IRRIGATION AND DRAINAGE
Irrig. and Drain. **63**: 573–583 (2014)
Published online 19 June 2014 in Wiley Online Library (wileyonlinelibrary.com) **DOI**: 10.1002/ird.1860

WHY IMPACTS OF IRRIGATION ON AGRARIAN DYNAMISM AND LIVELIHOODS ARE CONTRASTING: EVIDENCE FROM EASTERN INDIAN STATES†

SOUVIK GHOSH*, S. K. SRIVASTAVA, A. K. NAYAK, D. K. PANDA, P. NANDA AND ASHWANI KUMAR
Directorate of Water Management (ICAR), Bhubaneswar, Odisha, India

ABSTRACT

Irrigation, agriculture, poverty and standard of living were analysed in five eastern Indian states to delineate the links and/or missing links between the standard of living scenario and performance of the irrigation and agriculture sectors. Different indices were constructed for assessment of district- wise scenarios of irrigation, agriculture, poverty and standard of living; accordingly, the majority of the districts in the eastern Indian states showed both the irrigation and agricultural scenarios at a low level, which may be attributed to the meagre groundwater-irrigated area due to the low level of groundwater development (27%) and dependence on a surface irrigation system that suffers from a low level of irrigation efficiency and intensity. Lack of an assured irrigation service has a bearing on the low productivity of the major crop paddy and food grain production. Better living conditions and less poverty were found in the districts where relatively better irrigation and agricultural performance were observed. Multiple regression revealed 60% ($R^2 > 0.60$) variation in living conditions was predicted by the indicators of agriculture and poverty excluding the indicators of irrigation, which is attributed to the fact of lower groundwater exploitation for irrigation in most of the districts of eastern Indian states due to poor institutional and infrastructure support resulting in a lower impact of irrigation on the poverty and standard of living scenarios. Copyright © 2014 John Wiley & Sons, Ltd.

KEY WORDS: irrigation; groundwater development; agriculture; poverty; standard of living

Received 2 April 2014; Revised 21 February 2014; Accepted 21 February 2014

RÉSUMÉ

L'irrigation, l'agriculture, la pauvreté et le niveau de vie ont été analysés dans cinq États indiens de l'Est pour définir les liens et/ou liens manquants entre les scénarios de subsistance et la performance de l'irrigation et du secteur agricole. Différents indices ont été élaborés pour l'évaluation des scénarios d'irrigation, de l'agriculture, de la pauvreté et de la subsistance à l'échelle des districts d'irrigation; la majorité des districts d'irrigation dans les États indiens de l'Est a montré à la fois des niveaux très bas d'irrigation et de scénarios agricoles, ce qui peut être attribué à de maigres ressources en eaux souterraines par ailleurs peu développées (27%), et de la dépendance au système d'irrigation de surface à la fois peu efficace et peu intense. Les défaillances des services de l'irrigation ont une incidence sur la productivité du paddy des céréales alimentaires, qui est faible. De meilleures conditions de subsistance et moins de pauvreté ont été trouvées dans les districts où l'on a observé une relativement meilleure irrigation et une agriculture plus performante. La régression multiple a révélé (60% $R^2 > 0.60$) que les variations de la qualité de subsistance ont été prédites par les indicateurs de l'agriculture et de la pauvreté, à l'exclusion des indicateurs de l'irrigation. Ceci est attribué au fait de la baisse de l'exploitation des eaux souterraines pour l'irrigation dans la plupart des districts des États indiens de l'Est, induite par le faible appui institutionnel aux infrastructures et impliquant un faible impact de l'irrigation sur la pauvreté et le niveau de vie. Copyright © 2014 John Wiley & Sons, Ltd.

MOTS CLÉS: irrigation; développement des eaux souterraines; agriculture; pauvreté; niveau de vie

INTRODUCTION

Irrigated agriculture has been a major engine for economic growth in developing countries. Poverty alleviation with better standard of living has always been an important aim

* Correspondence to: Dr Souvik Ghosh, Directorate of Water Management (ICAR), Bhubaneswar, Odisha, India (Presently Professor, Dept. of Agril. Extension, Agril. Economics and Agril. Statistics, Institute of Agriculture, Visva-Bharati University, Sriniketan, West Bengal, India). E-mail: ghosh_wtcer@yahoo.com, souvik.ghosh@visva-bharati.ac.in
†Pourquoi les impacts de l'irrigation sur le dynamisme agricole et la subsistance sont-ils contrastés? Cas des Etats Indiens.

of the governments of developing countries when investing in the construction of irrigation infrastructure. In agriculture-dependent settings, irrigation contributes significantly to improve the standard of living and reducing poverty (Hussain and Hanjra, 2004). Multi-country studies provide further evidence that there are strong linkages between irrigation and poverty alleviation; however, the anti-poverty impacts of irrigation vary widely across different settings (Saleth *et al*., 2003; Sivamohan *et al*., 2004; Hussain, 2004). Irrigation has played a crucial role in agricultural growth and development due to its direct (Hasnip *et al*., 2001; Hussain and Hanjra, 2003) as well indirect (Narayanamoorthy and Bhattarai, 2004; Narayanamoorthy, 2007) positive impact on the rural economy in India. There has always been a significant contribution (about 60%) from irrigated agriculture to overall agricultural production in India (Planning Commission, 2012). Therefore, because of its yield-augmenting impact, irrigation development has always been the priority area of India's agricultural development strategy in successive five-year plans (FYPs), with massive financial support in the irrigation sector. Consequently, irrigation potential has increased from 22 million ha during the pre-plan period to 123 million ha at present, making India the world leader in the irrigation sector (Central Water Commission, Government of India, 2010). If irrigation has the potential to produce such profound impacts on agrarian dynamism, why are such impacts not visible in eastern India, where it is needed and which has the water resources to sustain intensive irrigation (Shah, 2004). Rural eastern India is still poverty stricken with narrow subsistence options in spite of plentiful water resources. The positive impact of irrigation development could not be achieved equally across different geographical regions, and unsustainable water resource development in one part coexists with underutilization in other parts of the country (Narayanamoorthy, 2011). The northern region of India showed better performance both in irrigation and agriculture, while the eastern region was found to be lagging behind in spite of a rich water resource base (Srivastava *et al*., 2012). This kind of mismatch demands an analysis of irrigation, agriculture, poverty and standard of living scenario in the eastern region of India.

METHODOLOGY

The present study was conducted in 119 districts of 5 eastern Indian states, viz. Odisha, West Bengal, Chhattisgarh, Jharkhand and Bihar (Figure 1).

Different indices were constructed for assessment of district-wise scenarios of irrigation, agriculture, poverty and standard of living, viz. groundwater development index (GWDI), irrigation coverage index (ICI), composite irrigation index (CII), agricultural development index (ADI),

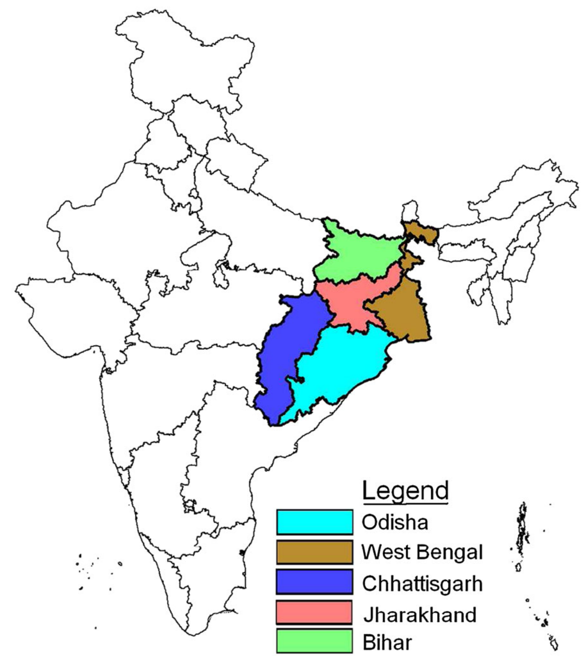

Figure 1. Study area: Eastern Indian States. This figure is available in colour online at wileyonlinelibrary.com/journal/ird

poverty ration index (PRI) and level of living index (LLI). A brief account of these indices is given below.

GWDI considered the district-wise gross annual draft (ha m) out of utilizable groundwater resource (ha m) and was calculated as

$$\mathrm{GWDI}_j = \frac{\mathrm{GWD}_j - \min \mathrm{GWD}_j}{\max \mathrm{GWD}_j - \min \mathrm{GWD}_j} \times 100 \quad (1)$$

where GWD_j = (gross annual draft of *j*th district/utilizable groundwater resource of the *j*th district).

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

$$\mathrm{ICI}_j = \frac{\mathrm{IC}_j - \min \mathrm{IC}_j}{\max \mathrm{IC}_j - \min \mathrm{IC}_j} \times 100 \quad (2)$$

where IC_j = (gross irrigated area of the *j*th district/gross sown area of the *j*th district).

CII was calculated averaging GWDI and ICI giving equal weight. ADI included seven indicators, viz. percentage of cultivable land to total land area, percentage of net sown area to total cultivable area, percentage of gross irrigated area, cropping intensity, yield of paddy (major crop), food grain production and per ha fertilizer consumption. To depict the district-wise agricultural development disparity scenario, a composite agricultural development index (ADI) was constructed by the 'deprivation method', using seven agricultural development indicators similar to those given in the report *Agricultural Growth in Orissa*—of the

Planning Commission (planningcommission.nic.in/plans/stateplan/sdr_orissa/sdr_orich4.doc).

The composite agricultural development index was calculated as

$$\mathrm{ADI}_j = \frac{\sum_{i=1}^{n} I_{\mathrm{ij}}}{\sum_{i=1}^{n} \mathrm{i}} \times 100 \quad (3)$$

where ADI_j is the index of the *j*th district:

$$I_{\mathrm{ij}} = \frac{X_{\mathrm{ij}} - \min X_{\mathrm{ij}}}{\max X_{\mathrm{ij}} - \min X_{\mathrm{ij}}} \quad (4)$$

where X_{ij} is the actual value of the *i*th indicator for the *j*th district; min X_{ij} and max X_{ij} are the minimum and maximum values of the i^{t}h indicator.

PRI was calculated on the basis of percentage of families below the poverty line (BPL) in the district:

$$\mathrm{PRI} = \frac{\max \mathrm{PR}_j - \mathrm{PR}_j}{\max \mathrm{PR}_j - \min \mathrm{PR}_j} \times 100 \quad (5)$$

where PR_j = (BPL families of the *j*th district/total rural families of the *j*th district)*100.

LLI included 14 variables viz. percentage of population above the poverty line, literacy rate, per capita food grain production, yield of major crop, percentage of gross irrigated area, percentage of village electrification, women's work participation rate, percentage of agricultural labourers to total main workers, percentage of cultivators to total main workers, percentage of industrial workers to total main workers, percentage of main workers to total population, percentage of urban population to total population, agricultural productivity per worker, and backward class (Scheduled Class/ Scheduled Tribe) 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

$$P_{\mathrm{ij}} = \frac{Y_{\mathrm{ij}} - \min Y_{\mathrm{ij}}}{\max Y_{\mathrm{ij}} - \min Y_{\mathrm{ij}}} \quad (6)$$

While index values of the negative variables like backward class population, poverty ratio, etc. were calculated as

$$P_{\mathrm{ij}} = \frac{\max Y_{\mathrm{ij}} - Y_{\mathrm{ij}}}{\max Y_{\mathrm{ij}} - \min Y_{\mathrm{ij}}} \quad (7)$$

where Y_{ij} is the actual value of the *i*th indicator for the *j*th district, min Y_{ij} and max Y_{ij} are the minimum and maximum values of the *i*th indicator.

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

$$\mathrm{LLI}_{\mathrm{j}} = \frac{\sum_{i=1}^{m} P_{\mathrm{ij}}}{\sum_{i=1}^{m} i} \times 100 \quad (8)$$

where $\mathrm{LLI}_{\mathrm{j}}$ is the index of the *j*th district.

District-wise data on selected variables were taken from the respective states' Economic Survey and Agricultural Statistics as available on the completion of the 10th FYP (March 2007), National Census 2001, and other published sources. District-wise values of different indices were calculated. Comparative analyses of different indices in the case of 119 districts falling under the five eastern India states, viz. Odisha, West Bengal, Chhattisgarh, Jharkhand and Bihar, were carried out and the districts were classified under each index (ranging from 0 to 100) 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).

RESULTS AND DISCUSSION

District-wise scenarios of irrigation, agriculture, poverty and standard of living are presented with the help of different indices derived for 119 districts of 5 eastern Indian states that included 30, 18, 16, 18 and 37 districts of Odisha, West Bengal, Chhattisgarh, Jharkhand and Bihar, respectively. Based on the values of different indices, maps were prepared with the help of Geomedia Professional GIS Software to depict the district-wise scenario of groundwater development, irrigation coverage, agricultural development, poverty and standard of living (Figure 2). Each index was categorized into five categories under which the frequency of districts was indicated, along with mean and standard deviation value of each index for each of the selected five eastern Indian states (Table I). Irrigation, agriculture, poverty and standard of living scenarios in the eastern Indian states are presented and discussed below.

Irrigation scenario

The GWDI values revealed only 26 out of 119 districts having high to very high GWDI values (>60), among which 18 districts were from Bihar, 4 from West Bengal and 2 each from Chhattisgarh and Odisha. The GWDI of 64 districts were very low to low (<40), which included 26, 16, 10, 9 and 3 districts of Odisha, Jharkhand, Chhattisgarh, West Bengal and Bihar respectively. Groundwater development ranged from 65% in Durg District of Chhattisgarh to 1% in Jalpaiguri and Darjeeling districts of West Bengal.

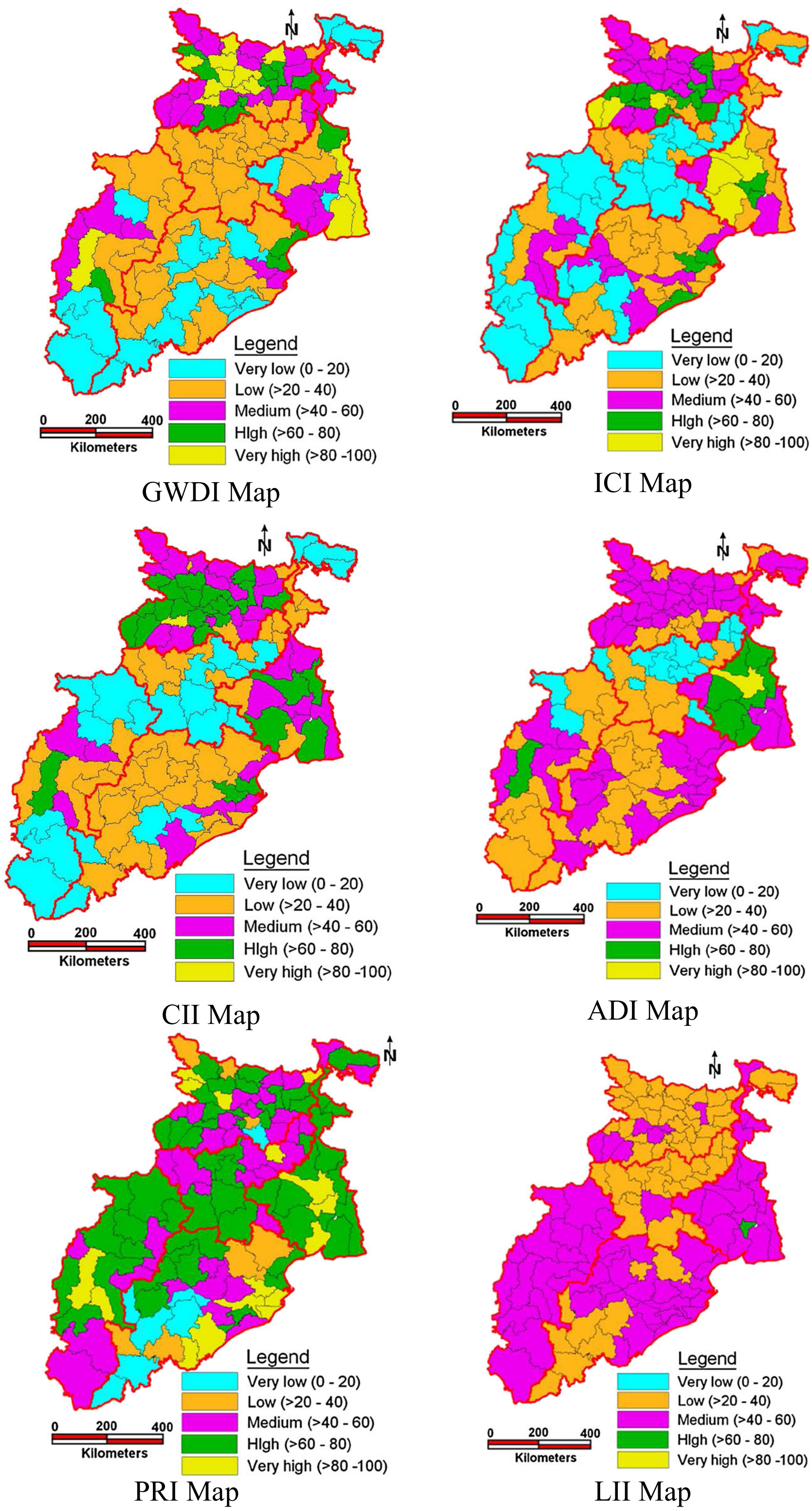

Figure 2. Irrigation, agriculture, poverty and standard of living scenario in districts of the eastern Indian states. This figure is available in colour online at wileyonlinelibrary.com/journal/ird

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

			Frequency of the districts under different categories				
Index	State	Mean ± SD	Very low (0-20)	Low (>20-40)	Medium (>40-60)	High (>60-80)	Very high (>80-100)
GWDI	Odisha (30)	26.41 ± 15.60	11	15	2	2	0
	West Bengal (18)	38.02 ± 29.05	6	3	5	1	3
	Chhattisgarh (16)	36.67 ± 23.82	4	6	4	1	1
	Jharkhand (18)	29.46 ± 6.74	0	16	2	0	0
	Bihar (37)	63.72 ± 18.02	0	3	16	9	9
	Overall (119)	41.23 ± 24.39	21	43	29	13	13
ICI	Odisha (30)	35.07 ± 15.86	5	16	6	3	0
	West Bengal (18)	48.76 ± 29.41	2	8	2	2	4
	Chhattisgarh (16)	19.67 ± 17.85	10	3	3	0	0
	Jharkhand (18)	15.08 ± 9.91	13	5	0	0	0
	Bihar (37)	57.33 ± 15.47	0	6	17	11	3
	Overall (119)	38.97 ± 24.00	30	38	28	16	7
CII	Odisha (30)	30.74 ± 13.16	4	20	4	2	0
	West Bengal (18)	43.39 ± 19.49	3	5	6	4	0
	Chhattisgarh (16)	28.17 ± 18.67	7	5	3	1	0
	Jharkhand (18)	22.27 ± 5.06	8	10	0	0	0
	Bihar (37)	58.80 ± 14.21	1	3	14	18	1
	Overall (119)	39.75 ± 20.20	23	43	27	25	1
ADI	Odisha (30)	38.42 ± 8.06	0	15	15	0	0
	West Bengal (18)	58.08 ± 12.57	0	1	9	7	1
	Chhattisgarh (16)	35.44 ± 12.77	2	9	4	1	0
	Jharkhand (18)	17.75 ± 4.41	13	5	0	0	0
	Bihar (37)	43.30 ± 6.78	0	10	27	0	0
	Overall (119)	39.39 ± 14.43	15	40	55	8	1
PRI	Odisha (30)	52.87 ± 28.91	6	4	6	8	6
	West Bengal (18)	71.10 ± 9.05	0	0	2	13	3
	Chhattisgarh (16)	66.43 ± 10.99	0	0	5	9	2
	Jharkhand (18)	60.12 ± 13.47	0	0	10	7	1
	Bihar (37)	60.36 ± 15.37	1	3	12	17	4
	Overall (119)	60.88 ± 19.24	7	7	35	54	16
LLI	Odisha (30)	42.23 ± 6.98	0	9	21	0	0
	West Bengal (18)	48.17 ± 6.22	0	2	15	1	0
	Chhattisgarh (16)	50.80 ± 5.10	0	0	16	0	0
	Jharkhand (18)	33.40 ± 4.77	0	17	1	0	0
	Bihar (37)	36.18 ± 4.81	0	31	6	0	0
	Overall (119)	41.06 ± 8.28	0	59	59	1	0

Figure in the parenthesis indicate number of districts; SD stands for standard deviation value

Overall groundwater development was found to be low (mean index value 41.2) in the eastern region of India, with quite high variation within individual states as well as regions (standard deviation 24.4).

The percentage of gross irrigated area out of gross cultivated area ranged from 91% (West Midnapore District in West Bengal) to 1% (East Singbhum District in Jharkhand). ICI values in only 23 districts were found to be high to very high, which included 14, 6 and 3 districts of Bihar, West Bengal and Odisha, respectively. Irrigation coverage was found to be very low to low (ICI < 40) in 68 districts, which included 21, 18, 13, 10 and 6 districts of Odisha, Jharkhand, Chhattisgarh, West Bengal and Bihar, respectively. Overall mean ICI was found to be 39.0 with standard deviation 24.0.

Overall irrigation scenario realized through CII that was calculated averaging GWDI and ICI. Out of 26 districts falling under the high to very high category of CII value (>60), there were 19 districts from Bihar along with 4 and 2 of West Bengal and Odisha, respectively and 1 (Durg District) of Chhattisgarh. Out of 119 districts, 66 had a very low to low (<40) CII value, including 24, 18, 12, 8 and 4 districts of Odisha, Jharkhand, Chhattisgarh, West Bengal and Bihar, respectively. CII value was highest (81.4) in the case of Jehanabad District of Bihar, while it was lowest (1.5) in the Dantewada District of Chhattisgarh with overall mean 39.8 and standard deviation 20.2.

Irrigation development has not been uniform across different regions of the country, as shown by the varying share of irrigation potential created (IPC) in ultimate irrigation potential (UIP) from 64.9% in the eastern region to 106% in the northern region of the country (Table II). Even among the eastern Indian states, irrigation development varied as it is found to be relatively low in Jharkhand, Chhattisgarh and Odisha as compared to Bihar and West Bengal, observable from the values of both GWDI and CII obtained in the present study (Table I). Low groundwater development in most of the eastern Indian states except Bihar and West Bengal had a bearing on lower percentage of IPC under groundwater irrigation in eastern India. More than 100% share of IPC in UIP in the northern region might be either because of under/overestimation of UIP/IPC (Dhawan, 1993) or unsustainable development of water resources in the region. There exists significant regional variation with 76, 65, 59 and 27% groundwater development in the northern, western, southern and eastern regions of the country, respectively, with estimated yearly replenishable groundwater potential of 105 billion cubic metres (BCM), 92 BCM, 76 BCM and 120 BCM in the northern, western, southern and eastern regions, respectively. Net area irrigated by groundwater wells rose from 28% in 1950–1951 to 61% in 2000–2001 (Government of India, 2005). The National Sample Survey Organization (NSSO) reported that 69% of *kharif* (wet season) acreage and 76% of *rabi* (dry season) acreage were irrigated with wells or tubewells (NSSO, 2005). The significant growth in tubewell irrigated area re-emphasized the growing importance of groundwater as a source of irrigation because of its reliability and higher irrigation efficiency of 70–80% compared to 25–45% of canal irrigation (Sharma, 2009). However, in most of the eastern Indian states, the surface water irrigation system is predominant as groundwater irrigation contributed to about 14, 21, 21, 46 and 55% share of IPC in Odisha, Jharkhand, Chhattisgarh, West Bengal and Bihar, respectively (Table III). Therefore, it is evident that

Table II. Zone-wise irrigation development (million ha) and its utilization (%) in India

Particulars	North	West	South	East	India
Ultimate irrigation potential (UIP)	42.7	36.5	25.4	33.7	140
Irrigation potential created (IPC)	45.1	33.5	22.1	21.8	123
Irrigation potential utilized (IPU)	37.1	22.6	16.6	14.3	91.1
% of IPC to UIP	105.6	91.9	86.8	64.9	88.1
% of IPC (Major & Medium) to UIP	33.0	27.7	33.5	28.1	30.2
% of IPC_Minor to UIP	72.6	64.2	53.4	36.8	57.9
% of IPC_Minor (surface) to UIP	3.0	8.9	20.5	11.4	10.1
% of IPC_Minor (groundwater) to UIP	69.6	55.3	32.8	25.4	47.8
% of IPU to IPC	82.4	67.3	75.0	65.5	73.9

Note: The data presented in the table are derived from Central Water Commission (2010).

Table III. Irrigation performance in five eastern Indian states

State	Particular	Major and medium	Minor (Surface)	Minor (Ground)	Minor (Total)	Total
Bihar	IPC (,000 ha)	2960 (36)	683 (8)	4490 (55)	5170 (64)	8180 (100)
	% utilization	64	60	60	60	61
Chattisgarh	IPC (,000 ha)	1810 (65)	380 (14)	595 (21)	975 (35)	2790 (100)
	% utilization	71	49	40	44	61
Jharkhand	IPC (,000 ha)	604 (59)	209 (20)	213 (21)	422 (41)	1030 (100)
	% utilization	73	65	72	69	71
Odisha	IPC (,000 ha)	1990 (53)	1230 (33)	525 (14)	1760 (47)	3750 (100)
	% utilization	95	48	42	46	72
West Bengal	IPC (,000 ha)	1770 (33)	1140 (21)	2450 (46)	3580 (67)	5350 (100)
	% utilization	89	52	59	57	68

Figures within parentheses are share of respective sources in total IPC
% utilization is the share of irrigation potential utilized out of irrigation potential created
Note: The data presented in the table are derived from Central Water Commission (2010).

relatively better groundwater development in Bihar and West Bengal has led to a better irrigation scenario in comparison to other three states in eastern India.

Overall, potential utilization of the groundwater irrigation system is relatively lower in the eastern region compared to other regions of the country, due to many constraints such as higher energy costs, operational costs, defunct lift points, etc. In the Indo-Gangetic Basin (IGB) covering eastern Indian states such asBihar and West Bengal, energy costs and availability ranked as the top challenge to farming (Shah *et al*., 2006). The diesel price squeeze on small-scale irrigation is heading towards a crisis that is particularly visible in eastern India, where electric tubewells are few and the ratio of rice (major crop) to diesel price is no longer favourable. In crop-sharing contracts for water sales in eastern India, tubewell owners claim one third to half of the total output for pump irrigation alone when they pay for diesel. The energy squeeze is gradually driving smallholders out of irrigation, and increasingly, from farming itself (Shah *et al*., 2009). With the government support and incentives the groundwater irrigation potential created (IPC); however, the gap between potential created and utilized has been concern raising the issues related to efficient use of groundwater resource for irrigation in the eastern Indian states. Non-functioning of groundwater extraction devices (GEDs) has led to poor utilization of irrigation potential, as about a quarter of the total GEDs were found to be non-functional as reported in the latest (4th) minor irrigation census (2006–2007). Many of the non-functional GEDs were not working mainly because of a lower discharge rate and mechanical breakdown of the devices. Suitable artificial recharge structures especially in hard rock regions, repairing and maintaining of GEDs through suitable policy instruments will go a long way in groundwater development and its effective utilization in the eastern Indian states. Thus while several states in the northern and southern part of the country witnessed overexploitation of groundwater, the eastern part is underutilizing its groundwater because of poor infrastructure and unfavourable geological conditions (Srivastava *et al*., 2012).

Agricultural development

Overall agriculture development represented by ADI values revealed that only 9 districts showed higher values (>60), 8 were from West Bengal along with 1 district (Durg District) of Chhattisgarh. A total of 55 districts showed a medium range of ADI values (>40–60), while the remaining 55 were in the very low to low category (<40); 15 districts of Odisha were found to be in the medium and low categories. It was observed that the majority of districts of Jharkhand (18) and Chhattisgarh (11) fell under the low to very low category. The majority of districts of Bihar (27) and West Bengal (9) were categorized under the medium range of ADI. Overall mean ADI was found to be 39.4 with standard deviation 14.4.

Rai *et al*. (2008) also reported that Jharkhand, Chhattisgarh and Odisha states are in the group of having the most low agricultural productive districts in India; as per the agricultural status index agro-climatic zone 7 (Jharkhand, Chhattisgarh and Odisha are in this zone, barring coastal districts of Odisha which are in zone 11) was categorized as low, while agro-climatic zones 3 (many districts of West Bengal) and 4 (all districts of Bihar) were medium status.

The present study revealed that agricultural development in districts of West Bengal is found to be comparatively better than other eastern Indian states, with relatively higher productivity of the major crop paddy (about $2.5\,t\,ha^{-1}$), food grain production (15.7 million t with productivity about $1.7\,t\,ha^{-1}$), cropping intensity (180%) and fertilizer consumption ($145\,kg\,ha^{-1}$). For Bihar state, the relationship between irrigation development (GWDI, ICI, CII) and agricultural development is positive but relatively weak compared to West Bengal. However, agricultural development of Bihar found to be better than other eastern Indian states like Odisha, Jharkhand and Chhattisgarh. In fact most of the districts of Bihar were in the medium category of agricultural development. This indicates that the potential of irrigation development is not fully realized. The possible reasons hover around issues of poor quality of irrigation rather than coverage (high coverage but unreliable water supply affecting crop growth, thus crop production adversely). Unreliable irrigation is also the reason for the low level of use of other complementary inputs (e.g. fertilizer consumption only $135\,kg\,ha^{-1}$, lower than the average national figure), low cropping intensity (138%), poor crop productivity (productivity of paddy about $1\,t\,ha^{-1}$, food grain production of about 7.8 million t with productivity about $1\,t\,ha^{-1}$), which were the components of the agriculture development index. Irrigation is only one of the many factors affecting agricultural development; therefore, in spite of a better irrigation scenario in about half of the total districts of Bihar, agricultural development was found to be at the medium level. In this context, Shah (2004) also observed a stagnant agrarian economy in the north Bihar region despite the rapid rise in tubewell density.

It is observed that the majority of the districts (all 18 in Jharkhand, 11 out of 16 in Chhattisgarh and 15 out of 30 in Odisha) in Jharkhand, Chhattisgarh and Odisha showed both irrigation and agricultural scenarios at a low level; this may be attributed to the fact of a meagre groundwater-irrigated area due to the low level of groundwater development and dependence on major and medium irrigation systems that mainly provide irrigation during the wet season with a low level of efficiency, where head-reach farmers undertook extensive cultivation of paddy rather than assured productive irrigation in the dry season, with a gap between created and utilized potential (Ghosh *et al.*, 2005, 2010; Mishra *et al.*, 2011). In Odisha's Hirakund project, head-end farmers enjoyed negative deprivation as they irrigated far more areas than they are supposed to, at the expense of tail-end farmers (Shah, 2004). While more than half of the gross sown area was found to be irrigated in West Bengal and Bihar, only about 31, 21 and 12% of the gross sown area in Odisha, Chhattisgarh and Jharkhand states, respectively, were irrigated, which reiterates the fact that the performance of groundwater irrigation influences the gross irrigated area. Thus lack of an assured irrigation service has a bearing on the low food grain productivity (hovering around 1–1.5 $t\,ha^{-1}$), cropping intensity (120–150%) and fertilizer consumption (50–70 $kg\,ha^{-1}$) in these three states of eastern India. The smaller the irrigation systems with well-managed infrastructure, relatively equitable water distribution and diversified cropping patterns, the greater the impacts of irrigation. Improving the performance of irrigation systems by improving water distribution across locations and enhancing land and water productivity through diversifying cropping patterns would help improve agricultural performance in the presently low-productivity parts of the system (Hussain *et al.*, 2006).

Extent of poverty

The extent of poverty studied on the basis of relative scenario of below poverty line (BPL) families in 119 districts of 5 selected states in eastern India, which was varied from 17.78% in Ganjam District to 88.7% in Nawapada District of Odisha. Overall about 45% families were BPL (standard deviation 13.8) in eastern India, which indicates a higher level of poverty in this region compared to other regions in the country. Overall mean PRI was found to be 60.9 with standard deviation 19.2. The very low to low PRI values (<40) of 14 districts indicated extreme poverty conditions, and this included 10 and 4 districts of Odisha and Bihar, respectively; however, 70 out of 119 districts showed relatively less poverty in comparison to other districts with very high to high PRI values (>60) that included 21, 16, 14, 11 and 8 districts of Bihar, West Bengal, Odisha, Chhattisgarh and Jharkhand, respectively. Medium PRI values were observed in 12, 10, 6, 5 and 2 districts of Bihar, Jharkhand, Odisha, Chhattisgarh and West Bengal, respectively. Thus, the extent of poverty was found to be maximum in Odisha and minimum in West Bengal, having relatively low and high level of irrigation as well as agricultural performance, respectively. In a mega study to explore the links between irrigation and poverty alleviation in six Asian countries (India, Pakistan, Bangladesh, China, Vietnam and Indonesia) covering 26 irrigation systems, it was revealed that irrigation did significantly reduce poverty as measured by household income; however, poverty was still high in irrigation systems, averaging 34% (it varied from 6 to 65%) with significant inter- and intra-country differences in poverty incidence in irrigation systems (Hussain, 2007a). The locational differences (upstream–downstream poverty differences in India of about 11%) in poverty were more pronounced in larger irrigation systems (surface irrigation), where locational inequities in water distribution and agricultural productivity differences were also high (Hussain *et al.*, 2006; Hussain, 2007b). The impact of groundwater irrigation on agriculture and poverty reduction is greater (Bhattarai and Narayanamoorthy, 2003; Shah, 2004; Narayanamoorthy, 2007), which also holds true in the context of the findings of present study. Mukherji (2007) in an extensive study in West Bengal reaffirmed groundwater irrigation with myriad benefits has been a source of much succour to the agrarian poor. Narayanamoorthy (2007) observed that the level of reduction of poverty is very low in states that already have a high incidence of poverty; however, a significant inverse relationship is observed between rural poverty and groundwater irrigation. Most of the eastern Indian states continue to stay in the high-incidence poverty group of Indian states. Not surprisingly, groundwater development in all these states is very low due to poor institutional and infrastructure support.

Standard of living

Standard of living of only one district (Howrah District of West Bengal) was found to be high (LLI of 62), while 59 districts fall under the medium and low categories. Overall mean LLI was 41.1 with standard deviation 8.3. It was observed that 21, 16, 15, 6 and 1 districts of Odisha, Chhattisgarh, West Bengal, Bihar and Jharkhand, respectively, were categorized under the medium category, while 31, 17, 9 and 2 districts of Bihar, Jharkhand, Odisha and West Bengal, respectively, had low LLI values. Thus the standard of living scenario of most of the districts in West Bengal, Odisha and Chhattisgarh states was at the medium level and standard of living of most of the districts in Bihar and Jharkhand was at a low level. The lower standard of living in districts of Jharkhand may be attributed to the overall low level of irrigation and agricultural development, in addition to other developmental parameters considered in assessing the standard of living. However, in spite of a better irrigation scenario in about half of all the districts of Bihar, agricultural development was found to be at the medium level which along with a relatively low level of other parameters determining the living standard contributed to the lower LLI. Rai *et al.* (2008) in their study on livelihood status of different agro-climatic zones in India reported that the livelihood status index of agro-climatic zones 7 (Jharkhand, Chhattisgarh and Odisha are in this zone, barring coastal districts of Odisha which are in zone 11) and 4 (all districts of Bihar) was categorized as low, while agro-climatic zone 3 (many districts of West Bengal) was medium status. The Task Force of the Planning Commission of India (2003) had identified 150 backward districts for a wage employment programme, out of which about half of were in the eastern Indian states, viz. 27, 19, 14, 7 and 6 districts of Odisha, Jharkhand, Chhattisgarh, West Bengal and Bihar, respectively. The landless households account for the majority of the poor who depend on non-crop sources of income including on- and off-farm wage labour (Hussain, 2007b). Past studies reported that livelihood-improving and poverty-reducing impacts of irrigation vary significantly across schemes in each country (Hasnip *et al.*, 2001).

Link between irrigation, agricultural development, poverty and standard of living

To draw relationships between irrigation resources, agricultural development, standard of living and poverty, in the first step the normality of CII, ADI and LLI was tested using SPSS 10.0 for Windows. As the index 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 IV).

Multiple regressions (stepwise backward elimination method) 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 may be considered suitable and accepted (Table V). The analyses revealed that 60% ($R^2 > 0.60$) variation in the standard of living was predicted by the indicators of agriculture and poverty in districts of five eastern Indian states, excluding the indicators of irrigation. Thus it differs from the fact that the impact of irrigation was relatively higher in temporal and

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

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

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

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

Variables	'b' value	Standard Error	't' value	'F' value	R^2
Model 1				17.9**	0.603
Constant	43.6	4.02	10.8**		
GWD	0.007	0.044	0.082		
GIA	0.017	0.031	0.210		
CL	0.278	0.041	3.21**		
NSA	0.342	0.035	4.37**		
CI	0.172	0.023	2.02*		
RY	0.374	0.001	3.33**		
FG	0.194	0.002	1.93*		
FC	0.121	0.010	1.54*		
BPL	-0.374	0.039	-5.63**		
Model 2				20.3**	0.603
Constant	43.5	3.99	10.9**		
GIA	0.016	0.030	0.20		
CL	0.281	0.038	3.524**		
NSA	0.341	0.035	4.39**		
CI	0.173	0.023	2.07*		
RY	0.378	0.001	3.66**		
FG	0.192	0.002	1.95*		
FC	0.121	0.010	1.55*		
BPL	-0.373	0.038	-5.76**		
Model 3				23.4**	0.603
Constant	43.4	3.93	11.0		
CL	0.277	0.036	3.58**		
NSA	0.346	0.033	4.67**		
CI	0.173	0.023	2.08*		
RY	0.377	0.001	3.67**		
FG	0.195	0.002	1.99*		
FC	0.126	0.009	1.71*		
BPL	-0.373	0.038	-5.78**		

**Significant at 0.01 level and
*Significant at 0.05 level; Dependent variable LLI; Predictors: groundwater development (GWD), gross irrigated area (GIA); cultivable land (CL); net sown area (NSA); cropping intensity (CI), rice yield (RY), food grain production (FG), fertilizer consumption (FC), below poverty line population (BPL)

spatial variations in rural poverty levels in India relative to other inputs (Shah, 2004); however, the deviation in eastern India may be attributed to the facts of inefficient surface irrigation systems having the tendency to atrophy and shrink their command areas, and lower groundwater exploitation for irrigation in most of the districts of the eastern Indian states resulting in the lower impact of irrigation on the poverty and standard of living scenario. Molden *et al.* (2007) mentioned that an effective irrigation service provides the environment for productive and sustainable agriculture vital for incomes and employment, economic growth and reducing poverty; however, poorly managed irrigation can have the opposite effect. Abundant water resources in the eastern region are not accessible to farmers at the right time and place because of poor irrigation infrastructure development, making it a high-potential but poorly performing region of the country (Narayanamoorthy, 2011). 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 widespread use of groundwater irrigation than of canal irrigation (Bhattarai and Narayanamoorthy, 2003; Shah, 2004; Narayanamoorthy, 2007). In this context, lower groundwater exploitation for irrigation in most of the eastern Indian states except Bihar and West Bengal has a bearing on the insignificant impact of irrigation development on the agricultural performance, poverty and standard of living scenarios in the eastern India (Rijsberman, 2003). A cubic metre of groundwater contributes more to productivity and livelihoods compared to the same of surface water (Shah, 2004). Thus, acceleration in investment by private farmers in groundwater irrigation may have a larger impact in enhancing agricultural production and income in the eastern region. Further, the lowest share of IPC in UIP (64.9%), least utilization of already created potential (65.5%) and least groundwater development (27%) in the eastern region set up a strong case to reframe new policies and regulations that facilitate better irrigation infrastructure in the region. Here, the major challenge is to find ways of bringing down water use cost below the upper threshold beyond which abundantly available water becomes too expensive for the poor to use to maintain livelihoods and food security (Shah *et al.*, 2009).

As revealed in the present study as well as in past ones, the impacts of irrigation vary across settings and the magnitude of the anti-poverty impacts of irrigation depend on a number of factors like structure of land distribution, condition of the irrigation infrastructure and its management (both groundwater and surface water), irrigation water management including allocation and distribution procedures, irrigation efficient production technologies, cropping patterns and crop diversification, support measures including information, input and output marketing. It is argued that there is no silver bullet to reduce poverty through water resources development and management. There is a need for combination of sustainable irrigation development with the development of appropriate pro-poor institutions and technologies to achieve a lasting and sustainable impact on poverty (Rijsberman, 2003). Better irrigation infrastructure development strategy in eastern Indian states to address the groundwater economy and arrest the tendency of surface irrigation systems to atrophy, bridging the gap between created and utilized potential, would result in better agricultural growth and a visible impact on the agrarian economy and livelihoods.

CONCLUSIONS

Assessment of district-wise scenarios of irrigation, agriculture, standard of living and poverty with the help of different indices in the districts of five eastern India states revealed the comparative scenario and unveiled the links and/or missing links between irrigation resources, agriculture scenario, poverty and standard of living. The irrigation and agricultural scenarios in the majority of the districts in eastern Indian states were found to be at a low level due to a meagre groundwater-irrigated area and dependence on a less efficient major and medium irrigation system. Lower groundwater exploitation for irrigation in eastern Indian states (only about 25% groundwater irrigation potential created in this region compared to 70% in the northern, 55% in the western and 33% in the southern region, with an overall average of 48% for the country as a whole) has resulted in a lower impact of irrigation on the poverty and standard of living scenarios. It is evident from the analyses that the eastern zone of India is not uniform, with a contrasting impact of irrigation on agriculture and livelihood. Eastern India, which was dubbed India's poverty square, is endowed with a very large groundwater reservoir and substantial surface water resources, but people lack the resources to exploit these water sources. The impact depends on the level of control over water resources (both surface and groundwater) by organized irrigators' associations/*Pani Panchayats* rather than on the endowment. Therefore, improved irrigation management with proper institutional and infrastructure support can contribute to poverty reduction and a better standard of living.

REFERENCES

Bhattarai M, Narayanamoorthy A. 2003. Impact of irrigation on rural poverty in India: an aggregate panel-data analysis. *Water Policy* **5**(5): 443–458.

Central Water Commission. 2010. Water and Related Statistics. CWC, Ministry of Water Resources: New Delhi, Government of India.

Dhawan BD. 1993. Indian Water Resource Development for Irrigation: Issues Critiques and Reviews. Commonwealth Publishers: New Delhi.

Ghosh S, Singh R, Kundu DK. 2005. Evaluation of irrigation-service utility from the perspective of farmers. *Water Resources Management* **19**: 467–482.

Ghosh S, Kumar A, Nanda P, Anand PSB. 2010. Group dynamics effectiveness of water user associations under different irrigation systems in an eastern India state. *Irrigation and Drainage* **59**: 559–574.

Government of India. 2005. Net Area Irrigated from Different Sources of Irrigation and Gross Irrigated Area in India during 1950–1951 to 2000–2001. Ministry of Agriculture: New Delhi. http://www.indiastat.com.

Hasnip N, Mandal S, Morrison J, Pradhan P, Smith L. 2001. Contribution of Irrigation to Sustaining Rural Livelihoods: Literature Review. HR Wallingford and Department of International Development: UK.

Hussain I. 2004. Pro-Poor Intervention Strategies in Irrigated Agriculture in Asia: China, Bangladesh, India, Indonesia, Pakistan and Vietnam. Poverty in Irrigated Agriculture: Realities, Issues, and Options with Guidelines. Summary and Synthesis of Findings and Conclusions. International Water Management Institute: Colombo, Sri Lanka.

Hussain I. 2007a. Pro-poor intervention strategies in irrigated agriculture in Asia: issues, lessons, options and guidelines. *Irrigation and Drainage* **56**: 119–126.

Hussain I. 2007b. Poverty-reducing impacts of irrigation: evidence and lessons. *Irrigation and Drainage* **56**: 147–164.

Hussain I, Hanjra MA. 2003. Does irrigation water matter for rural poverty alleviation? Evidence from South and South-East Asia. *Water Policy* **5**(5–6): 429–442.

Hussain I, Hanjra MA. 2004. Irrigation and poverty alleviation: review of the empirical evidence. *Irrigation and Drainage* **53**: 1–15.

Hussain I, Wijerathna D, Arif SS, Murtiningrum MA, Suparmi. 2006. Irrigation, Productivity and Poverty Linkages in Irrigation Systems in Java, Indonesia. *Water Resources Management* **20**: 313–336

Mishra A, Ghosh S, Nanda P, Kumar A. 2011. Assessing the impact of rehabilitation and irrigation management transfer in minor irrigation projects in Odisha, India: a case study. *Irrigation and Drainage* **60**: 42–56.

Molden D, Burton M, Bos MG. 2007. Performance assessment, irrigation service delivery and poverty reduction: benefits of improved system management. *Irrigation and Drainage* **56**: 307–320.

Mukherji A. 2007. Political economy of groundwater markets in West Bengal, India: Evolution, extent and impacts. PhD thesis, Cambridge University, UK.

Narayanamoorthy A. 2007. Does groundwater irrigation reduce rural poverty? Evidence from Indian states. *Irrigation and Drainage* **56**(2–3): 349–362.

Narayanamoorthy A. 2011. Development and composition of irrigation in India: temporal trends and regional patterns. *Irrigation and Drainage* **60**: 431–445.

Narayanamoorthy A, Bhattarai M. 2004. Can irrigation increase agricultural wages? An analysis across Indian districts. *Indian Journal of Labour Economics* **47**(2): 251–268.

National Sample Survey Organization (NSSO). 2005. Situation Assessment Survey of Farmers: Some Aspects of Farming. 59th Round, January–-December 2003, Report 496(59/33/3). Department of Statistics, Government of India: New Delhi.

Planning Commission. 2003. Report of the Task Force: Identification of Districts for Wage and Self Employment Programmes. Planning Commission, Government of India: New Delhi.

Planning Commission. 2012. Twelfth Five Year Plan 1912–2017, Vols I and II. Planning Commission, Government of India: New Delhi.

Rai A, Sharma SD, Sahoo PM, Malhotra PK. 2008. Development of livelihood index for different agro-climatic zones of India. *Agricultural Economics Research Review* **21**: 173–182.

Rijsberman F. 2003. Can development of water resources reduce poverty? *Water Policy* **5**(5): 399–412.

Saleth RM, Samad M, Namara R. 2003. Dynamics of irrigation–poverty linkages in rural India: analytical framework and empirical analysis. *Water Policy* **5**(5–6): 459–473.

Shah T. 2004. Water and welfare: critical issues in India's water future. *Economic and Political Weekly*, http://www.epw.org.in/showArticles.php?root=2004.

Shah T, Singh OP, Mukherji A. 2006. Some aspects of South Asia's groundwater irrigation economy: analyses from a survey in India, Pakistan, Nepal Terai and Bangladesh. *Hydrogeology Journal* **14**(3): 286–309.

Shah T, Hassan MU, Khattak MZ, Banerjee PS, Singh OP, Rehman SU. 2009. Is irrigation water free? A reality check. *World Development* **37**(2): 422–434.

Sharma KD. 2009. Groundwater management for food security. *Current Science* **96**: 1444–1447.

Sivamohan MVK, Scott C, Bouma J, Ganguly U, Thikawala S, Wijerathna D, Hussain I. 2004. Pro-Poor Intervention Strategies in Irrigated Agriculture in Asia – Poverty in Irrigated Agriculture in India – Issues and Options. Country Final Report – India. International Water Management Institute: Colombo, Sri Lanka.

Srivastava SK, Ghosh S, Kumar A. 2012. Spatial and Temporal Investment Pattern in Irrigation Development and its Impact on Indian Agriculture. Research Bulletin No. 55. Directorate of Water Management (Indian Council of Agricultural Research): Bhubaneswar, Odisha, India.