Environment and Ecology 37 (4B) : 1537—1545, October—December 2019
ISSN 0970-0420

Irrigation Development and Equity Implications in India: Revisiting Sustainable Development Agenda

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Received 30 August 2019 ; Accepted 17 October 2019 ; Published on 16 November 2019

ABSTRACT

The present study attempts to analyze the level of inequality in the distribution of irrigation in India using Theil's index. The level of inequity in distribution of irrigated land has increased over time from 0.40 in 1995 to 0.42 in 2010. A source-wise analysis reveals that level of inequity was the highest in well irrigation systems. Decomposition of Theil's index values indicate that, within state inequalities are predominant in groundwater irrigation systems while between state inequalities are prominent in surface irrigation systems. The analysis reveals existence of substantial regional disparities in the distribution of irrigated land.

Keywords Theil's index, Regional disparities, Property rights, Irrigation, Sustainable development.

INTRODUCTION

Irrigation development has played a vital role in increasing crop yields and farm income (Narayanamoorthy 2017). It has expanded tremendously in India since independence and now 90 million hectares of cultivable area is under irrigation, a four-fold increase since independence. However, the contribution of irrigation in increasing agricultural productivity and output growth is bettered only by fertilizers (Rada 2016). There exists complementary relationship between the adoption of yield increasing technology, irrigation development and other on-farm investment (Ghosh et al. 2016). Thus by enhancing crop productivity, stabilizing crop yields and promoting the adoption of modern agricultural practices, irrigation development has contributed significantly to increasing and stabilizing farm incomes (Hussain and Hanjra 2004). Through this pathway, irrigation development has helped in reducing rural poverty in developing countries, including India (Kumar et al. 2016).

The land available for agriculture has been declining steadily over the past few decades (Sharma 2015). In this context, yield increase along with increasing cropping intensity through multiple cropping seems to be the only plausible option to meet the increasing demand for food and fiber and enhancing farm incomes (Rasul 2016)). Therefore, cropping intensity and yield could be increased by judicious use of water, fertilizer, technology and expertise farmers and mobilize institutional resources in favor of marginal farm. Among aforesaid factors, availability of water throughout cropping season has a critical factor. In totality, Country like India, which receives 75% of its total rainfall during the *kharif*

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season (June–October), irrigation development is set to play a crucial role in food security and agriculture development and poverty reduction.

Attaining self-sufficiency in food grains would have remained unfulfilled in the absence of large scale investment in irrigation systems (Stone 2019), which facilitated the successful adoption of high yielding varieties of wheat and rice. Irrigation development in independent India can be traced into two distinct phases, viz., 1960s and 1970s (Mukherji 2016). Government spent heavily on the construction of public irrigation facilities like dams and canals. However, high initial investment, low conveyance efficiency and dependence on precipitation has prompted a shift in irrigation policy towards minor irrigation sources with special emphasis on hitherto untapped groundwater sources. Timely availability and the inherent flexibility of groundwater irrigation systems have led to a shift in preference towards groundwater sources (Gandhi and Namboodiri 2009). In addition to increase in farm income, irrigation development serves as an effective tool for reducing income inequality across farm classes (Hussain and Hanjra 2004). However, unequal access to irrigation facilities might severely hamper the income equalizing role of irrigation development. This distributional inequality may lead to widening of income differentials among small and large land owners (Sarkar 2012).

The past studies have pointed towards rising distributional inequalities irrigation distribution across farm classes (Hussain and Hanjra 2004, Gandhi and Namboodiri 2009, Sarkar 2012, Mukherji 2016). Small and marginal farmers have to bear a disproportionately large share of the negative externalities of groundwater depletion : Increased costs of extraction, Higher probability of well interference and Increased risk of failure due to smaller size of operational holdings and their socio-economic disposition (Jacoby 2017).

There is a growing discord between macro level studies that point towards declining inequalities and suggest a shift towards private irrigation sources (Shah and Raju 1989, Shah 2009, Shah 2011) and micro level studies which reveal rising inequalities favoring the disposition of large land holding classes (Sarkar 2011, Sarkar 2012, Sampath 1990, Selvarajan et al. 2001, Raju 2008). This necessitates a macro - level study on the equity implications of irrigation development with a special focus on the impact of different irrigation sources on distributional inequality. Regional disparities exist in the distribution of irrigation facilities across states due to differences in endowment of natural resources and socio-economic characteristics of the farming classes (Suresh et al. 2018).

There is a need to document these regional disparities while farming irrigation development policies. Moreover, the Government has implemented various programs to enhance the accessibility to irrigation facilities: Command Area Development Program, Accelerated Irrigation Benefits Scheme and Pradhan Mantri Krishi Sinchai Yojana. A heavy investment is made toward this. In order to step up the impact of irrigation, the equity considerations need to be accorded its due importance. Therefore, it is essential to estimate the current status and temporal trends in the level of distributional inequality of irrigation facilities.

Against this backdrop, the present study estimates the current status and temporal changes in the level of inequity in the distribution of irrigation across farm classes. It also has calculated regional disparities in the concentration of irrigation facilities. Finally, the role of property rights and institutions in ensuring equitable access and sustainable usage of groundwater has been discussed.

MATERIALS AND METHODS

Data sources

This study has used secondary data on irrigated area obtained from the various issues of agricultural census, viz., 1995, 2000, 2005 and 2010. Agricultural census provides grouped data on the distribution of land and source wise distribution of irrigated land and other characteristics of agricultural holdings. Data on the number of holdings and area under various irrigation sources like canals, tanks wells and tube-wells along with data on net cropped area and net irrigated area have been collected from the http://agcensus.dacnet.nic.in/.

Estimation method

Location coefficient

The status of irrigation development was examined using the changes in relative share of various sources of irrigation. The changes in distribution of irrigated land across farm classes was also computed for wholly irrigated, partially irrigated and totally un-irrigated holdings for two time periods, viz., 1995 and 2010. The location coefficient was employed to examine the regional disparities across major agrarian states. Two variants of the location coefficient were used: To measure the concentration of irrigated area and To measure the concentration of different sources of irrigation. The computational details of the two variants are provided below:

$$L_1 = \frac{\frac{Lij}{Lj}}{\frac{Li}{Ln}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

$$L_2 = \frac{\frac{Lsj}{Lj}}{\frac{Li}{Ln}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Here in the subscripts *i* refer to the state *s* refers to the source of irrigation (*i* ranges from 1 to 15 and *s* ranges from 1 to 5). L_n refers to net sown area and net irrigation area in equation 1 and 2 respectively. If the value of location coefficient exceeds 1 then we may infer that the distribution of irrigation benefit is biased in favor of the state whereas a value below 1 may indicate a strong bias in distribution against the state. If the value of location coefficient is equal to 1 it indicates that there is no regional bias in irrigation distribution.

Theil index

Kakwani (1980), Cowell (1977) had developed seven axioms: Principles of scale independence, Equal additions, Population, Strong principle of transfers, Weak principle of transfers, Symmetry values and Normalized values, to evaluate different measures of inequality. Further, Sampath (1990) has examined the suitability of these criteria in relation to irrigation and concludes that the Theil's information measure satisfies all relevant axioms. The assumption of normalized values is found to be overly restrictive. In addition to fulfilling all relevant axioms of inequality, the Theil's information criterion has the added advantage of being perfectly decomposable, thus facilitating the decomposition of total inequality into between group and within group inequalities. In the present study the Theil's index values have been further decomposed into between state and within state inequalities. The following formula has been used for estimation of Theil's information measure.

$$T(X:Y) - \sum_{i-1}^{n} Xi\, Ln \left(\frac{Xi}{Yi} \right) \quad \ldots \ldots \ldots \ldots \ldots \ldots (3)$$

Where, T (x : y) is the value of Theil's information measure ; x_i is number of households in i^{th} farm size class as a proportion of the total no. of farming households in the country ; y_i is the irrigation attribute of i^{th} farm size class as a proportion of total in the country. For the decomposition of Theil's information measure, the following formula was used:

$$T(X:Y) = I_o(X:Y) + \sum_{y=1}^{G} X_g I_g \; (X:Y) \ldots \ldots \ldots \ldots (4)$$

Where, I_o (x : y) is the measure of between state inequality ; X_g is g^{th} state's household share and I_g (x : y) is a measure of inequality within state.

RESULTS

Irrigation development : An analysis across farm classes

The percentage change in fully, partially and wholly irrigated holdings in 2010 over 1995 levels was computed and it was found that all farm classes except small and marginal farmers registered a decline in number of households as well as acreage. The number of wholly irrigated households increased across all farm classes with small and marginal farmers the

Table 1. Temporal changes in distribution of irrigation in 2010 over 1995 (in percent). Source: Agricultural census 1995 and 2010.

Farm size	Total		Canal		Tanks		Wells		Tube-wells		Other sources		Irrigated holdings	
	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area	No.	Area
Marginal	30	28	29	24	– 7	– 4	90	72	50	52	10	5	42	37
Small	14	15	3	12	– 26	– 14	17	39	34	59	8	33	18	35
Semi-medium	– 3	–3	–8	2	– 43	– 27	– 11	12	30	46	–2	31	3	21
Medium	–17	–18	–14	– 5	– 52	– 35	– 34	– 17	26	40	– 12	33	–12	9
Large	–31	–30	–25	– 20	– 64	– 38	– 52	– 43	19	34	–38	41	–28	– 5
All classes	20	–2	17	5	– 16	– 18	33	9	44	48	7	25	28	22

largest gainers, i.e., 47 and 42% increase in irrigated area (Table 1). The percent increases in irrigated households have been greater than increase in total number of households under small and marginal farm classes. However, marginal and small farm classes have registered 31 and 13% increase in area under wholly un-irrigated households. Increase in area under irrigation among larger land holding classes has been lower for semi-medium, medium and large farmers, i.e., 29, 19 and 31%. But there has been a substantial decline in area under un-irrigated households for semi-medium, medium and large farm classes, i.e., 8, 25 and 31%. This indicates that the distribution of benefits of irrigation have not been proportional.

Further, four major sources of irrigation, viz., canals, tanks, wells and tube-wells were considered for trend analysis. Trends and shifts in area under various irrigation sources in 2010 over 1995 levels were computed to assess the performance of different sources of irrigation across different farm classes (Table 1). The results reveal a clear shift towards groundwater irrigation for all farm classes. Small and marginal farmers have been the principal gainers in absolute terms having registered 59 and 52% increase in area under tubewell irrigation systems. Well irrigation systems have also expanded considerably by 39 and 72 in 2010 over 1995. Well irrigation systems primarily consist of dugwells, which draw water from the water bearing strata while tubewell systems comprise bore wells and tubewells that draw water from deeper strata.

In the contrary, medium and large farmers have registered a significant decline in area under well irrigation systems, i.e., 17 and 43%. Area under canal irrigation and tank irrigation systems has also declined significantly. However, there has been a substantial increase in area under tube-well irrigation systems, viz., 40% for large farmers and 34% for medium farmers. It clearly points to the fact that the tube well irrigation in India is expanding across all classes of farm households, proportionally higher for small holders in terms of number of well irrigation structures and for large holders in terms of area operated. Small and marginal farmers have registered an increase in area under canal irrigation systems by 12 and 24% respectively.

Regional disparities in irrigation development

Regional disparities have been observed across the irrigation sources and states in India. Regional disparities arise due to differences in natural resources endowment like availability of groundwater and perennial or seasonal nature of the rivers. The concentration of irrigation facilities for major agriculture states was analyzed using the location coefficient using agriculture census data of 2010 (Table 2). It was found that Punjab, Haryana and UP have a larger concentration of irrigated agriculture than the national average. Maharashtra, Karnataka and Odisha were found to have significantly low concentration of irrigated area. Thus, irrigation development is matter of great concern in these states. Canal irrigation systems were heavily concentrated in states of Maharashtra, Karnataka, Rajasthan and Odisha, which incidentally also had lower concentration of net irrigated area. In other words, Punjab, Haryana and UP were found to

Table 2. Estimates of location coefficient for irrigation sources, 2010. Source: Author estimation, 2019.

State	Net irri-ga-ted area	Ca-nal	Tank	Well	Tube-well
Andhra Pradesh	0.94	1.41	3.59	0.82	0.70
Gujarat	1.02	0.77	0.32	2.01	0.56
Karna-taka	0.66	1.09	1.30	0.63	1.03
Kerala	0.54	0.60	3.46	2.07	0.15
Madhya Pradesh	1.08	0.61	0.65	2.06	0.68
Maha-rashtra	0.41	1.24	0.68	2.52	0.09
Odisha	0.65	2.69	1.41	0.12	0.12
Punjab	2.46	0.78	0.05	0.01	1.75
Rajas-than	0.79	0.92	0.21	1.73	0.93
Tamil Nadu	1.24	0.84	4.41	2.51	0.25
Uttar Pradesh	1.88	0.74	0.22	0.40	1.60
West Bengal	1.54	0.56	1.94	0.07	1.44
Haryana	2.23	1.85	0.07	0.07	1.06
Bihar	0.90	0.48	0.01	0.10	0.48
All India	1.17	1.04	1.31	1.08	0.77

have high concentration of groundwater irrigation systems composed primarily of tube-well irrigation systems.

Equity impacts of irrigation development

Distribution of land has close linkages to the distribution of benefits of irrigation due to the property rights associated with groundwater in India. Therefore, Theil's measure of entropy for distribution of land holdings was calculated. It was found that inequity in groundwater distribution has declined marginally over the last decade. On the one hand, Theil's measure for gross irrigated area declined from 1995 to 2000 but has increased ever since. A source wise analysis reveals that inequality in canal irrigation systems has marginally declined, while that of non-canal irrigation systems have increased substantially (Table 3). It can be safely concluded that the increase in distributional inequality is driven mainly by non-canal irrigation systems. The increase in inequality in gross cropped

Table 3. Estimates of Theil's index values for different irrigation sources All India Level. Source: Author estimation, 2019.

Sources	1995	2000	2005	2010
Total area	0.59	0.55	0.55	0.52
Net irrigated area	0.40	0.40	0.40	0.43
Canal	0.39	0.40	0.33	0.39
Non-canal	0.41	0.40	0.40	0.44
Tank	0.17	0.11	0.11	0.16
well	0.79	0.66	0.74	0.61
Tube-well	0.34	0.32	0.36	0.42
Other sources	0.26	0.27	0.29	0.46

area, while land distribution has become less skewed, albeit marginally, indicates that socio-economic factors other than size of holding are crucial in increasing distributional inequalities. This is corroborated by the fact that inequality has worsened in non-canal irrigation systems, which requires larger amounts of private investment. The two major components of non-canal irrigation systems are well and tube-well irrigation systems. Well irrigation systems show the highest levels of inequality in absolute terms.

Since Theil's measure is composed of two factors, viz., within group inequalities and between group inequalities. The decomposition of this measure will help us to understand with greater clarity the prime drivers of inequality. Decomposition analysis of net irrigated area reveals that there has been a decline in absolute values of between state inequalities (BTSE) indicating a reduction in regional bias in irrigation development over a period of time. On the other hand, increase in within state inequalities (WTSE) is concerning. Increase in WTSE point towards an increasing gap between small and large land holding classes in terms of access to irrigation (Table 4). Canal

Table 4. Decomposition of Theil's index values for irrigation. Source: Author estimation, 2019. BTSE indicates inequality between states and WTSE indicates inequality within state.

	BTSE		WTSE		% BTSE	
Sources	1995	2010	1995	2010	1995	2010
Total area	0.18	0.13	0.41	0.39	31	25
Canal	0.15	0.14	0.24	0.24	39	37
Tank	0.10	0.10	0.07	0.06	59	62
Well	0.58	0.39	0.21	0.21	74	65
Tube-well	0.22	0.27	0.12	0.15	65	64
NIA	0.17	0.15	0.24	0.28	42	35

Table 5. Theil's index values for different states, 2010. Source: Authors estimation, 2019.

States	Total	Canal	Tanks	Wells	Tube-wells	Other sources	Irrigated holdings
Andhra Pradesh	0.37	0.13	0.13	0.30	0.42	0.40	0.23
Gujarat	0.43	0.43	0.17	0.35	0.61	0.38	0.39
Karnataka	0.41	0.24	0.17	0.16	0.64	0.40	0.37
Kerala	0.38	0.63	0.90	0.24	0.39	0.71	0.48
Madhya Pradesh	0.42	0.37	0.38	0.48	0.54	0.33	0.45
Maharashtra	0.37	0.29	0.15	0.40	0.33	0.15	0.31
Odisha	0.25	0.21	0.24	0.33	0.11	0.26	0.22
Punjab	0.37	0.52	0.37	0.12	0.35	0.13	0.38
Rajasthan	0.64	0.73	0.15	0.15	0.32	0.23	0.38
Tamil Nadu	0.40	0.33	0.12	0.38	0.26	0.30	0.30
Uttar Pradesh	0.34	0.29	0.65	0.42	0.37	0.14	0.36
West Bengal	0.22	0.20	0.16	0.21	0.20	0.25	0.20
Haryana	0.62	0.61	0.50	0.80	0.62	0.68	0.62
Bihar	0.29	0.30	0.23	0.29	0.30	0.34	0.30

irrigation systems have registered a decline in BTSE, but the level of WTSE has increased. Well irrigation systems have registered a decline in BTSE as a result of expansion of groundwater irrigation across the country. The level of WTSE has also declined and corroborating our hypothesis that shift of large farmers away from well irrigation systems have led to improving distribution inequality in well irrigation systems. Tube-well irrigation systems were the only source to show an increase in both BTSE and WTSE.

Inequality across states

The source-wise analysis of inequalities of irrigation in 2010 reveals that Haryana had the highest levels of inequality in the distribution of land holdings and well irrigated areas (Table 5). Kerala has highest inequality in the distribution of tank irrigation systems, while Rajasthan had the highest inequality in the distribution of canal irrigation systems. Karnataka had highest levels of inequality in the distribution of tube-well irrigation. Intriguingly the inequality in the distribution of land holdings was lower than the inequality in distribution of irrigated areas in all states except Punjab, UP and Kerala. Mean value of inequality was found to be the highest in tube-well irrigation systems and the lowest in tank irrigation system. Variability in inequality indices across states is found to be highest in tank irrigation systems and minimum in canal irrigation systems.

DISCUSSION

Fragmentation in landholdings and overexploitation of groundwater

The regional disparity in distribution of irrigation development in general and groundwater irrigation in particular seems to have led to the emergence of issues of intergenerational inequality in regions of higher irrigation concentration. The irrigation policy of the government that laid excessive emphasis on groundwater irrigation systems have led to over exploitation and unsustainable usage of groundwater resources (Shah 2011). Low water use efficiency and the dependence on water intensive rice-wheat cropping system have led to unsustainable groundwater usage (Sarkar 2011, Singh 2011, Jeevandas et al. 2008). On the other hand, in alluvial zones, over-exploitation has emerged as the single most important factor (Badiani and Jessoe 2013). However, the tube-well development is both a cause and effect of receding of groundwater. Inequality conditions under tube-well irrigation systems have worsened revalidating the above hypothesis of water scavenging economy that disproportionately benefit well off farmers. There has been a decline in water tables in regions having high concentration of tube-well irrigation systems (CGB 2014). Increasing distributional inequalities are in line with macro level observation of regional bias in the concentration of tube-well irrigation development. Receding water tables and increase in pressure on groundwater means that resources poor farmers often have to bear a disproportionately large share of the negative externalities associated with groundwater depletion (Jacoby 2017). This might lead to distributional inequalities in access to tube-well irrigation systems though a feedback mechanism.

Food security, groundwater and sustainable farming

In order to ensure food security on a sustainable basis, three concerns need to be addressed: The adequate supply of irrigation water to sustain the growth in agriculture production at regional level, The water security for poor farmers (marginal) to grow for subsistence and The adequate economic incentive for farmers to maximize their production from the available land water with least environmental consequences (Kumar 2003). Kumar (2003) argued that the capacity to augment the existing irrigation potential through conventional technologies is fast reaching the limits. The area under surface irrigation is increasingly facing the threat of land degradation and productivity declined. On the other hand, the demand for water from urban domestic and industrial sectors is growing in leaps and bounds. This coupled with the widening gap between the overall demand and supplies would severely limit water availability for producing food for the growing population (Mukherjee 2007). The situation has become more complex due to continuously fragmentation in operation landholding. The poor marginal and small farmers face several constraints in adopting agricultural technologies and agronomic practices needed to maximize the productivity of land and water (Hoogesteger and Wester 2018). The shortage of biomass limits the ability of farmers to adopt organic farming practices that are more sustainable. These are some of the major concerns of sustainable agricultural production and food security (Nayak 2009).

Property rights and equity impacts

Previous studies on equity impacts on irrigation had proposed a shift in focus towards privately owned irrigation systems with emphasis on subsidized investment to ensure greater equity and efficiency in irrigation (Sampath 1990, Shah 2011). Another strand of thought recommends a shift towards Rawlasian allocation of canal irrigation water to reduce inequality (Selvarajan et al. 2001, Janakarajan and Monech 2006). The present study discusses the role of property rights in ensuring equal access to irrigation with special emphasis on groundwater irrigation. India's groundwater law is based on the Estatement Act, 1882, which gives right to everyone to extract water from under his land. The close links between land ownership and water entitlements coupled with a flat rate tariff on electricity consumed for agricultural purpose, water have led to groundwater overdraft and depletion (Shah 2011, Kumar et al. 2011). Farmer's individual effort to appropriate economic benefit will lead to collective welfare loss and the loss will fall disproportionately on small farmers (Nagaraj et al. 2003). Greater risk associated with well failures and their inabilities to bear heavy losses associated with them make small farmers more vulnerable to negative externalities of resource mining (Solomon and Rao 2018). By privatising the access to groundwaters resources, although initially equity position improved, in the long run small and marginal farmers are the net losers due to their limited financial abilities. This could lead to widening of farm income inequalities in the future. The demand and supply of water in agriculture could be matched by adopting following solutions: Flexibility in allocating supplies in response to both short-term and long-term, Security of tenure to encourage investment and maintenance of water use system, while allowing for users to respond voluntarily to incentives to reallocate supplies, Whether or not the user is confronted with the real opportunity costs of the resources, Predictability of the outcome of the transfer, Equity impacts, Whether or not the public values are adequately reflected in the process and Low transaction costs of moving water from one use to another use.

CONCLUSION

The study has revealed that there is an increase in distributional inequalities across farm classes as indicated by Theil index values. Regions belonging to the upper tracts of Indo-Gangetic plains have exploited both canal and groundwater potential on a large scale, while regions of Eastern and peninsular India lagging behind. On the other hand, Eastern India, despite having abundant groundwater potential, has lagged behind. Decomposition analysis reveals that both BTSE and WTSE state inequality has increased for tube-well irrigation systems highlighting the dangers of a water scavenging economy that perpetuates inequity. The provision of electricity subsidies has disproportionately benefitted the better off farmers perpetuating inequities in distribution of groundwater irrigation and accentuating income differentials. In the light of above evidences, the present study suggested following policy implication: There is need to decouple right to groundwater from that of land, which could facilitate equitable access to water leading to better social outcomes, Conjunctive usage of irrigation water and a balanced irrigation policy taking into account the natural resources endowments and constraints is essential for sustainable irrigation development, Increasing awareness among farmers about the consequences of competitive well deepening and devising policies to nudge them towards conservation of groundwater resources is essential Low-cost water saving technologies will be enable the poorest sections of the communities to practice irrigated agriculture with very limited water in water scarce regions and Institutional reforms in the water sector, effecting the establishment and enforcement of private and tradable water rights on groundwater and the water supplied from public reservoirs, can together bring about a significant increase in farm outputs with the reduction in the aggregate demand for water in agriculture.

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