j - min.\ PR_j)]$

Where, PR_j = (BPL rural families of jth district / total rural families of jth district)

LLI included 14 variables *viz.* % of rural families above poverty line, literacy rate, per capita food grain production, yield of major crop, % of gross irrigated area to gross cropped area, % of village electrification, women work participation rate, % of agricultural laborers to total main workers, % of cultivators to total main workers, % of industrial workers to total main workers, % of main workers to total population, percentage of urban population to total population, agricultural productivity per worker, and SC/ST population. To ensure the index values for the selected variables move in same direction the index value was calculated as follows:

Index values for the positive variables like literacy rate, agricultural productivity, etc were calculated as:

(Actual value – Min. value) / (Max. value – Min. value)

While index values of the negative variables like SC/ST population, poverty ratio, etc were calculated as:

(Max. value – Actual value) / (Max. value – Min. value)

On the basis of the index value of each selected indicator a composite index was derived giving equal weight and there by district-wise LLI value was calculated as:

$$LLI_j = \frac{\sum_{k=1}^{m} P_{kj}}{\sum_{k=1}^{m} k}$$

Where, LLI_j is the index of j^{th} district and equal weight to all the indicators (k=1,2,....m)

$P_{kj} = (Y_{kj} - min\ Y_{kj}) / (max\ Y_{kj} - min\ Y_{kj})$

Where, Y_{kj} is the actual value of k^{th} variable for j^{th} district

min Y_{kj} and max Y_{kj} are the minimum and maximum value of k^{th} variable

Assessment of district wise scenario of irrigation, agriculture, living and poverty was done with the help of different indices constructed for the study. Firstly, analyses were done for the inter-district comparison within a single state. Thus, districts of Orissa, West Bengal, Chhattisgarh, Jharkhand and Bihar were analysed within the respective state. Thereafter, comparative analyses of different indices in case of 119 districts falling under five eastern India states *viz.* Orissa, West Bengal, Chhattisgarh, Jharkhand and Bihar carried out.

District-wise data on selected variables were taken from respective states' Economic Survey (2004-05, 2005-06), Agricultural Statistics (2004-05, 2005-06), 2001 Census, BPL Survey 1997 (BPL census was conducted in 2002 but it could not be published due to restriction by Supreme Court; since BPL census conducted every five years, a fresh survey should have been done in 2007; however, before it happens the Planning Commission asked the State to go for a progressive downward revision) and other published sources. District wise values of different indices were calculated. Each index ranged from 0.0 to 1.0. The districts were classified under each index into five categories depending on respective index value *viz.* very low (0.0 to 0.2), low (>0.2 to 0.4), medium (>0.4 to 0.6), high (>0.6 to 0.8) and very high (>0.8 to 1.0).

3. FINDINGS AND DISCUSSION

3.1 Analyses for districts of Orissa

Apprising district wise irrigation scenario latest as on March 2007 in Orissa revealed that the created irrigation potential out of total potential varied among the 30 districts of Orissa ranging from 19% (Nawarangpur dist.) to 93% (Puri dist.) in *kharif* and 8% (Bolangir dist.) to 61% (Puri dist.) in *rabi* season. Groundwater development varied from 6% (Malkangiri dist.) to 47 % (Balasore dist.). Groundwater development was less than 20% in 23 districts with state average of about 18% (Table 1).

Table 1. Irrigation scenario in the districts of Orissa

Particular	Frequency of districts (n=30)					
	Ground water development	Irrigation potential development		Irrigation potential utilization		GIA out of GCA
		Kharif	*Rabi*	*Kharif*	*Rabi*	
> 80 %	--	3	--	9	23	--
>70 to 80 %	--	3	--	4	1	--
>60 to 70 %	--	3	1	5	4	1
>50 to 60 %	--	2	--	10	1	5
>40 to 50 %	2	5	3	--	--	2
>30 to 40 %	2	7	3	1	1	7
>20 to 30 %	3	6	6	1	1	10
>10 to 20 %	21	1	14	--	--	4
< 10 %	2	--	3	--	--	1
State (%)	*18.31*	*47.36*	*22.23*	*69.71*	*80.53*	*33.21*
Maximum (%)	*47.46*	*93.02*	*60.80*	*96.11*	*98.63*	*61.59*
Minimum (%)	*6.02*	*19.20*	*8.60*	*22.64*	*25.48*	*9.27*

The GWDI values of 25 districts found low to very low; only 4 districts value found >0.6 (high to very high) as evident from Tables 2, 3 and 4. The irrigation utilization varied from 23 to 96% and 25 to 98% of created potential in *kharif* and *rabi* season, respectively. Irrigation intensity varied from 14% (Nawarangpur dist.) to 125% (Puri dist.) with a state average 52%. The gross irrigated area ranged from 9% (Nawarangpur dist.) to 62% (Jajpur dist.) of gross cultivated area with a state average 33%. ICI values of 15 districts were very low to low, while that of 8 districts was high to very high. CII value varied from 0.21(Nawarangpur dist.) to 0.81 (Bhadrak dist.). CII of 14 districts was low, while 6 districts were found under high category.

Table 2. Different indexes in the districts of Orissa

District	GWDI	ICI	CII	ADI	LLI	PRI
1. Balasore	1.00	0.64	0.69	0.72	0.49	0.33
2. Bhadrak	0.95	0.95	0.81	0.76	0.58	0.52
3. Bolangir	0.26	0.13	0.31	0.45	0.42	0.67
4. Sonepur	0.13	0.85	0.64	0.66	0.57	0.35
5. Cuttack	0.30	0.85	0.62	0.67	0.60	0.91
6. Jajpur	0.72	1.00	0.76	0.61	0.43	0.69
7. Jagatsingpur	0.21	0.27	0.30	0.48	0.53	0.90
8. Kendrapara	0.62	0.41	0.48	0.58	0.53	0.70
9. Dhenkanal	0.24	0.30	0.30	0.39	0.43	0.63
10. Angul	0.28	0.24	0.33	0.41	0.46	0.72
11. Ganjam	0.47	0.67	0.62	0.71	0.50	0.84
12. Gajpati	0.29	0.18	0.32	0.50	0.40	0.66
13. Kalahandi	0.20	0.51	0.52	0.56	0.39	0.63
14. Nawapara	0.24	0.16	0.33	0.35	0.27	0.00
15. Keonjhar	0.18	0.27	0.35	0.46	0.39	0.24
16. Koraput	0.02	0.49	0.41	0.47	0.35	0.05
17. Malkangiri	0.00	0.29	0.27	0.39	0.41	0.10
18. Nawarangpur	0.26	0.00	0.21	0.41	0.30	0.33
19. Rayagarh	0.16	0.29	0.34	0.35	0.30	0.37
20. Mayurbhanj	0.38	0.42	0.42	0.43	0.43	0.22
21. Kandhamal	0.11	0.08	0.22	0.19	0.31	0.20
22. Boudh	0.26	0.57	0.54	0.44	0.45	0.15
23. Puri	0.11	0.90	0.67	0.68	0.55	0.45
24. Khurda	0.19	0.51	0.44	0.54	0.56	0.72
25. Nayagarh	0.11	0.27	0.31	0.41	0.40	0.49
26. Sambalpur	0.10	0.48	0.42	0.56	0.61	0.71
27. Bargarh	0.20	0.79	0.56	0.77	0.61	0.69
28. Deogarh	0.13	0.32	0.38	0.32	0.28	0.19
29. Jharsuguda	0.40	0.23	0.41	0.43	0.53	1.00
30. Sundargarh	0.23	0.29	0.35	0.31	0.41	0.56
Max. Value	*1.00*	*1.00*	*0.81*	*0.77*	*0.61*	*1.00*
Min. Value	*0.00*	*0.00*	*0.21*	*0.19*	*0.27*	*0.00*
Mean	*0.29*	*0.45*	*0.44*	*0.50*	*0.45*	*0.50*
Standard deviation	*0.24*	*0.28*	*0.16*	*0.15*	*0.10*	*0.28*

Table 3. Classification of districts of Orissa under each index

Categories	Frequency of the districts					
	GWDI	ICI	CII	ADI	LLI	PRI
Very low (0.0-0.20)	13	5	0	1	0	6
Low (>0.2-0.4)	12	10	14	6	9	6
Medium (>0.4-0.6)	1	7	9	15	19	4
High (>0.6-0.8)	2	3	6	8	2	10
Very high (>0.8-1.0)	2	5	1	0	0	4

District wise agricultural development was assessed on the basis of data on selected indicators for the year 2004-05 being categorized as a normal year without any flood, drought or other natural calamities affecting agricultural performance. ADI values of 30 districts ranged from 0.77 (Bargarh dist.) to 0.19 (Kandhamal dist.). Half of the districts showed medium ADI values (>0.4-0.6); while 6 and 8 districts indicated low (>0.2-0.4) and high (>0.6-0.8) agricultural development, respectively (Tables 2, 3 and 4). Level of living of 19 and 9 districts found as medium (with LLI value >0.4-0.6) and low (with LLI value >0.2-0.4), respectively. Sambalpur and Bargarh are only two districts with high LLI value. Poverty was explored through the % of rural families under below poverty line to total number of rural families. About 60% of BPL rural families comprised of the agricultural labourers, marginal and small farmers families; it ranged from 25% (Ganjam) to 94% (Nawarangpur). PRI values of 10 districts were in high range (higher the value of index lower is the poverty), while 12 districts showed the very high to high poverty level with PRI values in the range of 0.0 to 0.2 and >0.2 to 0.4, respectively. Rural poverty was highest in Nawapara district (86 % of rural families are BPL); however, it was lowest in Jharsuguda where more than half of the rural families were BPL. Overall in Orissa 66 % of rural families was found BPL.

Table 4. Categorisation of districts of Orissa on the basis of index values

Category	GWDI	ICI	CII	ADI	LLI	PRI
Very high (>0.8-1.0)	Balasore Bhadrak	Bhadrak Jajpur Cuttack Sonepur Puri	Bhadrak			Cuttack Ganjam Jagatsinpur Jharsuguda
High (>0.6-0.8)	Jajpur Kendrapara	Balasore Ganjam Bargarh	Balasore Sonepur Cuttack Jajpur Puri Ganjam	Balasore Bhadrak Sonepur Cuttack Puri Bargarh Jajpur Ganjam	Sambalpur Bargarh	Bolangir Jajpur Kendrapara Dhenkanal Angul Gajpati Kalahandi Khurda Sambalpur Bargarh

Medium (>0.4-0.6)	Ganjam	Kendrapara Kalahandi Koraput Mayurbhanj Boudh Khurda Sambalpur	Kendrapara Kalahandi Koraput Mayurbhanj Boudh Khurda Bargarh Sambalpur Jharsuguda	Jagatsingpur Kendrapara Gajpati Kalahandi Koraput Boudh Khurda Sambalpur Jharsuguda Bolangir Angul Keonjhar Nawarangpur Mayurbhanj Nayagarh	Balasore Bhadrak Bolangir Sonepur Cuttack Jajpur Jagatsingpur Kendrapara Dhenkanal Angul Ganjam Gajpati Malkangiri Mayurbhanj Boudh Puri Khurda Jharsuguda Sundargarh	Bhadrak Puri Nayagarh Sundargarh
Low (>0.2-0.4)	Bolangir Cuttack Jagatsingpur Dhenkanal Angul Gajpati Nawapara Nawarangpur Mayurbhanj Boudh Jharsuguda Sundargarh	Jagatsinpur Dhenkanal Angul Keonjhar Malkangiri Rayagarh Nayagarh Deogarh Jharsuguda Sundargarh	Bolangir Jagatsingpur Dhenkanal Angul Gajpati Nawapara Keonjhar Malkangiri Nawarangpur Rayagarh Kandhamal Nayagarh Deogarh Sundargarh	Dhenkanal Nawapara Malkangiri Rayagarh Deogarh Sundargarh	Kalahandi Nawapara Keonjhar Koraput Nawaranpur Rayagarh Kandhamal Nayagarh Deogarh	Balasore Sonepur Keonjhar Nawarangpur Rayagarh Mayurbhanj
Very low (0.0-0.20)	Sonepur Kalahandi Keonjhar Koraput Malkangiri Rayagarh Kandhamal Puri Khurda Nayagarh Sambalpur Deogarh Bargarh	Bolangir Nawapara Gajpati Nawranpur Kandhamal	Nawarangpur Kandhamal	Kandhamal		Nawapara Koraput Malkangiri Kandhamal Boudh Deogarh

A linkage matrix was prepared showing frequency of districts under various combinations of links between irrigation, agriculture, living and poverty (Table 5).

Irrigation – agriculture link was found in 23 districts; however, it narrowed down to 14 and 13 districts in case of agriculture – living and irrigation – living link, respectively. Irrigation – poverty and agriculture – poverty link was visible in 11 and 9 districts, respectively. Irrigation – agriculture – living – poverty link was seen only in 5 districts.

Table 5. Linkage matrix showing frequency of districts under various combinations of links between irrigation, agriculture, living and poverty in Orissa

Types of Links	No. of Districts			
	Index: High to Very high	Index: Medium	Index: Low to Very low	Total
Irrigation - Agriculture	8	8	7	23
Agriculture – Living	1	9	4	14
Irrigation – Living	1	5	7	13
Living - Poverty	2	3	7	12
Irrigation - Poverty	4	0	7	11
Irrigation – Agriculture – Living	1	4	5	10
Irrigation – Agriculture – Poverty	4	0	5	9
Agriculture - Poverty	4	0	5	9
Irrigation – Living - Poverty	1	0	6	7
Agriculture – Living – Poverty	1	0	4	5
Irrigation – Agriculture – Living - Poverty	1	0	4	5

The extent of association between irrigation, agriculture, living and poverty was understood through a correlation matrix (Table 6). Correlation matrix revealed that ADI is significantly related with GWDI, ICI and CII; while LLI is significantly related with ICI, CII, ADI and PRI. Correlation coefficient values between PRI and ADI as well as PRI and LLI were significant. However, the regression analyses revealed that 71% variation in ADI is explained by CII (Fig. 1). It is relevant to note that ICI and CII values were lowest in Nawarangpur district showing very poor irrigation scenario with highest % of agril. labourers, marginal and small farmers families below poverty line in rural areas to total number of rural families. In contrast, Balasore and Bhadrak districts were agriculturally developed with highest groundwater development. The marginal impact of groundwater irrigation on poverty reduction is larger than that of canal irrigation, which is due to greater control in the application and wide spread use of groundwater irrigation than of canal irrigation (Bhattarai and Narayanmoorthy, 2003). In recent years investments made by the private farmers in groundwater irrigation may have a larger impact on livings for poor people than the public investments in large-scale surface water irrigation systems (Rijsberman, 2003). In this context, lower groundwater exploitation for irrigation in Orissa has bearing on the lower impact of irrigation development on the poverty and living scenario in the state.

Table 6. Correlation matrix of different indicators in districts of Orissa

	GWDI	ICI	CII	ADI	LLI	PRI
GWDI	1.000					
ICI	0.399*	1.000				
CII	0.615**	0.947**	1.000			
ADI	0.513**	0.827**	0.843**	1.000		
LLI	0.271	0.641**	0.580**	0.751**	1.000	
PRI	0.238	0.191	0.200	0.400*	0.619**	1.000

** significant at 0.01 level and * significant at 0.05 level

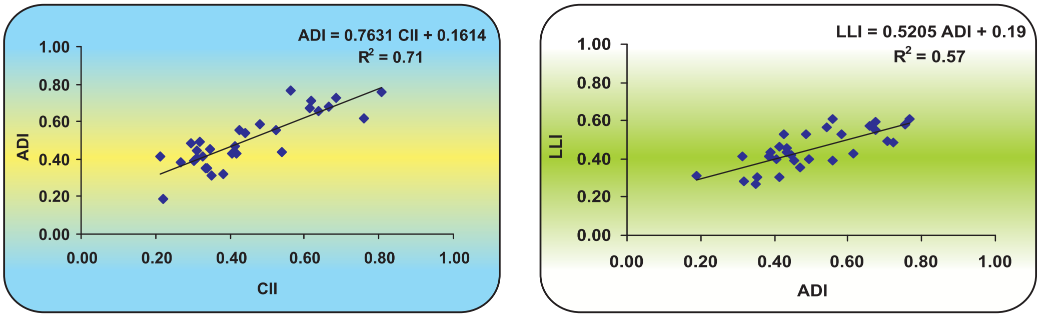
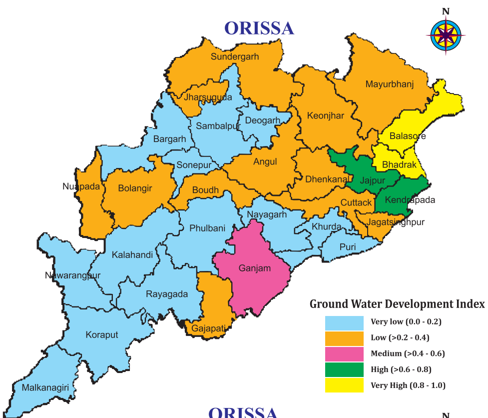
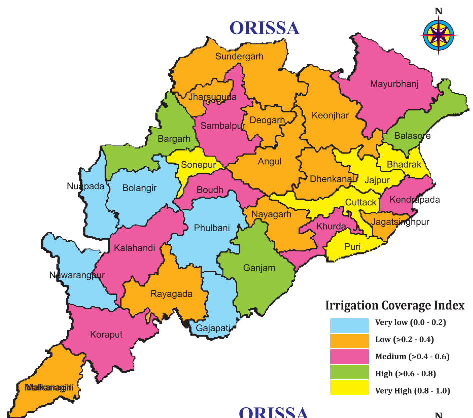
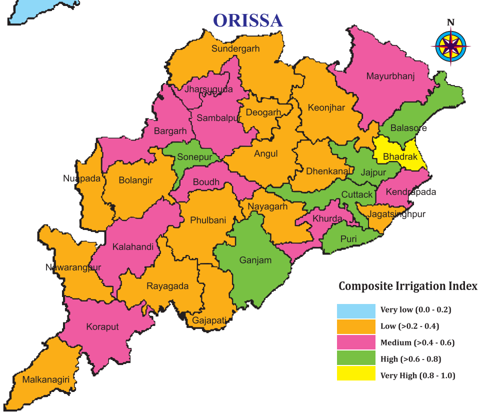
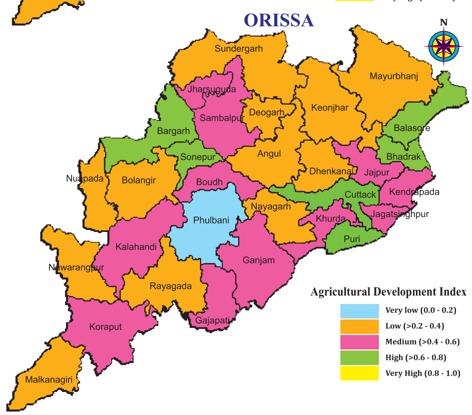


Fig. 1 Regression between ADI and CII; LLI and ADI









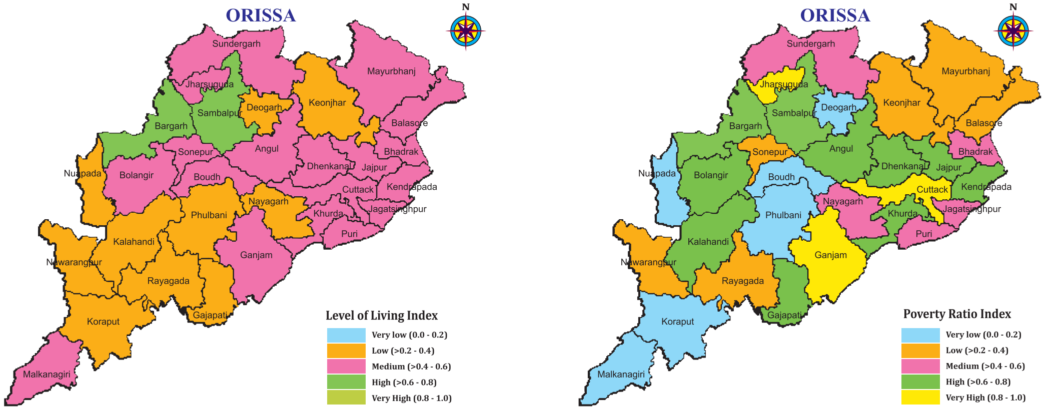


Fig. 2 District maps of different indices in Orissa

3.2 Analyses for districts of West Bengal

Groundwater development in West Bengal varied from 1% (Darjeeling and Jalpaiguri dists.) to 57 % (Nadia dist.) with an average of 25%. The GWDI values of 8 districts were found low to very low; while 4 districts value was high to very high (>0.6). The irrigation utilization or irrigation coverage (ratio of gross irrigated to gross sown area) varied from 12% (Darjeeling) to 91% (Midnapore West dist.) with an average of 46%. Five districts showed high to very high irrigation coverage index value (ICI>0.6). CII value varied from 0.002 (Darjeeling dist.) to 0.740 (Midnapore West dist.). CII values of 8 districts were low to very low (< 0.4), while that of 5 districts each was medium (>0.4 to 0.6) and high (>0.6 to 0.8) as evident from Tables 7, 8 and 9.

ADI values of 18 districts in West Bengal ranged from 0.741 (Bardhaman dists.) to 0.224 (Darjeeling dist.). Six districts showed high (>0.6-0.8) agricultural development while seven and five districts showed medium (>0.4-0.6) and low (>0.2-0.4) ADI values, respectively.

Level of living of 11 and 6 districts was found as medium (with LLI value >0.4-0.6) and low (with LLI value >0.2-0.4), respectively. Only Howrah district had high LLI value (0.624). PRI values of 6 districts were in high range (higher the value of index lower is the poverty), while 9 districts showed the very high to high poverty level with PRI values in the range of 0.0 to 0.2 and >0.2 to 0.4, respectively. Poverty was found highest in Darjeeling and Coochbihar districts (46 % families BPL); however, it was lowest in Bardhaman district, where 26% families were BPL.

Table 7. Different indexes in the districts of West Bengal

District	GWDI	ICI	CII	ADI	LLI	PRI
1. Darjeeling	0.003	0.000	0.002	0.224	0.387	0.000
2. Jalpaiguri	0.000	0.295	0.154	0.319	0.324	0.523
3. Coochbihar	0.061	0.028	0.045	0.444	0.314	0.021
4. Dinajpur (N)	0.531	0.186	0.362	0.522	0.350	0.270
5. Dinajpur (S)	0.209	0.152	0.184	0.500	0.403	0.143
6. Malda	0.515	0.198	0.361	0.478	0.436	0.377
7. Murshidabad	0.867	0.203	0.539	0.641	0.458	0.155
8. Nadia	1.000	0.261	0.636	0.601	0.484	0.605
9. 24 Parganas (North)	0.985	0.151	0.571	0.513	0.470	0.432
10. 24 Parganas (South)	0.985	0.318	0.658	0.344	0.302	0.457
11. Howrah	0.227	0.644	0.449	0.593	0.624	0.706
12. Hooghly	0.542	0.583	0.575	0.673	0.554	0.859
13. Bardhaman	0.421	0.960	0.711	0.741	0.567	1.000
14. Birbhum	0.234	0.946	0.610	0.658	0.462	0.119
15. Bankura	0.242	0.885	0.582	0.482	0.471	0.196
16. Purulia	0.132	0.436	0.293	0.251	0.327	0.138
17. Midnapore East	0.483	0.216	0.354	0.364	0.423	0.968
18. Midnapore West	0.483	1.000	0.740	0.699	0.520	0.671
Min. Value	*0.000*	*0.000*	*0.002*	*0.224*	*0.302*	*0.000*
Max. Value	*1.000*	*1.000*	*0.740*	*0.741*	*0.624*	*1.000*
Mean	*0.440*	*0.415*	*0.435*	*0.503*	*0.438*	*0.424*
Standard deviation	*0.336*	*0.336*	*0.227*	*0.155*	*0.093*	*0.321*

Table 8. Classification of districts of West Bengal under each index

Categories	Frequency of the districts					
	GWDI	ICI	CII	ADI	LLI	PRI
Very low (0.0-0.20)	4	6	4	0	0	7
Low (>0.2-0.4)	4	5	4	5	6	2
Medium (>0.4-0.6)	6	2	5	7	11	3
High (>0.6-0.8)	0	1	5	6	1	3
Very high (>0.8-1.0)	4	4	0	0	0	3

Links between irrigation, agriculture, living and poverty was revealed through a linkage matrix (Table 10). The extent of association between different indexes realized with the help of correlation matrix (Table 11), which showed that ADI was significantly related with ICI and CII, while LLI was significantly related with ICI, CII, ADI and PRI. Correlation coefficient values between PRI and CII as well as PRI and LLI were significant. The regression analyses revealed that 49% variation in ADI is explained by CII, while 58% variation in LLI is explained by ADI (Fig. 3).

Table 9. Categorisation of districts of West Bengal on the basis of index values

Category	GWDI	ICI	CII	ADI	LLI	PRI
Very high (>0.8-1.0)	Nadia Murshidabad N 24 Parganas S. 24 Parganas	Bardhaman Birbhum Bankura Midnapore West				Hooghly Bardhaman Midnapore East
High (>0.6-0.8)		Howrah	Nadia S. 24 Parganas Bardhaman Birbhum W Midnapore	Hooghly Bardhaman Murshidabad Nadia Birbhum W. Midnapore	Howrah	Howrah W. Midnapore Nadia
Medium (>0.4-0.6)	Dinajpur (N) Malda Hooghly Bardhaman Midnapore (E) W Midnapore	Hooghly Purulia	Murshidabad N 24 Parganas Howrah Hooghly Bankura	Coochbihar Dinajpur (N) Dinajpur (S) Malda N 24 Parganas Howrah Bankura	Murshidabad Nadia N 24 Parganas Hooghly Bardhaman Birbhum Bankura Midnapore (E) W Midnapore Malda Dinajpur (S)	Jalpaiguri N24 Parganas S 24 Parganas
Low (>0.2-0.4)	Dinajpur (S) Howrah Birbhum Bankura	Nadia S 24 Parganas E Midnapore Jalpaiguri N24 Parganas	Dinajpur (N) Malda Purulia Midnapore East	Darjeeling Jalpaiguri S 24 Parganas Purulia Midnapore East	Darjeeling Jalpaiguri Coochbihar Dinajpur (N) S 24 Parganas Purulia	Dinajpur (N) Malda
Very low (0.0-0.20)	Darjeeling Jalpaiguri Coochbihar Purulia	Darjeeling Coochbihar Dinajpur (N) Dinajpur (S) Malda Murshidabad	Darjeeling Jalpaiguri Coochbihar Dinajpur (S)			Dinajpur (S) Darjeeling Coochbihar Dinajpur (S) Murshidabad Bankura Purulia

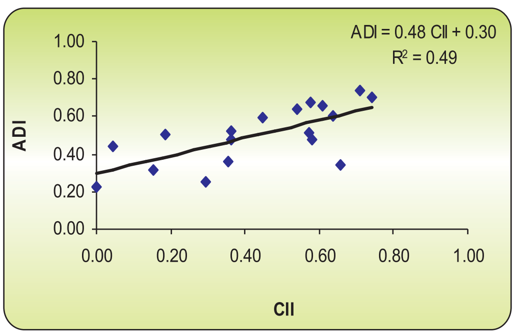
Table 10. Linkage matrix showing frequency of districts under various combinations of links between irrigation, agriculture, living and poverty in West Bengal

Types of Links	No. of Districts			
	Index: High to Very high	Index: Medium	Index: Low to Very low	Total
Irrigation - Agriculture	4	3	4	11
Agriculture – Living	0	4	4	8
Irrigation – Living	0	4	5	9
Living - Poverty	3	1	2	6
Irrigation - Poverty	4	1	2	7
Irrigation – Agriculture – Living	1	1	4	6
Irrigation – Agriculture – Poverty	0	1	3	4
Agriculture - Poverty	3	1	2	6
Irrigation – Living - Poverty	0	1	4	5
Agriculture – Living – Poverty	0	1	2	3
Irrigation –Agriculture –Living -Poverty	0	1	2	3

Table 11. Correlation matrix of different indicators in districts of West Bengal

	GWDI	ICI	CII	ADI	LLI	PRI
GWDI	1.000					
ICI	-0.107	1.000				
CII	0.656**	0.680**	1.000			
ADI	0.343	0.586*	0.697**	1.000		
LLI	0.172	0.594**	0.579*	0.759**	1.000	
PRI	0.302	0.370	0.503*	0.399	0.569*	1.000

** significant at 0.01 level and * significant at 0.05 level



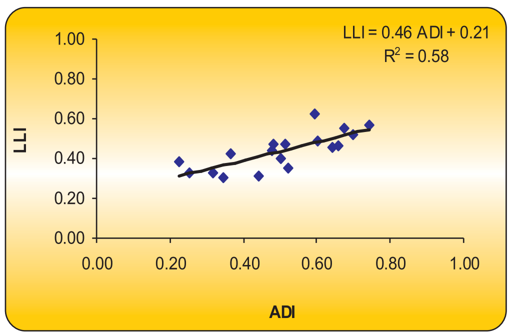
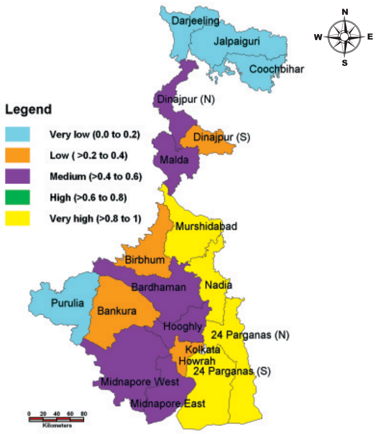
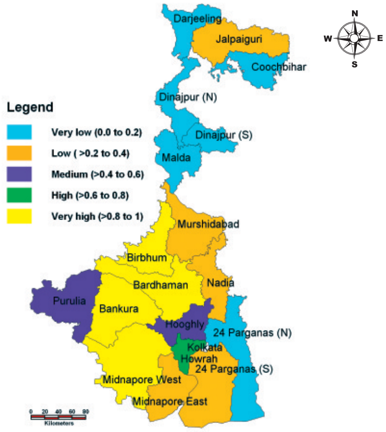


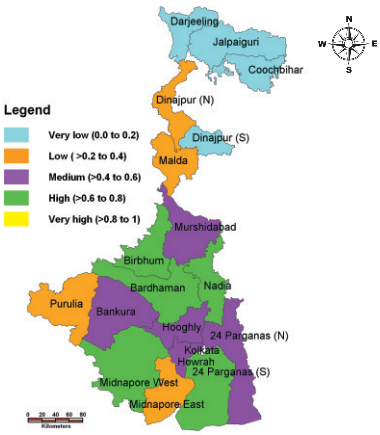
Fig. 3 Regression between ADI and CII; LLI and ADI



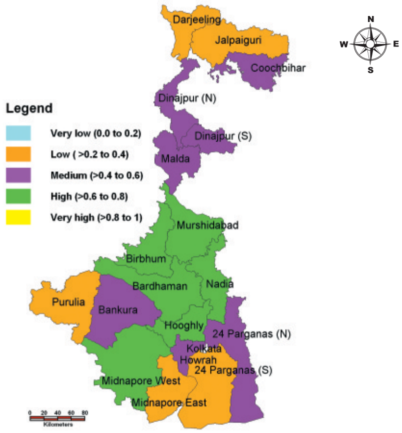
Groundwater Development Index



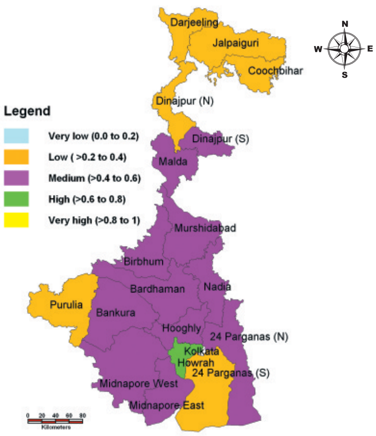
Irrigation Coverage Index



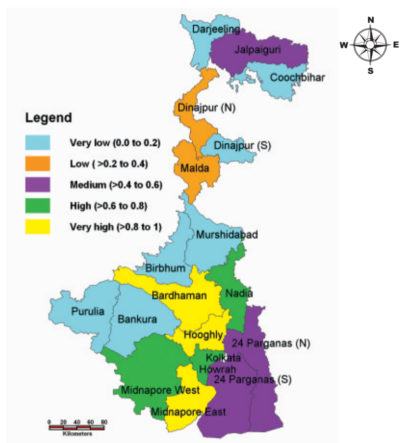
Composite Irrigation Index



Agricultural Development Index



Level of Living Index



Poverty Ration Index

Fig. 4 District maps of different indices in West Bengal

3.3 Analyses for districts of Chhattisgarh

In Chhattisgarh, groundwater development ranged from 2% (Dantewada dist.) to 65% (Durg dist) with a state average of 25%. GWDI value of Durg and Dhamtari districts was very high and high; however, 10 districts showed low to very low value. Irrigation coverage varied from 50% of gross sown area in Janjgir-Champa dist. to 1.5% in Bastar dist. ICI values of 10 districts were low to very low (<0.4). Composite irrigation index of Durg, Dhamtari and Janjgir-Champa districts were high but 10 districts showed low to very low CII values (Tables 12, 13 and 14).

ADI values of Durg, Raipur, Dhamtari, Janjgir-Champa and Bilaspur districts were high; however, 8 and 3 districts showed low to very low and medium ADI values, respectively. Level of living of 8 and 6 districts was found as medium (with LLI value >0.4-0.6) and low (with LLI value >0.2-0.4), respectively. Dhamtari and Durg were the two districts indicating high level of living value. Seven districts of Chhattisgarh showed PRI values >0.6 that indicated relatively lower level of poverty (about 35% families BPL), lowest being Durg dist. (30%). Highest BPL families was found in Mahasamund district (53%) whose PRI value along with another 5 districts fall under very low to low category (<0.4).

Table 12. Different indexes in the districts of Chhatisgarh

District	GWDI	ICI	CII	ADI	LLI	PRI
1. Koriya	0.230	0.088	0.159	0.170	0.396	0.794
2. Sargujar	0.281	0.108	0.194	0.276	0.301	0.385
3. Jashpur	0.258	0.033	0.146	0.213	0.470	0.756
4. Raipur	0.297	0.834	0.566	0.711	0.562	0.838
5. Mahasamund	0.335	0.444	0.390	0.556	0.517	0.000
6. Dhamtari	0.610	0.945	0.778	0.704	0.681	0.968
7. Durg	1.000	0.522	0.761	0.751	0.603	1.000
8. Rajnandgaon	0.445	0.280	0.362	0.452	0.571	0.550
9. Kabardha	0.510	0.292	0.401	0.366	0.476	0.319
10. Bilaspur	0.505	0.584	0.544	0.626	0.459	0.426
11. Janjgir	0.473	1.000	0.737	0.675	0.539	0.542
12. Korba	0.179	0.075	0.127	0.138	0.337	0.793
13. Raigarh	0.362	0.332	0.347	0.445	0.393	0.187
14. Bastar	0.064	0.000	0.032	0.241	0.382	0.042
15. Kanker	0.109	0.152	0.131	0.368	0.556	0.787
16. Dantewada	0.000	0.005	0.003	0.091	0.393	0.062
Min. Value	*0.000*	*0.000*	*0.003*	*0.091*	*0.301*	*0.000*
Max. Value	*1.000*	*1.000*	*0.778*	*0.751*	*0.681*	*1.000*
Mean	*0.354*	*0.356*	*0.355*	*0.424*	*0.477*	*0.528*
Standard deviation	*0.243*	*0.336*	*0.260*	*0.224*	*0.105*	*0.336*

Table 13. Classification of districts of Chhattisgarh under each index

Categories	Frequency of the districts					
	GWDI	ICI	CII	ADI	LLI	PRI
Very low (0.0-0.20)	4	7	7	5	0	4
Low (>0.2-0.4)	6	3	3	3	6	2
Medium (>0.4-0.6)	4	3	3	5	8	3
High (>0.6-0.8)	1	0	3	3	2	4
Very high (>0.8-1.0)	1	3	0	0	0	3

Table 14. Categorisation of districts of Chhattisgarh on the basis of index values

Categories	GWDI	ICI	CII	ADI	LLI	PRI
Very high (>0.8-1.0)	Durg	Raipur Dhamtari Janjgir				Raipur Dhamtari Durg
High (>0.6-0.8)	Dhamtari		Dhamtari Durg Janjgir	Dhamtari Durg Janjgir Bilaspur Raipur	Dhamtari	Koriya Jashpur Korba Kanker
Medium (>0.4-0.6)	Rajnandgaon Kabardha Bilaspur Janjgir	Mahasamund Durg Bilaspur	Bilaspur Raipur	Raigarh Mahasamund Rajnandgaon	Jashpur Raipur Mahasamund Durg Rajnandgaon Kabardha Bilaspur Janjgir Kanker	Rajnandgaon Bilaspur Janjgir
Low (>0.2-0.4)	Koriya Sargujar Jashpur Raipur Mahasamund Raigarh	Rajnandgaon Kabardha Raigarh	Rajnandgaon Kabardha Mahasamund Raigarh	Sargujar Kabardha Kanker Bastar Jashpur	Koriya Sargujar Korba Raigarh Bastar Dantewada	Sargujar Kabardha
Very low (0.0-0.20)	Korba Bastar Kanker Dantewada	Koriya Sargujar Jashpur Korba Bastar Kanker Dantewada	Koriya Sargujar Jashpur Korba Bastar Kanker Dantewada	Koriya Dantewada Korba		Mahasamund Raigarh Bastar Dantewada

Links between irrigation, agriculture, living and poverty was understood through a linkage matrix (Table 15). Correlation values of different indices of districts of Chhattisgarh (Table 16) revealed significant association of ADI with GWDI, ICI and

CII. LLI also showed significance with GWDI, ICI CII and ADI. However, PRI did not indicate significant coefficient value except with LLI. 88% variation in ADI is explained by CII and 58% variation in LLI is explained by ADI (Fig. 5)

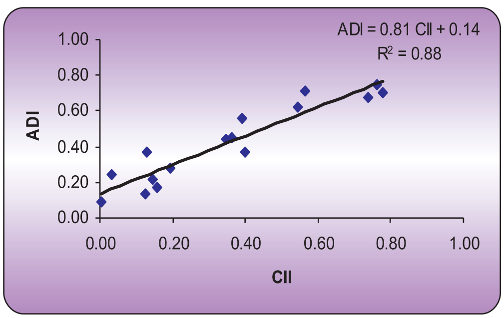
Table 15. Linkage matrix showing frequency of districts under various combinations of links between Irrigation, Agriculture, Living and Poverty in Chhattisgarh

Types of Links	No. of Districts			
	Index: High to Very high	Index: Medium	Index: Low to Very low	Total
Irrigation - Agriculture	3	0	8	11
Agriculture – Living	1	3	6	10
Irrigation – Living	1	2	5	8
Living - Poverty	2	1	6	9
Irrigation - Poverty	3	1	4	8
Irrigation – Agriculture – Living	1	1	4	6
Irrigation – Agriculture – Poverty	1	0	5	6
Agriculture - Poverty	2	0	4	6
Irrigation – Living - Poverty	1	1	4	6
Agriculture – Living – Poverty	1	1	3	5
Irrigation –Agriculture –Living -Poverty	1	0	3	4

Table 16. Correlation matrix of different indicators in districts of Chhattisgarh

	GWDI	ICI	CII	ADI	LLI	PRI
GWDI	1.000					
ICI	0.598*	1.000				
CII	0.855**	0.927**	1.000			
ADI	0.753**	0.906**	0.939**	1.000		
LLI	0.591*	0.698**	0.728**	0.764**	1.000	
PRI	0.420	0.321	0.405	0.306	0.498*	1.000

** significant at 0.01 level and * significant at 0.05 level



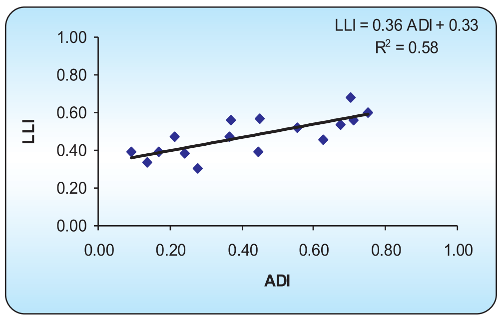
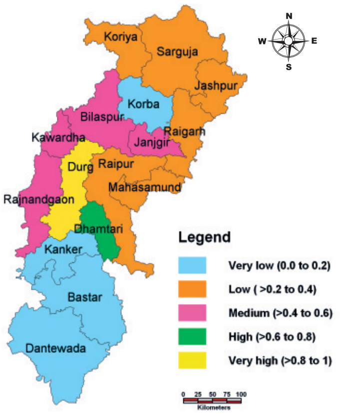
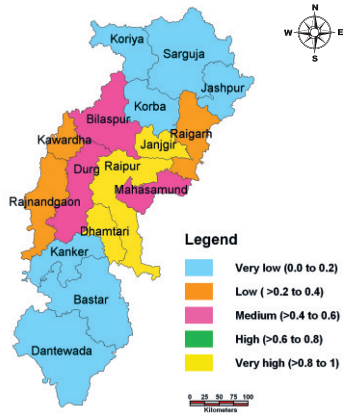


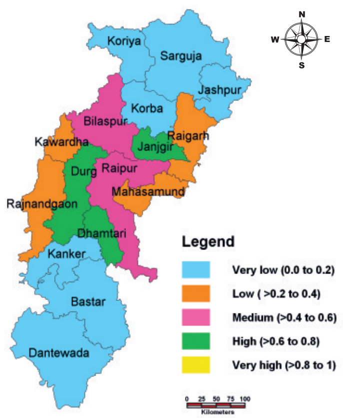
Fig. 5 Regression between ADI and CII; LLI and ADI



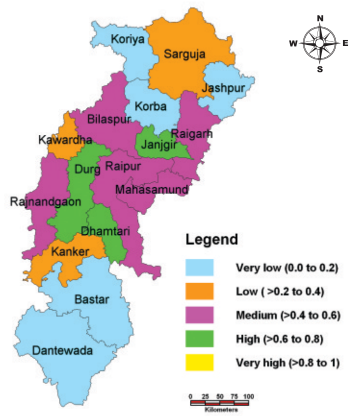
Groundwater Development Index



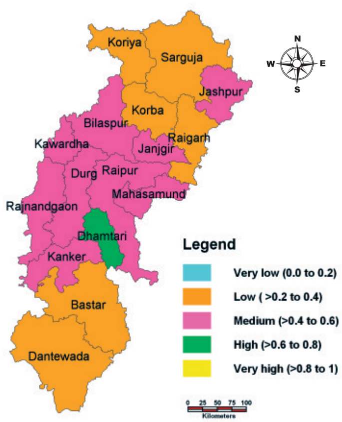
Irrigation Coverage Index



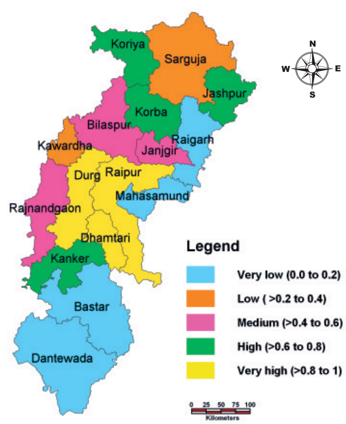
Composite Irrigation Index



Agricultural Development Index



Level of Living Index



Poverty Ration Index

Fig. 6 District maps of different indices in Chattisgarh

3.4 Analyses for districts of Jharkhand

In Jharkhand, groundwater development index (GWDI) value was lowest in West Singhbhum district (ground water development 15%) and highest in Sahebganj and Pakur districts (about 30%) with state average ground water development of 20%. Irrigation coverage was found highest in Chatra district (30%) and lowest in East Singbhum district (1%). Only 12% of the cultivated area was found irrigated in the state. Composite irrigation index (CII), derived on the basis of GWDI and irrigation coverage index (ICI), ranged from 0.11 (Gumla dist.) to 0.67 (Deoghar dist.) Sahibganj and Pakur were other two districts having high CII values (>0.6).

Agricultural development index (ADI) value was found highest (0.61) for Deoghar and lowest (0.23) for Dhanbad district. ADI values of eight districts showed medium (>0.4-0.6) while that of nine districts showed low (>0.2-0.4) level as evident from Tables 17, 18 and 19.

Table 17. Different indexes in the districts of Jharkhand

District	GWDI	ICI	CII	ADI	LLI	PRI
1. Dumka	0.11	0.40	0.25	0.57	0.46	0.14
2. Godda	0.41	0.39	0.40	0.50	0.31	0.14
3. Deogarh	0.65	0.70	0.67	0.60	0.56	1.00
4. Sahebganj	1.00	0.32	0.66	0.50	0.43	0.14
5. Pakur	0.95	0.28	0.62	0.47	0.49	0.52
6. Harizaribag	0.14	0.41	0.27	0.42	0.51	0.99
7. Koderma	0.10	0.52	0.31	0.37	0.50	0.99
8. Chatra	0.07	1.00	0.54	0.31	0.41	0.99
9. Giridh	0.11	0.46	0.28	0.39	0.34	0.35
10. Bokaro	0.06	0.97	0.52	0.32	0.42	0.35
11. Dhanbad	0.17	0.12	0.15	0.23	0.45	0.35
12. Ranchi	0.16	0.25	0.20	0.61	0.58	0.96
13. Lohardaga	0.56	0.37	0.46	0.44	0.47	0.35
14. Gumla	0.12	0.10	0.11	0.32	0.48	0.49
15. E.Singhbhum	0.54	0.00	0.27	0.38	0.47	0.35
16. W. Singhbhum	0.00	0.40	0.20	0.40	0.36	0.49
17. Palamu	0.10	0.96	0.53	0.36	0.29	0.00
18. Garhwa	0.20	0.94	0.57	0.32	0.29	0.14
Min. Value	*0.000*	*0.000*	*0.110*	*0.226*	*0.288*	*0.000*
Max. Value	*1.000*	*1.000*	*0.672*	*0.606*	*0.576*	*1.000*
Mean	*0.308*	*0.449*	*0.379*	*0.423*	*0.444*	*0.507*
Standard deviation	*0.318*	*0.300*	*0.183*	*0.106*	*0.081*	*0.345*

Table 18. Classification of districts of Jharkhand under each index

Categories	Frequency of the districts					
	GWDI	ICI	CII	ADI	LLI	PRI
Very low (0.0-0.20)	12	3	3	0	0	5
Low (>0.2-0.4)	0	7	7	9	5	5
Medium (>0.4-0.6)	3	3	5	8	13	3
High (>0.6-0.8)	1	1	3	1	0	0
Very high (>0.8-1.0)	2	4	0	0	0	5

Table 19. Categorisation of districts of Jharkhand on the basis of index values

Categories	GWDI	ICI	CII	ADI	LLI	PRI
Very high (>0.8-1.0)	Sahebganj Pakur	Chatra Bokaro Palamu Garhwa				Deogarh Harizaribag Koderma Chatra Ranchi
High (>0.6-0.8)	Deogarh	Deogarh	Deogarh Sahebganj Pakur	Deogarh		
Medium (>0.4-0.6)	Godda Lohardaga E.Singhbhum	Harizaribag Koderma Giridhi	Chatra Bokaro Lohardaga Palamu Garhwa	Dumka Godda Sahebganj Pakur Harizaribag Ranchi Lohardaga W Singhbhum	Dumka Deogarh Sahebganj Pakur Harizaribag Koderma Chatra Bokaro Dhanbad Ranchi Lohardaga Gumla E.Singhbhum	Pakur Gumla W Singhbhum
Low (>0.2-0.4)		Dumka Godda Sahebganj Pakur Ranchi Lohardaga W Singhbhum	Dumka Godda Harizaribag Koderma Giridh E Singhbhum Ranchi	Koderma Chatra Giridh Bokaro Dhanbad Gumla E.Singhbhum Palamu Garhwa	Godda Giridh W Singhbhum Palamu Garhwa	Giridh Bokaro Dhanbad Lohardaga E.Singhbhum
Very low (0.0-0.20)	Dumka Harizaribag Koderma Chatra Giridh Bokaro Dhanbad Ranchi Gumla W Singhbhum Palamu Garhwa	Dhanbad Gumla E.Singhbhum	Dhanbad Gumla W.Singbhum			Dumka Godda Sahebganj Palamu Garhwa

Poverty was lowest (31%) in Deoghar and highest (59%) in Palamu district in Jharkhand. PRI values of five districts were in high range (higher the value of index lower is the poverty), while 10 districts showed the very high to high poverty level with PRI values in the range of 0.0 to 0.4. Poverty was highest in Palamu district (59 % families are BPL); however, it was lowest in Deoghar district where 31% families were BPL Level of living of 13 and 5 districts was found as medium (LLI >0.4-0.6) and low (LLI >0.2-0.4), respectively. Deoghar district had highest LLI value (0.58) while both Palamu and Garhwa districts were having lowest LLI value (0.29).

Links between irrigation, agriculture, living and poverty was studied through a linkage matrix (Table 20) and extent of association was determined through a correlation matrix (Table 21). In case of districts of Jharkhand, correlation matrix revealed that ADI was significantly related with GWDI, while LLI was significantly related with ICI, and ADI. Correlation coefficient value between PRI and LLI was highly significant.

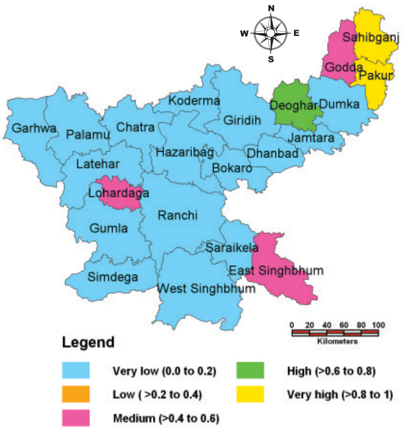
Table 20. Linkage matrix showing frequency of districts under various combinations of links between Irrigation, Agriculture, Living and Poverty in Jharkhand

Types of Links	No. of Districts			
	Index: High to Very high	Index: Medium	Index: Low to Very low	Total
Irrigation - Agriculture	1	1	5	7
Agriculture – Living	1	5	3	9
Irrigation – Living	0	2	3	5
Living - Poverty	0	1	1	2
Irrigation - Poverty	0	0	5	5
Irrigation – Agriculture – Living	1	2	6	9
Irrigation – Agriculture – Poverty	0	2	4	6
Agriculture - Poverty	0	0	3	3
Irrigation – Living - Poverty	0	0	2	2
Agriculture – Living – Poverty	0	1	3	4
Irrigation –Agriculture –Living -Poverty	0	0	1	1

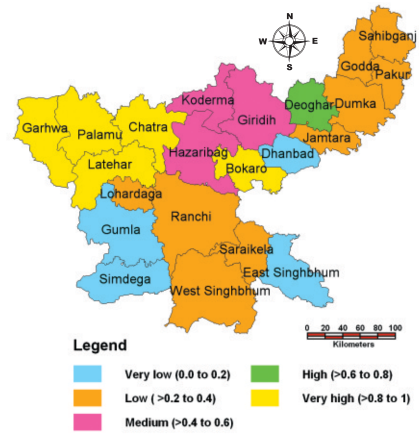
Table 21. Correlation matrix of different indicators in Jharkhand

	GWDI	ICI	CII	ADI	LLI	PRI
GWDI	1.000					
ICI	0.309	1.000				
CII	0.582*	0.593**	1.000			
ADI	0.416*	0.185	0.195	1.000		
LLI	0.258	0.440*	0.158	0.415*	1.000	
PRI	0.125	0.014	0.094	0.165	0.690**	1.000

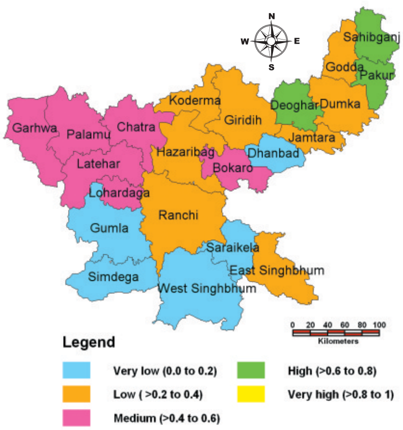
** significant at 0.01 level and * significant at 0.05 level



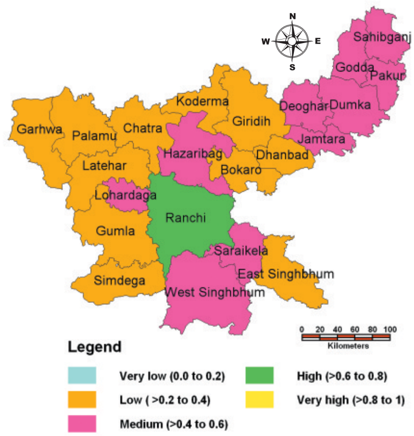
Groundwater Development Index



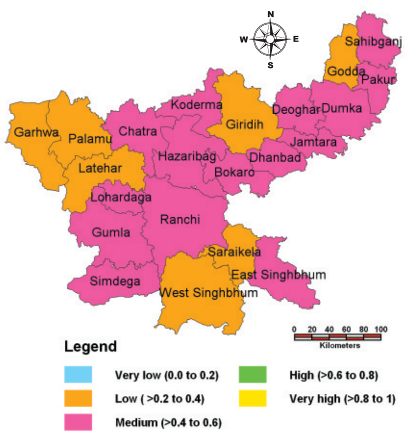
Irrigation Coverage Index



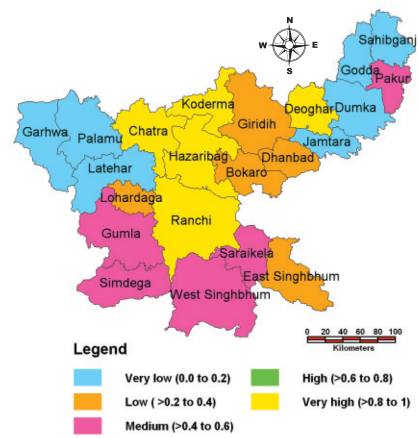
Composite Irrigation Index



Agricultural Development Index



Level of Living Index



Poverty Ration Index

Fig. 7 District maps of different indices in Jharkhand

3.5 Analyses for districts of Bihar

Groundwater development ranged from 22% (Banka dist.) to 61% (Begusarai dist) with state average of 42% in Bihar. Gross irrigated area (305 Th. ha) out of gross cultivated area was highest (84%) in Rohtas dist. resulting highest ICI value; while it was lowest in Kishanganj dist. (25%). CII values were found highest in Jehanabad district while another eight districts showed high CII values. CII values of seven and four districts were low and very low, respectively (Tables 22, 23 and 24).

Table 22. Different indexes in the districts of Bihar

District	GWDI	ICI	CII	ADI	LLI	PRI
1. Arraria	0.20	0.19	0.19	0.42	0.31	0.44
2. Aurangabad	0.17	0.48	0.33	0.45	0.48	0.72
3. Banka	0.00	0.80	0.40	0.38	0.43	0.57
4. Begusarai	1.00	0.42	0.71	0.49	0.37	0.61
5. Bhabua	0.17	0.84	0.51	0.44	0.48	0.66
6. Bhagalpur	0.31	0.29	0.30	0.40	0.39	0.63
7. Bhojpur	0.38	0.69	0.54	0.51	0.43	0.57
8. Buxar	0.38	0.68	0.53	0.51	0.45	0.55
9. Darbhanga	0.41	0.41	0.41	0.40	0.35	0.81
10. E. Champaran		0.43	0.43	0.43	0.38	0.82
11. Gaya	0.45	0.35	0.40	0.29	0.39	0.49
12. Gopalganj	0.50	0.37	0.43	0.52	0.48	0.92
13. Jamui	0.08	0.12	0.10	0.14	0.41	0.00
14. Jehanabad	0.86	0.78	0.82	0.45	0.44	0.75
15. Katihar	0.63	0.37	0.50	0.50	0.35	0.81
16. Khagaria	0.59	0.60	0.59	0.46	0.42	0.65
17. Kishanganj	0.08	0.00	0.04	0.36	0.32	1.00
18. Lakhisarai	0.42	0.69	0.56	0.32	0.43	0.33
19. Madhepura	0.71	0.64	0.68	0.57	0.53	0.79
20. Madhubani	0.28	0.32	0.30	0.35	0.36	0.72
21. Munger	0.30	0.56	0.43	0.33	0.44	0.70
22. Muzaffarpur	0.90	0.23	0.57	0.47	0.36	0.70
23. Nalanda	0.43	0.94	0.69	0.52	0.50	0.48
24. Nawadah	0.66	0.56	0.61	0.30	0.44	0.64
25. Patna	0.96	0.64	0.80	0.49	0.53	0.83
26. Purnia	0.19	0.46	0.32	0.51	0.34	0.72
27. Rohtas	0.32	1.00	0.66	0.76	0.65	0.75
28. Saharsa	0.53	0.41	0.47	0.52	0.45	0.61
29. Samastipur	0.85	0.33	0.59	0.45	0.35	0.59
30. Saran	0.51	0.44	0.48	0.46	0.45	0.75
31. Seikhpura	0.76	0.18	0.47	0.39	0.42	0.67
32. Shivhar		0.15	0.15	0.35	0.28	0.77
33. Sitamarhi	0.87	0.08	0.48	0.34	0.28	0.38
34. Siwan	0.82	0.36	0.59	0.50	0.48	0.94
35. Supal	0.92	0.65	0.78	0.47	0.47	0.50
36. Vaishali	0.91	0.35	0.63	0.46	0.38	0.91
37. W. Champaran	0.12	0.43	0.27	0.45	0.34	0.37

Min. Value	*0.000*	*0.000*	*0.039*	*0.138*	*0.280*	*0.000*
Max. Value	*1.000*	*1.000*	*0.819*	*0.761*	*0.652*	*1.000*
Mean	*0.505*	*0.465*	*0.480*	*0.436*	*0.415*	*0.652*
Standard deviation	*0.297*	*0.239*	*0.188*	*0.102*	*0.077*	*0.195*

Table 23. Classification of districts of Bihar under each index

Categories	Frequency of the districts					
	GWDI*	ICI	CII	ADI	LLI	PRI
Very low (0.0-0.20)	8	6	4	1	0	1
Low (>0.2-0.4)	6	9	7	12	16	3
Medium (>0.4-0.6)	8	11	17	23	20	8
High (>0.6-0.8)	4	8	8	1	1	17
Very high (>0.8-1.0)	9	3	1	0	0	8

* Shivhar and East Champaran districts are not included

Table 24. Categorisation of districts in Bihar on the basis of index values

Categories	GWDI	ICI	CII	ADI	LLI	PRI
Very high (>0.8-1.0)	Begusarai	Bhabua	Jehanabad			Darbhanga
	Jehanabad	Nalanda				E.Champaran
	Muzaffarpur	Rohtas				Gopalganj
	Patna					Katihar
	Samastipur					Kishanganj
	Sitamarhi					Patna
	Siwan					Siwan
	Supal					Vaishali
	Vaishali					
High (>0.6-0.8)	Katihar	Banka	Begusarai	Rohtas	Rohtas	Aurangabad
	Madhepura	Bhojpur	Madhepura			Begusarai
	Nawadah	Buxar	Nalanda			Bhabua
	Seikhpura	Jehanabad	Nawadah			Bhagalpur
		Lakhisarai	Patna			Jehanabad
		Madhepura	Rohtas			Khagaria
		Patna	Supal			Madhepura
			Vaishali			Madhubani
						Munger
						Muzaffarpur
						Nawadah
						Purnia
						Rohtas
						Saharsa
						Saran
						Seikhpura
						Shivhar
Medium (>0.4-0.6)	Darbhanga	Aurangabad	Bhabua	Arraria	Aurangabad	Arraria
	Gaya	Begusarai	Bhojpur	Aurangabad	Banka	Banka
	Gopalganj	Darbhanga	Buxar	Begusarai	Bhabua	Bhojpur
	Khagaria	E.Champaran	Darbhanga	Bhabua	Bhojpur	Buxar

	Lakhisarai Nalanda Saharsa Saran	Khagaria Munger Nawadah Purnia Saharsa Saran WChamparan	E.Champaran Gopalganj Katihar Khagaria Lakhisarai Munger Muzaffarpur Saharsa Samastipur Saran Seikhpura Sitamarhi Siwan	Bhojpur Buxar E.Champaran Gopalganj Jehanabad Katihar Khagaria Madhepura Madhubani Muzaffarpur Nalanda Patna Purnia Saharsa Samastipur Saran Siwan Supal Vaishali WChamparan	Buxar Gopalganj Jamui Jehanabad Khagaria Lakhisarai Madhepura Munger Nalanda Nawadah Patna Saharsa Saran Seikhpura Siwan Supal	Gaya Nalanda Samastipur Supal
Low (>0.2-0.4)	Bhagalpur Bhojpur Buxar Madhubani Munger Rohtas	Bhagalpur Gaya Gopalganj Katihar Madhubani Muzafarpur Samastipur Siwan Vaishali	Aurangabad Banka Bhagalpur Gaya Madhubani Purnia W. Champaran	Banka Bhagalpur Darbhanga Gaya Kishanganj Lakhisarai Madhubani Munger Nawadah Seikhpura Shivhar Sitamarhi	Arraria Begusarai Bhagalpur Darbhanga E.Champaran Gaya Katihar Kishanganj Madhubani Muzaffarpur Purnia Samastipur Shivhar Sitamarhi Vaishali W Champaran	Lakhisarai Sitamarhi W Champaran
Very low (0.0-0.20)	Arraria Aurangabad Banka Bhabua Jamui Kishanganj Purnia W. Champaran	Arraria Jamui Kishanganj Seikhpura Shivhar Sitamarhi	Arraria Jamui Kishanganj Shivhar	Jamui		Jamui

ADI value of only Rohtas districts was found high (0.76); however, 23 districts showed medium ADI values. Agriculture development was lowest in Jamui district (ADI 0.14), while it was in the low range for another 12 districts. The cropping intensity ranged from 177% (Saharsa dist.) to 105% (Banka dist.). Level of living of only Rohtas district in Bihar was found high with LLI value 0.65 and that of

Shivhar district was lowest with LLI value 0.28; there were another 15 districts whose LLI values fall in low category (>0.2-0.4). Rest of the 20 districts' level of living assessed to be medium. BPL families were highest in Jamui dist (83%) and lowest in Kishanganj dist. (26%). Lakhisarai, Sitamahi and West Champaran were other three districts having relatively higher poverty (>60%). Seventeen and eight districts of Bihar showed PRI values >0.6-0.8 and >0.8, respectively (Tables 22, 23 and 24).

Links between irrigation, agriculture, living and poverty was studied through a linkage matrix (Table 25). Correlation values of different indices of districts of Bihar (Table 26) indicated significant association of ADI with ICI and CII. LLI also showed significance with ICI, CII and ADI. However, PRI indicated significant coefficient value only with ADI.

Table 25. Linkage matrix showing frequency of districts under various combinations of links between Irrigation, Agriculture, Living and Poverty in Bihar

Types of Links	No. of Districts			
	Index: High to Very high	Index: Medium	Index: Low to Very low	Total
Irrigation - Agriculture	1	12	7	20
Agriculture – Living	1	13	6	20
Irrigation – Living	1	8	7	16
Living - Poverty	1	8	4	13
Irrigation - Poverty	6	3	2	11
Irrigation – Agriculture – Living	1	6	2	9
Irrigation – Agriculture – Poverty	1	4	1	6
Agriculture - Poverty	1	3	1	5
Irrigation – Living - Poverty	1	2	1	4
Agriculture – Living – Poverty	1	4	0	5
Irrigation – Agriculture – Living - Poverty	1	2	0	3

Table 26. Correlation matrix of different indicators in districts of Bihar

	GWDI	ICI	CII	ADI	LLI	PRI
GWDI	1.000					
ICI	-0.059	1.000				
CII	0.763**	0.626**	1.000			
ADI	0.215	0.512**	0.509**	1.000		
LLI	0.050	0.740**	0.555**	0.526**	1.000	
PRI	0.242	-0.005	0.158	0.453**	0.134	1.000

** significant at 0.01 level and * significant at 0.05 level

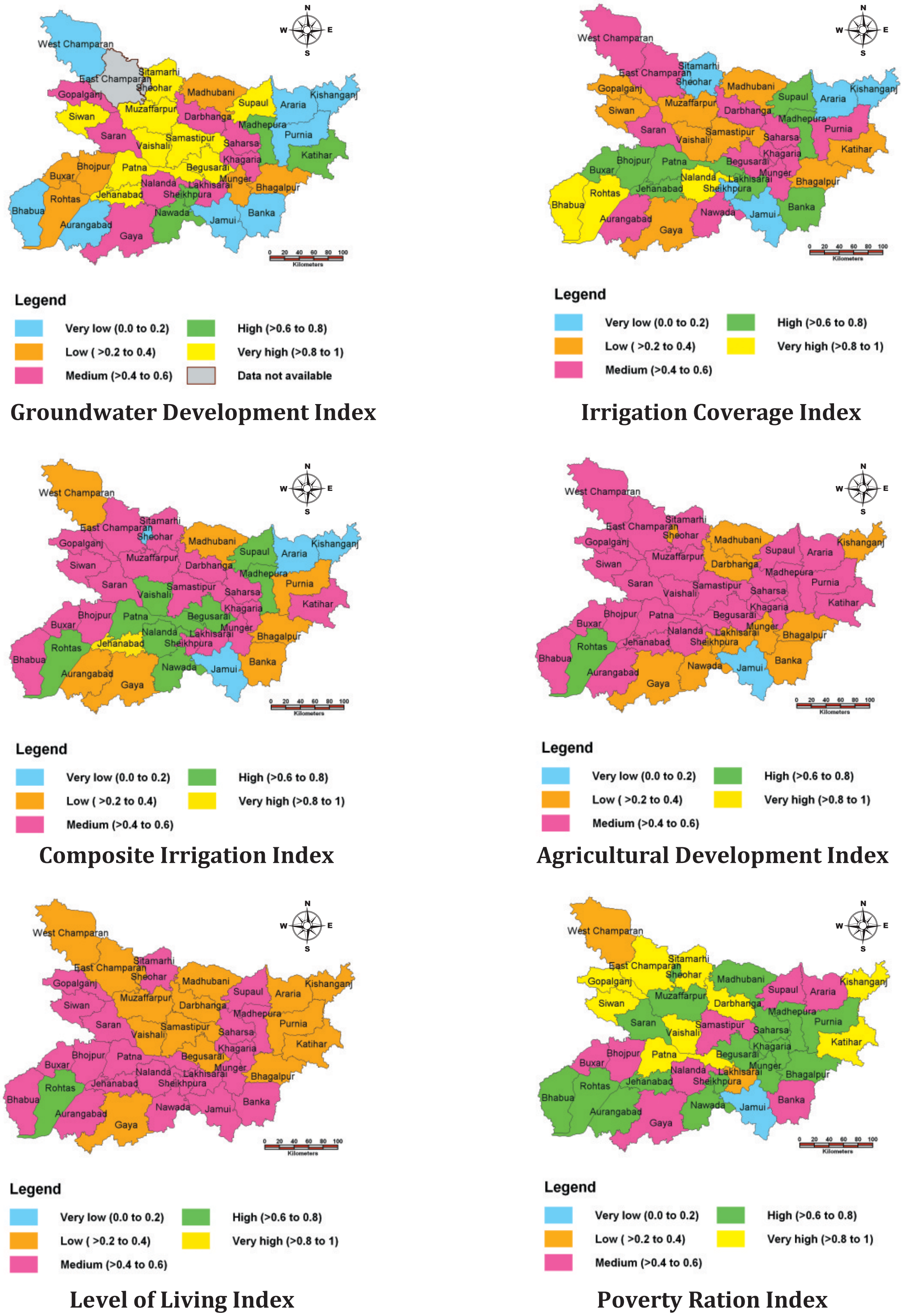


Fig. 8 District maps of different indices in Bihar

3.6 Comparative scenario considering all districts of selected five states

After the analyses were done for the inter-district comparison within a single state, comparative analyses of different indices in case of 119 districts of five eastern India states viz. Orissa, West Bengal, Chhattisgarh, Jharkhand and Bihar were carried out which revealed the comparative scenario of irrigation, agriculture, level of living and poverty on different indices. As large numbers of districts were being compared together, the range of each index was widened, which ranged from 0 to 100. It was worth mentioning here that the comparison of 119 districts together on respective index was done after calculating the index value which has taken into consideration following criteria:

> Index value for the positive variable (like cropping intensity, agril. productivity, etc) was calculated as
> [(Actual value – Minimum value) / (Maximum value – Minimum value)]*100
>
> While index value of the negative variable (like SC/ST population, poverty ratio, etc) was calculated as
> [(Maximum value – Actual value) / (Maximum value – Minimum value)]*100

On the basis of the index value of each selected indicator composite indices (CII, ADI and LLI) were developed giving equal weightage to respective variables/parameters of the index.

Unlike earlier analyses of the districts within a single state, where minimum and maximum value of the districts of the same state was considered, here during the comparative analyses of 119 districts together, minimum and maximum values of 119 districts were considered while respective index was calculated.

Accordingly, district wise values of different indices were calculated. Each index ranged from 0 to 100. The districts were classified under each index into five categories depending on respective index value *viz.* very low (0 to 20), low (>20 to 40), medium (>40 to 60), high (>60 to 80) and very high (>80 to 100) and presented in Table 27.

Groundwater development ranged 65% in Durg district of Chhattisgarh to 1% in Jalpaiguri and Darjeeling districts of West Bengal. The GWDI values revealed 26 out of 119 districts were having high to very high GWDI values (>60) among which 18 districts were from Bihar, 4 districts from West Bengal and 2 districts each from Chhattisgarh and Orissa. Percentage of gross irrigated area out of gross cultivated area ranged from 91% (West Midnapore in West Bengal) to 1% (East Singbhum in Jharkhand). ICI values of 23 districts found to be high to very high which included 14, 6 and 3 districts of Bihar, West Bengal and Orissa, respectively. CII value was highest in case of Jehanabad district of Bihar while it was lowest in

Dantewada district of Chhattisgarh. Out of 26 districts falling under high to very high category of CII value, 19 districts represented from Bihar along with 4 and 2 districts of West Bengal and Orissa, respectively and Durg district of Chhattisgarh.

Table 27. Comparative scenario of irrigation, agriculture, level of living and poverty in districts of five eastern India states categorized on the basis of index values

Index	State	Frequency of the districts under different categories				
		Very low (0-20)	Low (>20-40)	Medium (>40-60)	High (>60-80)	Very highg (>80-100)
GWDI	Orissa	11	15	2	2	0
	West Bengal	6	3	5	1	3
	Chhattisgarh	4	6	4	1	1
	Jharkhand	0	16	2	0	0
	Bihar*	0	3	14	9	9
ICI	Orissa	5	16	6	3	0
	West Bengal	2	8	2	2	4
	Chhattisgarh	10	3	3	0	0
	Jharkhand	13	5	0	0	0
	Bihar	0	6	17	11	3
CII	Orissa	4	20	4	2	0
	West Bengal	3	5	6	4	0
	Chhattisgarh	7	5	3	1	0
	Jharkhand	8	10	0	0	0
	Bihar	1	3	14	18	1
ADI	Orissa	0	15	15	0	0
	West Bengal	0	1	9	7	1
	Chhattisgarh	2	9	4	1	0
	Jharkhand	13	5	0	0	0
	Bihar	0	10	27	0	0
LLI	Orissa	0	9	21	0	0
	West Bengal	0	2	15	1	0
	Chhattisgarh	0	0	16	0	0
	Jharkhand	0	17	1	0	0
	Bihar	0	31	6	0	0
PRI	Orissa	6	4	6	8	6
	West Bengal	0	0	2	13	3
	Chhattisgarh	0	0	5	9	2
	Jharkhand	0	0	10	7	1
	Bihar	1	3	12	17	4

* Shivhar and East Champaran districts are not included

Table 28. Categorisation of districts of five eastern India states based on mean and standard deviation value

Index	Category*	Frequency of the districts of selected states under different categories					
		Orissa	West Bengal	Chhattisgarh	Jharkhand	Bihar	Total
GWDI (Mean 41.23 SD 24.39)	Low (<16.84)	8	4	3	0	0	15
	Medium (16.84-65.62)	20	10	12	18	21	81
	High (>65.62)	2	4	1	0	14	21
	Total	30	18	16	18	35	117
ICI (Mean 38.97 SD 24.00)	Low (<14.97)	2	2	7	12	0	23
	Medium (14.97-62.96)	26	10	9	6	23	74
	High (>62.96)	2	6	0	0	14	22
	Total	30	18	16	18	37	119
CII (Mean 39.75 SD 20.20)	Low (<19.55)	3	2	7	7	1	20
	Medium (19.55-59.95)	25	12	8	11	17	73
	High (>59.95)	2	4	1	0	19	26
	Total	30	18	16	18	37	119
ADI (Mean 39.39 SD 14.43)	Low (<24.96)	1	0	3	17	1	22
	Medium (24.96-59.82)	28	8	11	1	35	83
	High (>59.82)	1	10	2	0	1	14
	Total	30	18	16	18	37	119
LLI (Mean 41.06 SD 8.28)	Low (<32.78)	3	0	0	9	8	20
	Medium (32.78-49.34)	22	9	6	9	28	74
	High (>49.34)	5	9	10	0	1	25
	Total	30	18	16	18	37	119
PRI (Mean 60.88 SD 19.24)	Low (<41.64)	10	0	0	1	4	15
	Medium (41.64-80.12)	14	15	14	16	29	88
	High (>80.12)	6	3	2	1	4	16
	Total	30	18	16	18	37	119

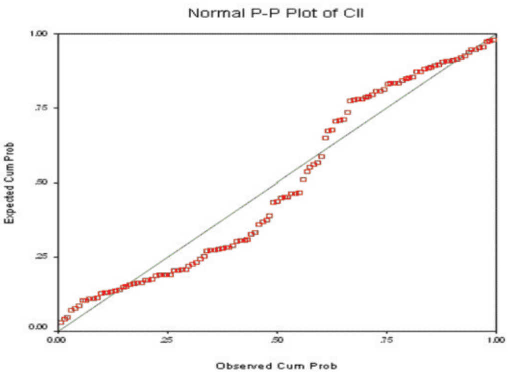
* Low: < (Mean - SD), Medium: (Mean - SD) to (Mean + SD), High: > (Mean+ SD); SD stands for Standard Deviation

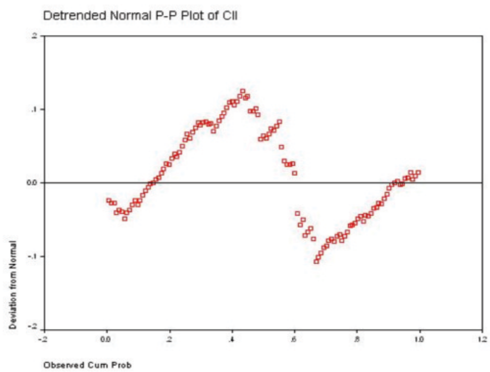
Overall agriculture development representing by ADI values revealed out of 9 districts showing higher values (>60), 8 were from West Bengal along with Durg district of Chhattisgarh. Total of 55 districts showed medium range ADI values (>40-60), while rest 55 showed low to very low category. 15 districts of Orissa were found to be each in medium and low category. It was observed that 11, 18 and 10 districts of Chhattisgarh, Jharkhand and Bihar, respectively fall under low to very low category; however, only one district (Darjeeling) of West Bengal fall in this category. Majority of districts (27 districts) of Bihar categorised under medium range of ADI; however, all 18 districts of Jharkhand fall in low to very low range of ADI values (Table 27).

Poverty varied widely showing as high as 88% (in Nuapada district of Orissa) to 17% (Ganjam district of Orissa) BPL families. PRI values of 14 districts indicated extreme poverty condition which included 10 and 4 districts of Orissa and Bihar, respectively. Out of all 119 districts, 70 districts showed relatively less poverty in comparison to other districts. Level of living of only Howrah district of West Bengal was found as high (LLI of 62) while 59 districts fall each under medium and low category. It was observed that 31, 17, 9 and 2 districts of Bihar, Jharkhand, Orissa and West Bengal, respectively showed low LLI values while 21, 16, 15, 6 and 1 districts of Orissa, Chhattisgarh, West Bengal, Bihar and Jharkhand, respectively categorised under medium category (Table 27).

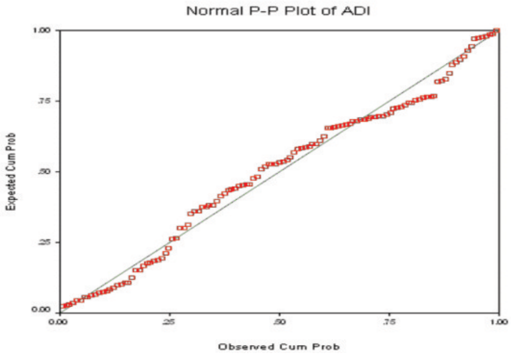
To draw relationships between irrigation resources, agricultural development, level of living and poverty, at the first step normality of CII, ADI and LLI tested using SPSS 10.0 for Windows program. Expected normal quantiles calculated using Blom's proportional estimation formula and assigning the mean to ties.

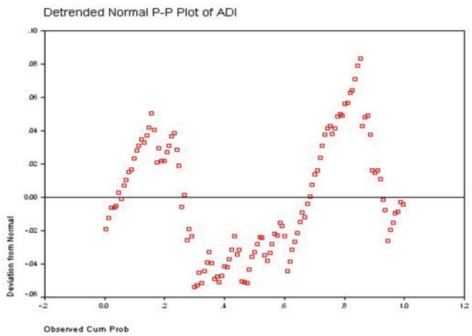
In the model for variable CII, normal distribution parameters estimated: location=39.75 scale=20.20



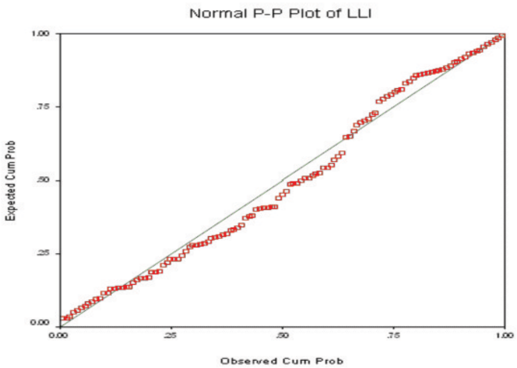


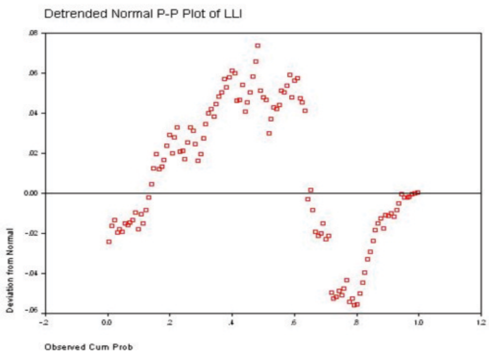
In the model for variable ADI, normal distribution parameters estimated: location=39.39 scale=14.43.





In the model for variable LLI, normal distribution parameters estimated: location=41.06 scale=8.28.





As the indices values were found to be normally distributed, correlation and regression analyses were carried out with those values. Correlation values of different indices of all 119 districts together showed significant association of ADI with GWDI, ICI and CII at 1% level of significance. LLI had significant association with ADI and PRI (r =0.45). PRI showed significant correlation with GWDI, CII and ADI and LLI (Table 29).

Table 29. Correlation matrix of different indices in districts of five eastern India states

	GWDI	ICI	CII	ADI	LLI	PRI
GWDI	1.000					
ICI	0.391**	1.000				
CII	0.836**	0.823**	1.000			
ADI	0.359**	0.644**	0.594**	1.000		
LLI	-0.030	0.190	0.117	0.450**	1.000	
PRI	0.227*	0.144	0.211*	0.262*	0.451**	1.000

** significant at 0.01 level and * significant at 0.05 level

The correlation analyses showed significant association between the indices as well as between the indicators of irrigation, agriculture and poverty scenario of

119 districts, respectively at 1% and 5% level of significance (Table 30). Multiple regressions (stepwise) were run using SPSS 10.0 statistical analyses software. Three models were generated through stepwise elimination of insignificant variables; however, the value of R^2 was not changed; thus the last model was considered suitable and accepted. Accordingly the equation showing relationship between living (L) as dependent variable and indicators of irrigation, agriculture and poverty scenario as independent variables / predictors is given below:

$$L = 43.43 + 0.277\ CL + 0.346\ NSA + 0.173\ CI + 0.377\ RY + 0.195\ FG + 0.126\ FC - 0.373\ BPL$$

The analyses revealed that 60% ($R^2 > 0.60$) variation in living was predicted by the indicators of irrigation, agriculture and poverty in districts of five eastern Indian states (Table 31).

Table 30. Correlation matrix of different indicators of irrigation and agriculture scenario in districts of five eastern India states

	GWD	GIA	CL	NSA	CI	RY	FG	FC	BPL
GWD	1								
GIA	0.394**	1							
CL	0.568**	0.493**	1						
NSA	0.243**	0.423**	0.206*	1					
CI	0.231*	0.226*	0.192*	0.432**	1				
RY	0.223**	0.112	0.026	0.190*	0.514**	1			
FG	0.094	0.329**	0.270**	0.364**	0.379**	0.704**	1		
FC	0.402**	0.504**	0.557**	0.139	0.150	0.023	0.171	1	
BPL	-0.227**	-0.155	-0.240**	-0.100	-0.189*	-0.231*	-0.263**	-0. 162	1

GWD: groundwater development, GIA: gross irrigated area; CL: cultivable land; NSA: Net sown area; CI: cropping intensity, RY: rice yield; FG: food grain; FC: fertilizer consumption, BPL: below poverty line population

Table 31. Multiple regressions between level of living and indicators of irrigation, agriculture and poverty in districts of five eastern Indian states

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.777[a]	.603	.570	5.4164
2	.777[b]	.603	.574	5.3912
3	.777[c]	.603	.577	5.3672

a. Predictors: (Constant), BPL, NSA, FERTI, RICEYIEL, GWDEV, GIA, CI, CL, FOODGRAI

b. Predictors: (Constant), BPL, NSA, FERTI, RICEYIEL, GIA, CI, CL, FOODGRAI

c. Predictors: (Constant), BPL, NSA, FERTI, RICEYIEL, CI, CL, FOODGRAI

ANOVA [d]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4727.307	9	525.256	17.904	.000[a]
	Residual	3109.717	106	29.337		
	Total	7837.024	115			
2	Regression	4727.111	8	590.889	20.330	.000[b]
	Residual	3109.913	107	29.065		
	Total	7837.024	115			
3	Regression	4725.901	7	675.129	23.437	.000[c]
	Residual	3111.123	108	28.807		
	Total	7837.024	115			

a. Predictors: (Constant), BPL, NSA, FERTI, RICEYIEL, GWDEV, GIA, CI, CL, FOODGRAI

b. Predictors: (Constant), BPL, NSA, FERTI, RICEYIEL, GIA, CI, CL, FOODGRAI

c. Predictors: (Constant), BPL, NSA, FERTI, RICEYIEL, CI, CL, FOODGRAI

d. Dependent Variable: LLI

Coefficients [a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	43.566	4.021		10.835	.000
	GWDEV	3.63E-03	.044	.007	.082	.935
	GIA	6.436E-03	.031	.017	.210	.834
	CL	.131	.041	.278	3.213	.002
	NSA	.154	.035	.342	4.366	.000
	CI	4.65E-02	.023	.172	2.016	.046
	RICEYIEL	4.576E-03	.001	.374	3.331	.001
	FOODGRAI	4.777E-03	.002	.194	1.930	.056
	FERTI	1.509E-02	.010	.121	1.542	.126
	BPL	-.222	.039	-.374	-5.634	.000
2	(Constant)	43.536	3.985		10.925	.000
	GIA	6.191E-03	.030	.016	.204	.839
	CL	.132	.038	.281	3.524	.001
	NSA	.154	.035	.341	4.393	.000
	CI	4.68E-02	.023	.173	2.065	.041
	RICEYIEL	4.619E-03	.001	.378	3.662	.000
	FOODGRAI	4.746E-03	.002	.192	1.950	.054
	FERTI	1.506E-02	.010	.121	1.547	.125
	BPL	-.222	.038	-.373	-5.757	.000
3	(Constant)	43.425	3.931		11.048	.000
	CL	.131	.036	.277	3.584	.001
	NSA	.156	.033	.346	4.670	.000
	CI	4.69E-02	.023	.173	2.076	.040
	RICEYIEL	4.612E-03	.001	.377	3.674	.000
	FOODGRAI	4.802E-03	.002	.195	1.994	.049
	FERTI	1.570E-02	.009	.126	1.712	.090
	BPL	-.222	.038	-.373	-5.781	.000

a. Dependent Variable: LLI

3.7 Strategy for effective utilization of water/irrigation resources through adoption of scientific technologies for agricultural development and improved living

Extreme climatic aberrations in the form of natural calamities like cyclone, floods, and droughts affect the agricultural scenario of eastern Indian states. Uneven distribution of rainfall leads to scarcity of irrigation water in *rabi* season and accumulation of excess water in *kharif* season. Flat topography without natural disposing point also contributes to this waterlogging. The presence of salt stress in soil and groundwater along the coastal zone also limits the crop productivity. Similarly, the small size of land holdings with absentee landlordism becomes a strong challenge. In addition, poor infrastructural facilities for agro-marketing, processing and cold storage, absence of cooperative collective farming and low mechanization lead to poor agricultural productivity of this zone. The major source of irrigation is through canals and tanks. During *kharif*, rice is the predominant crop of this zone followed by sugarcane, cotton and tobacco. In dry season the pulses (black gram and green gram), winter paddy and vegetables occupy the major area. Due to absence of irrigation water during *rabi,* sizeable area remains fallow.

It is evident from the above analyses of irrigation, agriculture, poverty and level of living of the districts of eastern Indian states that the zone is not uniform. The districts are heterogeneous with respect to resource endowment and their exploitation. The irrigation, agricultural and socio-economic scenarios also vary considerably across the eastern region. Thus, it is not possible to give similar strategy or technological options treating the whole zone or a particular state as one entity.

In view of it, the districts are divided into three categories viz. high potential - high productivity districts, medium potential - medium productivity and low potential - low productivity districts (Table 28). Based on the respective characteristics of three groups of districts, the technological alternatives have been identified.

The future productivity and living options are dependent upon technological alternatives, which can bring substantial changes without endangering the natural resource base. With this in view the technological options have been identified for each of the afore-said three categories of districts.

High potential - high productivity districts

This group comprises of the districts, whose irrigation, agriculture and living scenario are found to be better having respective index values more than mean + standard deviation. More than 20 districts are found in this category. This has higher irrigated area, cropping intensity, rice productivity and food grain productivity, etc. However, this might have put a strain on natural resources. Thus any strategy for future planning should take care of sustainability issues of natural resources i.e. land and water. With this in view, the following technological options are screened out for its future application on large scale to improve the overall food availability, production, cropping intensity and quality of life.

- Expansion of available area under high yielding varieties and hybrids of rice and other promising crops:
  The present level of adoption of high yielding varieties of rice is less. This indicates that there is a scope for increasing the area under HYV in majority of districts. The area under HYV is expected to increase which will increase the yield by 1 t/ha. This will facilitate an additional production.
- Increasing the irrigated area through groundwater exploitation and rainwater conservation/harvesting:
  As irrigated agriculture plays a vital role in increasing the overall production, the irrigated area as % of gross sown area can be increased considerably as the groundwater availability is quite good. Rainwater management for replenishing the groundwater will be a prerequisite
- Crop diversification from rice to high value crops:
  With decreasing returns from rice cultivation there is claimer for crop diversification from rice to commercial crops, such as vegetables, sunflower, floriculture and medicinal plants. It is assumed that crop diversification will lead to reduction in rice production which will be an important component in visualizing food scenario. However, crop diversification substituting rice can be done only in areas irrigated by groundwater.
- Enhancing bio-fertilizer application under Integrated Nutrient Management and Integrated Pest Management for commercial crops:
  The non judicious use of chemical fertilizer will not only reduce soil productivity in long run but will also lead to groundwater pollution. Thus for proper management of soil health and to sustain the soil and crop productivity of this region, the integration of bio-fertilizer in overall nutrient management is essential.
- Adoption of Integrated Farming System under favourable agro ecosystem:
  The region is vulnerable to natural calamities like floods, cyclones, drought and sea water inundation. For cushioning the farming community due to reduction in crop production, there is need to reduce the risk by adopting Integrated Farming System. IFS can consist of water loving crops, horticultural crops and aquaculture. In addition to the expected additional produce due to conversion of favorable sites to IFS, it will also aid in higher employment generation.
- Reclamation and management of waterlogged areas:
  The seasonal waterlogging in this region is caused primarily due to water congestion in monsoon due to high rainfall and poor outfall conditions.

These areas can be put under suitable ecosystem under water chestnut, makhana, hogla as well as short duration aquaculture.

- Conversion of marginal lands to horticultural and floriculture enterprises: Horticultural crops like coconut, cashew, banana and papaya as well as floriculture have to be promoted on large scale in marginal and culturable waste lands of this region.

The first three technological options mentioned above will directly contribute towards enhancing the food grain production and the remaining technologies will help in increasing the production of non food crops, enhancing the net returns and sustaining the agricultural production system.

Medium potential - medium productivity districts

This group comprises of most number of districts, whose irrigation, agriculture and living scenario are found to be at medium level having respective index values between mean – standard deviation to mean + standard deviation. More than 75 districts are found in this category. In view of its resource base and constraints following technologies have been suggested for increasing food production sustainable natural resource management and income generation by alternate use of land resources.

- Rainwater harvesting and management:
  If the excess runoff water is captured through various *in-situ* or *ex-situ* techniques, good amount of water can be obtained for irrigation during dry periods. It is assumed that uplands and medium will be treated by enhanced dyke height. The rainwater management activities will contribute to enhanced groundwater recharge so that the withdrawal due to intensive groundwater development is replenished. The enhance area can be brought under cultivation by rain water harvesting.
- Increase in irrigated area by groundwater development:
  The groundwater resources are abundant but its utilization is meager. Thus a substantial scope exists to enhance groundwater utilisation in this zone for both *kharif* and *rabi* crop for providing supplemental irrigation. So within the safe limit of gray border line of 65% groundwater development, a rate of 10% increase in net sown area can be made over a period of five years.
- Substitution of traditional rice cultivars by HYV/hybrid rice cultivars:
  Under emerging scenario it is possible to increase the area under rice cultivation (rice being a major crop of this zone) @ 10 % over present net sown area in this zone. Instead of rice if low water requiring diversified cropping system is adopted, then the cropping intensity can be further increased from existing value without any adverse effect on soil health and environment. The climate induced surge in availability of water in Mahanadi and Brahmani is Ist and 2nd highest among twelve major river basins in the country. Under this scenario, rice cultivation in *kharif* as main

crop is inevitable despite its low return potential. In fact, vast tract of rice field act as a very efficient reservoir of huge surface runoff water during *kharif* providing an indirect drainage relief. The dyke height increase technology needs large scale adoption particularly in low lying areas of these two river basins, which will not only improve groundwater recharge but also will help in restoration of soil wealth. The use of suitable high yielding cultivars, long duration-submergence tolerant cultivars etc are to be taken up in phased manner. So emphasis will be to increase yield under long duration submergence tolerant rice cultivars in semi deep areas (50-70 cm) with adoption of suitable cultivars like Panidhan, Durga, CR 1018 etc. and cultivating cultivars like Saraswati, Hanseswari etc in deep water areas (> 1 m). Thus yield improvement of rice from existing about 1 t/ha to 2- 2.5 t/ha will be possible in *kharif.* Again to offset the low *kharif* yield through cultivation of high yielding cultivars during *rabi,* the yield rate of 3.0 t/ha can be easily obtained from irrigated rice in case groundwater is fully exploited by the farmers of this zone leaving coastal zone where there is risk of saline water intrusion due to overdraft of groundwater.

- Integrated farming system:
  Considering vulnerability to climate induced disasters like flood, cyclone etc, dependence on mono crop like rice is risky enterprise in this zone. Excess water situation is going to prevail in part of this zone. Here crop diversification in *kharif* through land modification and development of pond based aquaculture-centric integrated farming system needs further attention. Study at DWM in low lying flood prone areas in Mahanadi basin has suggested benefits of adoption of pond based aquaculture-centric integrated farming system model. On dyke enterprise of horticulture, poultry, duckery add to the income generation and viability to the system.
- Management of waterlogged areas:
  Trapping lens of sweet water floating above saline groundwater through sub-surface water harvesting structure is found viable and can be implemented in waterlogged areas along coastal line. In addition, alternate cropping strategies by growing aquatic crops like swamp taro (a vegetable in marshy land), water chestnut, makhana, lotus offer viable technological options in marshy land and permanently waterlogged areas.

Low potential - low productivity districts

This group comprises of the districts, whose irrigation, agriculture and living scenario are found to be at lower level having respective index values less than mean – standard deviation. More than 20 districts are found in this category. Some of the districts under this group have undulating hilly topography, subsistence agriculture, with poor groundwater availability and limited irrigated area. The additional area can be brought under high yielding varieties of rice. These groups of districts has substantial culturable wasteland, unculturable wasteland and pasture. The culturable wasteland can be put up under different fruit crops with suitable rainwater harvesting measures. Similarly unculturable wasteland can be brought under bio-fuel plantation *viz.* Jatropha and the like, which have immense potential. The rejuvenation of pasture with strong linkage with livestock will make a significant impact on income of the people. Keeping in view the resource potential and constraints, following technological options have been identified for enhancing food production, sustainable natural resource management and living opportunities.

- Expansion of irrigation facilities through rainwater harvesting and flow based minor irrigation.
- Substitution of traditional varieties by HYVs.
- Pressurized irrigation system:
  Pressurized irrigation system especially gravity-fed has immense potential in case of the undulating topography. The adoption of this technology will increase irrigated area during *rabi* and facilitate the cultivation of vegetables, flowers, medicinal plants on a larger scale.
- Rejuvenation of pastures alongwith rainwater management
- Conversion of culturable wastelands to horticulture alongwith rainwater management
- Conversion of unculturable wastelands to bio-fuel plantation
- Conversion of culturable wastelands to horticulture along with rainwater management
- Soil amendment for reclamation

3.8 Computerized database

A database was developed on "Irrigation, agriculture, level of living and poverty scenario in the districts of eastern Indian states" using MS Access as backend database software (Figures 9, 10, 11 and 12). This database comprises with 25 database tables containing detail district-wise information on irrigation, agriculture, poverty level and level of living. These database tables provide secure data update and data query facility. Any database table can be easily queried by selecting appropriate data filed with desired criteria. Many pre-defined queries have also been developed.

Opening and using data base : Double click on 'db1.mdb' file and it will open database browser where the view of Fig. 9 will appear. For seeing data within the table double click on it. For adding or removing particular field or modifying field's title, right click on desired table name and select 'Design View'.

Query : Click on query tab as shown in Fig. 9 on left side in the screen. It will list all pre-designed queries. Double click on any query title to execute it. To modify any query, right click on it and select 'Design View'. It will open query design window where criteria can be modified, more field for display that satisfy given criteria can be added, etc.

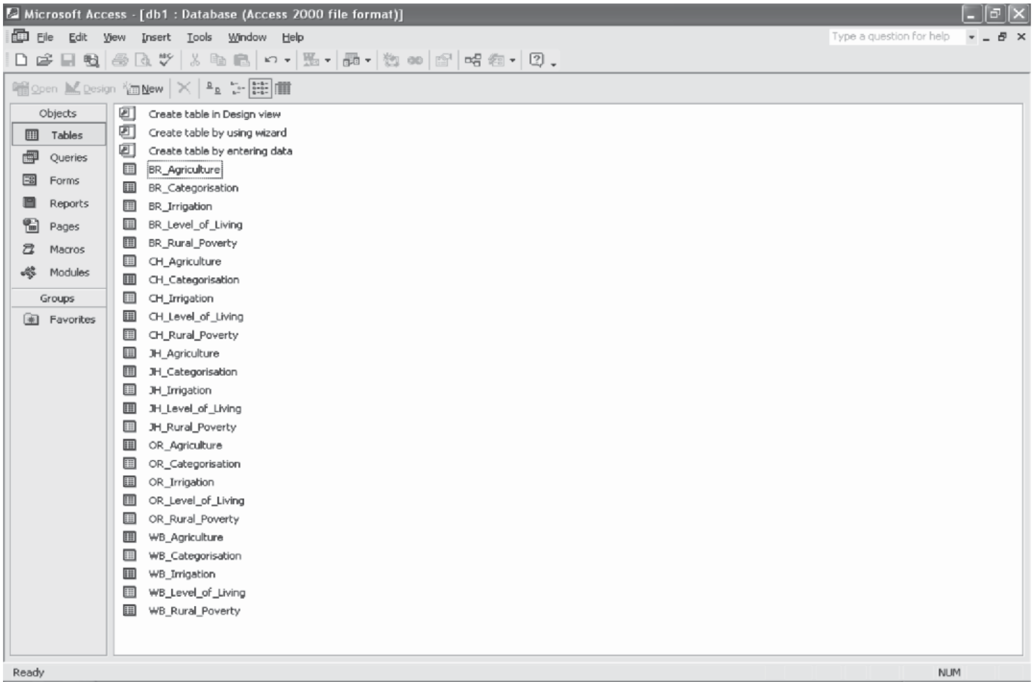
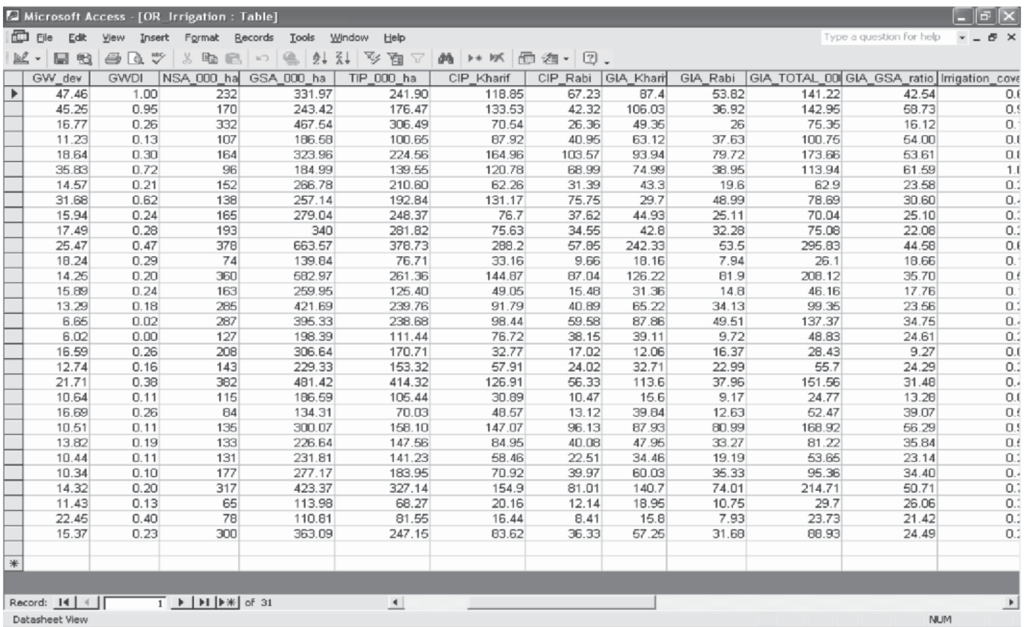


Fig. 9 MS Access database tables



GW_dev	GWDI	NSA_000_ha	GSA_000_ha	TIP_000_ha	CIP_Kharif	CIP_Rabi	GIA_Kharif	GIA_Rabi	GIA_TOTAL_00	GIA_GSA_ratio	Irrigation_cove
47.46	1.00	232	331.97	241.90	118.85	67.23	87.4	53.82	141.22	42.54	0.
45.25	0.95	170	243.42	176.47	133.53	42.32	106.03	36.92	142.95	58.73	0.
16.77	0.26	332	467.54	306.49	70.54	26.36	49.35	26	75.35	16.12	0.
11.23	0.13	107	186.58	100.65	87.92	40.95	63.12	37.63	100.75	54.00	0.
18.64	0.30	164	323.96	224.56	164.96	103.57	93.94	79.72	173.66	53.61	0.
35.83	0.72	96	184.99	139.55	120.78	68.99	74.99	38.95	113.94	61.59	1.
14.57	0.21	152	266.78	210.60	62.26	31.39	43.3	19.6	62.9	23.58	0.
31.68	0.62	138	257.14	192.84	131.17	75.75	29.7	48.99	78.69	30.60	0.
15.94	0.24	165	279.04	248.37	76.7	37.62	44.93	25.11	70.04	25.10	0.
17.49	0.28	193	340	281.82	75.63	34.55	42.8	32.28	75.08	22.08	0.
25.47	0.47	378	663.57	378.73	288.2	57.85	242.33	53.5	295.83	44.58	0.
18.24	0.29	74	139.84	76.71	33.16	9.66	18.16	7.94	26.1	18.66	0.
14.25	0.20	360	582.97	261.36	144.87	87.04	126.22	81.9	208.12	35.70	0.
15.89	0.24	163	259.95	125.40	49.05	15.48	31.36	14.8	46.16	17.76	0.
13.29	0.18	285	421.69	239.76	91.79	40.89	65.22	34.13	99.35	23.56	0.
6.65	0.02	287	395.33	238.68	98.44	59.58	87.86	49.51	137.37	34.75	0.
6.02	0.00	127	198.39	111.44	76.72	38.15	39.11	9.72	48.83	24.61	0.
16.59	0.26	208	306.64	170.71	32.77	17.02	12.06	16.37	28.43	9.27	0.
12.74	0.16	143	229.33	153.32	57.91	24.02	32.71	22.99	55.7	24.29	0.
21.71	0.38	382	481.42	414.32	126.91	56.33	113.6	37.96	151.56	31.48	0.
10.64	0.11	115	186.59	105.44	30.89	10.47	15.6	9.17	24.77	13.28	0.
16.69	0.26	84	134.31	70.03	48.57	13.12	39.84	12.63	52.47	39.07	0.
10.51	0.11	135	300.07	158.10	147.07	96.13	87.93	80.99	168.92	56.29	0.
13.82	0.19	133	226.64	147.56	84.95	40.08	47.96	33.27	81.22	35.84	0.
10.44	0.11	131	231.81	141.23	58.46	22.51	34.46	19.19	53.65	23.14	0.
10.34	0.10	177	277.17	183.95	70.92	39.97	60.03	35.33	95.36	34.40	0.
14.32	0.20	317	423.37	327.14	154.9	81.01	140.7	74.01	214.71	50.71	0.
11.43	0.13	65	113.98	68.27	20.16	12.14	18.95	10.75	29.7	26.06	0.
22.45	0.40	78	110.81	81.55	16.44	8.41	15.8	7.93	23.73	21.42	0.
15.37	0.23	300	363.09	247.15	83.62	36.33	57.25	31.68	88.93	24.49	0.

Fig. 10 Data entry screen

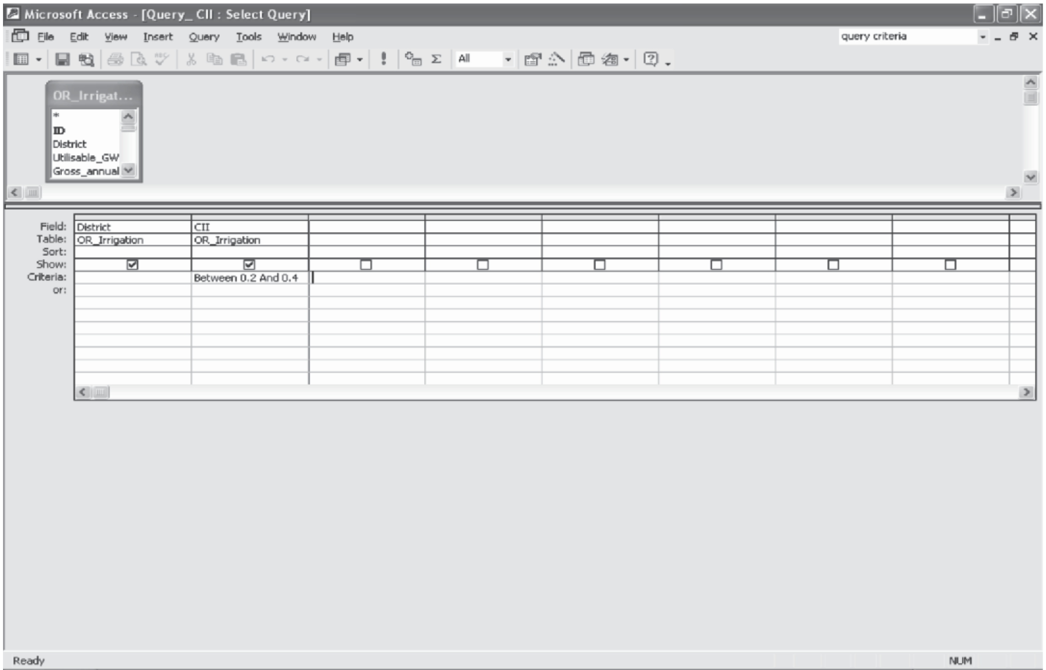


Fig. 11 A sample query screen to select database table and criteria
(Here it will list all districts having CII between 0.2 to 0.4)

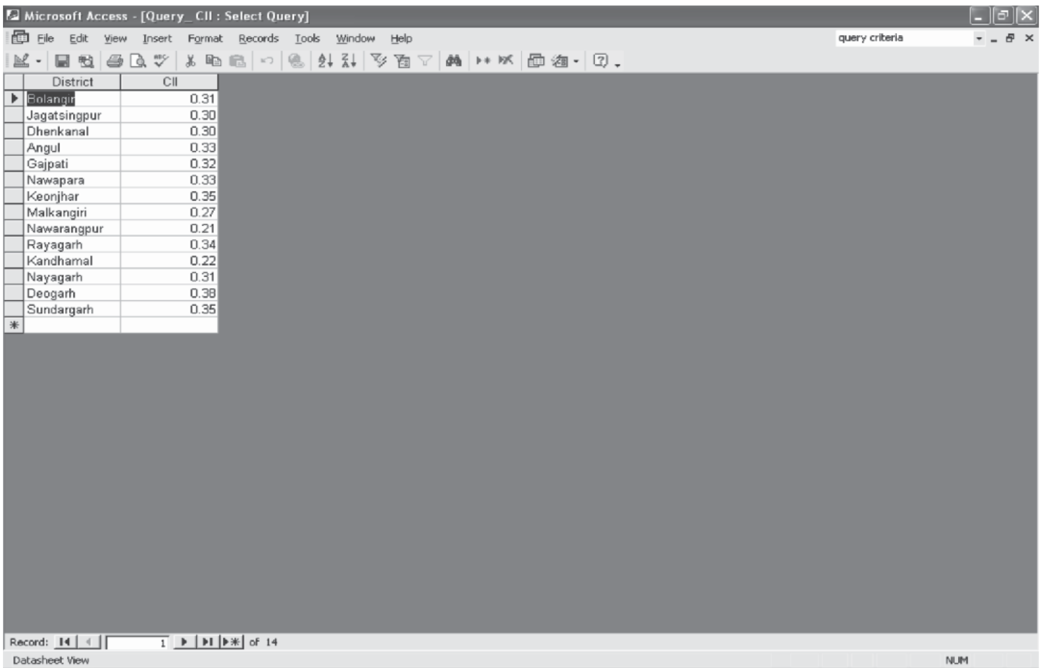


Fig. 12 Result of executing above query

4. CONCLUSION

Assessment of district wise scenario of irrigation, agriculture, living and poverty was done with the help of different indices constructed for the study. Firstly, analyses were done for the inter-district comparison within a single state. Thus, districts of Orissa, West Bengal, Chhattisgarh, Jharkhand and Bihar were analysed within the respective state. Thereafter, comparative analyses of different indices in case of 119 districts falling under five eastern India states carried out that revealed the comparative scenario of irrigation, agriculture, level of living and poverty on different indices. Thus, the study has unveiled the links and/or missing links between irrigation resources, agriculture scenario, level of living and poverty in districts of eastern India. During the process of analyses computer database has been created and based on the analyses a strategy is formulated for improving living conditions of the poor through effective utilization of water resources in agriculture by adoption of scientific agricultural water management technologies.

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