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Groundwater Utilisation and Distributional Inequality in India: A Spatio-Temporal Analysis

S. Kiruthika and D. Suresh Kumar*

ABSTRACT

Development of groundwater irrigation (GWI) in India has been very impressive after the introduction of the green revolution. Though GWI provides additional benefits to farmers, continuous exploitation of groundwater has resulted in a dramatic decline in the water table and led to salinization and quality deterioration in many parts of the country. The present paper aims to examine the distributional o in groundwater resources and the extent of depletion of groundwater resources across size groups. Substantial inequality persists in the distribution of land among different farm size groups resulting in inequality in accessibility of groundwater resources. Unequal distribution of groundwater sources in favour of the medium and large farmers was proved by the Theil's index of 0.607 in 2005-2006 which increased to 1.071 in 2015-16. Providing subsidies for adoption of water management technologies like drip and sprinkler will reduce the water use by farmers. Other measures like imposing spacing norms between wells, licensing well digging activities, and community management may also be encouraged.

Keywords: Groundwater, irrigation, over-exploitation, inequality, Theil's index

JEL: Q15, Q16, Q25

I

INTRODUCTION

India is the largest user of groundwater in the world using 260 cubic km per year which accounts 25 per cent of all groundwater extracted globally. Out of the total net annual groundwater availability, 90 per cent is used for irrigation while the rest 10 per cent is used for domestic and industrial purposes (Government of India, 2018). Groundwater irrigation contributes significantly to agricultural production because of its reliable supply during the critical stages of plant growth and catalytic effects on inputs like fertilisers (Pingali *et al*., 1997; Bhattarai *et al*., 2001). It is estimated that around 70-80 per cent of value of irrigated production depend on groundwater (Dains and Pawar, 1987).

Unlike other sources of irrigation, groundwater irrigation in India is owned, managed and controlled by farmers themselves (Shah, 1993; Vaidyanathan, 1996). Decentralised availability, easy accessibility, cheap power pricing policies, lack of ineffective groundwater legislations and absence of well-defined property rights made groundwater a major source for agriculture and drinking water supply (Selvarajan *et al.*, 2001; Suhag, 2016; Suresh Kumar and Palanisami, 2019). Injudicious and

* Assistant Professor, Department of Agricultural Economics, Adhiparasakthi Horticultural College, Ranipet -632 506 and Professor and Head, Department of Agricultural Economics, Tamil Nadu Agricultural University, Coimbatore-625 104 (Tamil Nadu), respectively.

inefficient use of groundwater in agriculture led to depletion of the resource as exploitation of aquifer is often carried out by thousands of individual users who act in a completely independent manner from each other (Llamas and Martinez-Santos, 2005). Access to groundwater resource has favoured growing high water loving crops like rice, wheat, sugarcane and cotton to traditional low water requiring crops. It is observed that the states of Punjab, Haryana, Tamil Nadu, Telangana and Uttar Pradesh are the least sustainable in groundwater use for irrigation (Srivastavaa *et al.*, 2018).

It is found that there exists a considerable inequality in distribution of irrigable area across farm size class which is lower than inequality in land distribution. It necessitates ensuring equality in groundwater distribution among farmers of different size groups (Sampath, 1990). Inequality in the distribution of irrigated area shows mixed trend of declining in the period 1970/71 to 1976/77 and increasing in the period 1976/77 to1980/81 (Sampath, 1992). Selvarajan *et al.* (2001) analysed inter-farm size inequality in irrigation distribution in India at all-India level as well as at the state level using Theil's entropy measure which indicated a mixed trends during 1970s and 1980s. The inequality in distribution of flow and lift irrigation increased between decades and declined within decade at national level whereas wide inter-state variation is seen in the level of inequality with highest inequality in Bihar (Selvarajan *et al.*, 2001).

There exists a close nexus between groundwater irrigation and surface irrigation development. Recharge of groundwater from perennial rivers and developments in canal irrigation lead to increase in area under groundwater irrigation in northern and eastern parts of India but decline in the area irrigated by tanks and canal (Narayanamoorthy, 2010). Unlike the surface irrigation, where the equitable distribution of water could be better achieved by functioning of institutions at different levels, achieving equality in groundwater use and extraction is hard to achieve as it is privately owned. Thus, there is a need to study inequality in distribution of groundwater resources across size group of farmers. Realising the significance of groundwater and its contribution to the economic development, the present paper aimed to study the level of inequality in accessing groundwater for irrigation among different size groups across major states of India. The study is focused on finding answers to following questions (i) what is the extent of utilisation of groundwater in irrigation? (ii) whether there is inequality in access to groundwater sources among different farm size classes? and (iii) whether the inequality is a reason for groundwater depletion?

Groundwater abstraction structures like dug wells and tube wells were taken as a proxy for access to groundwater sources. It is hypothesised that (i) there exists an inequality in distribution between number of land holdings and area of land holding across different farm size classes, (ii) the distributional inequality between number of landholdings and number of groundwater sources across different farm size groups have increased over the decade, (iii) there is no significant relationship between the distributional inequality and groundwater depletion. To test the hypothesis the present paper aimed to (i) examine the long term trends in groundwater utilisation in agriculture (ii) estimate the level of inequality in distribution of groundwater sources among different size groups across major states of India and (iii) analyse the relationship between distributional inequality and groundwater depletion.

II

DATA AND METHODOLOGY

2.1. *Data*

To fulfil the objectives of the study, secondary data on number and area of land holdings according to farm size classes are collected at the national level and state level from *All India Report on Agriculture Census 2005-2006* and *2015-2016*. The number of dug wells, tube wells – shallow, medium and deep tube wells owned by different farm size classes was collected from 4th and 5th Minor Irrigation Census. Data was collected for five different farm size classes, viz., marginal (less than 1 ha), small (1-2 ha), semi- medium (2-4 ha), medium (4-10 ha) and large (10-20 ha and above).

2.2. *Methodology*

Land availability and accessibility to irrigation water play a vital role in the determination of the level and distribution of agricultural production and in turn fortitude income distribution among farmers. An essential pre-requisite for ensuring equitable distribution of income through irrigation-led agricultural development is the equitable distribution of land and water resources. Thus quantitative assessment of inequality in irrigation water distribution is extremely important for supporting irrigation policy. Since groundwater has become the major source of irrigation an appraisal on its equality in distribution is highly significant for improved irrigation policy decision-making. Any useful method of inequality must integrate both objective and normative measures (Sampath, 1990). Seven inequality measures such as range, relative mean deviation, variance, coefficient of variation, standard deviation of algorithms, Gini coefficient and Theil's entropy measure were considered. Among these Theil's entropy measure was found to be more adaptable than the remaining measures analysed as it had attractive cardinal properties and suitable for decomposition analysis.

2.2.1. *Theil's Entropy* Measure

Theil's entropy measure (Theil, 1967; Sampath, 1990) used in this analysis is outlined as follows:

$$T_1\,(y:x) = \sum_{i=1}^{n} y_i \ \ln\left(\frac{y_i}{x_i}\right) \qquad \text{.... (1)}$$

where; x_i = relative frequency values of the households in i-th farm size class; and y_i = relative frequency values of the irrigation attribute in i-th farm size class

$$T_2\ (x : y) = \sum_{i=1}^{n} x_i \ \ln\left(\frac{x_i}{y_i}\right) \qquad \text{…. (2)}$$

where; x_i = total no. of households in i-th farm-size class as a proportion of total in the country as a whole and y_i = irrigation attribute of i-th farm size class as a proportion of total in the country as a whole; i = 1, 2 ...9 in this study.

Both [1] and [2] are Theil's two variants of the information theoretic measure, which are analogous. They differ only in terms of the weighting within-set inequalities. Following (Sampath, 1990), T2 is used in our analysis since our interest is in showing the extent of inequality in groundwater resource distribution across agricultural farm households. The range of Theil’s index is between zero and infinity and increased value over the decade indicates increased inequality.

2.2.1.1. *Inequality Decomposition*

$$I\ (x : y) = I_o(x : y) + \sum_{g=1}^{G} X_g I_g \ \ (x : y) \qquad \text{…. (3)}$$

$$I_0\ (x : y) = \sum_{g=1}^{G} X_g \ln\ (x_g/y_g) \qquad \text{…. (4)}$$

where, x_g = g-th state’s household share and y_g = g-th state’s irrigation attribute share; $I_o(x{:}y)$ is the between-state inequality; $I_g(x{:}y)$ is the inequality within the state and;

$$X_g = \sum_{i \in s_g} x_i \text{ and } Y_g = \sum_{i \in s_g} y_i \ ; \ g = 1, \ldots.. , G$$

where; x_i = i-th farm-size class household population share of g-th state; y_i = i-th conditional irrigation attribute share; and letting S_g, g=1,….,G (=9) for the g-th state.

$$I_g(x{:}\,y) = \sum_{i \in s_g} p_i \ln\left(\frac{p_i}{n_i}\right), \qquad g = 1, \ldots\ldots, G \qquad \text{…. (5)}$$

$$P_i = x_i/x_g \ ; \ n_i = y_i/y_g \ \ i \in s_g,\ g = 1, \ldots, G$$

Using Theil's entropy measure, inter-farm size inequality in groundwater distribution in India was analysed at all-India level as well as at the state level. Furthermore, the inequality at the all India level was also decomposed into its constituent parts namely 'between states' inequality and 'within states' inequality. Such an analysis will help in quantifying the sources of inequality for better irrigation policy decisions. Extending this analysis to cover more irrigation attributes would also help in better understanding of inequality status in irrigation distribution with respect to different sources of irrigation.

2.2.2. *Inter-State Analysis of Inequality in Groundwater Distribution*

Given that groundwater development is basically a state domain, inter-state analysis will help in gaining a better understanding of the nature, diversity, and magnitude of the inequality problem

$$I = \sum_{i=1}^{G} x_i \ln (x_i/y_i) \quad \text{…. (6)}$$

where;

x_i = the proportion of households in farm-size group 'i' in the state,

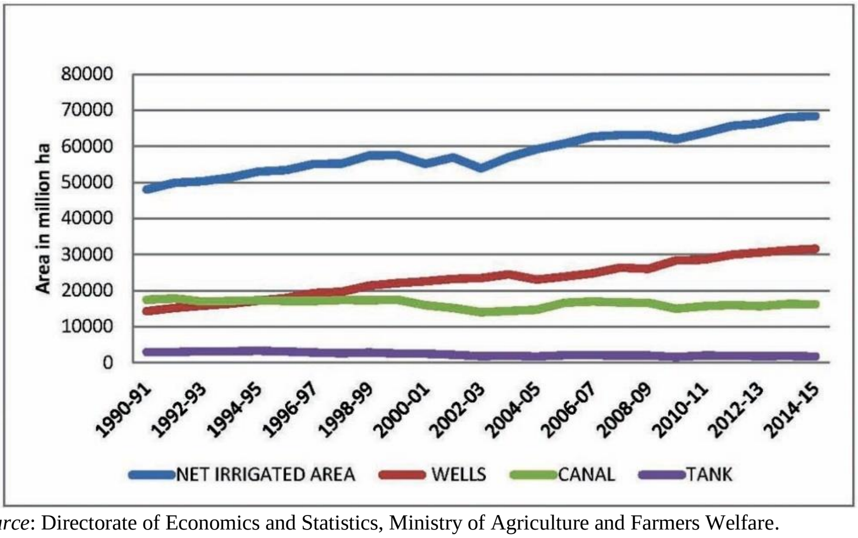
y_i = the proportion of wells that pertains to the i-th farm-size group in the state.

III

RESULTS AND DISCUSSION

3.1. *Trend in Groundwater Utilisation*

The net irrigated area in India increased from 12.46 mha in 1960-1961 to 68.38 mha in 2014-2015 as seen in Figure 1. It is observed from Table 1 that the net area irrigated under groundwater sources increased from 32.6 per cent of net irrigated area in 1960 to 62.82 per cent in 2015 while net area irrigated by canal decreased from 41.9 per cent in 1960 to 23.66 per cent in 2015. Similarly, the area irrigated by tanks declined from 16.6 per cent in 1960 to 2.5 per cent in 2015. The compound annual growth rate calculated for the years 1990 to 2015 shows that the area irrigated by groundwater increased at the rate of 3.50 per cent per annum while net area irrigated by canal and tank declined by 0.14 per cent and 2 per cent per annum respectively.



Source: Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare.

Figure 1. Source Wise Net Irrigated Area in India.

TABLE 1. AREA IRRIGATED UNDER DIFFERENT SOURCES TO NET IRRIGATED AREA

(*per cent to total net irrigated area*)

Sources	1960	1980	1990	2015
(1)	(2)	(3)	(4)	(5)
Groundwater	32.60	49.50	55.8	62.82
Canals	41.90	38.00	35.00	23.66
Tank	16.60	6.50	5.50	2.50

Source: *Agricultural Statistics at a Glance* (various issues).

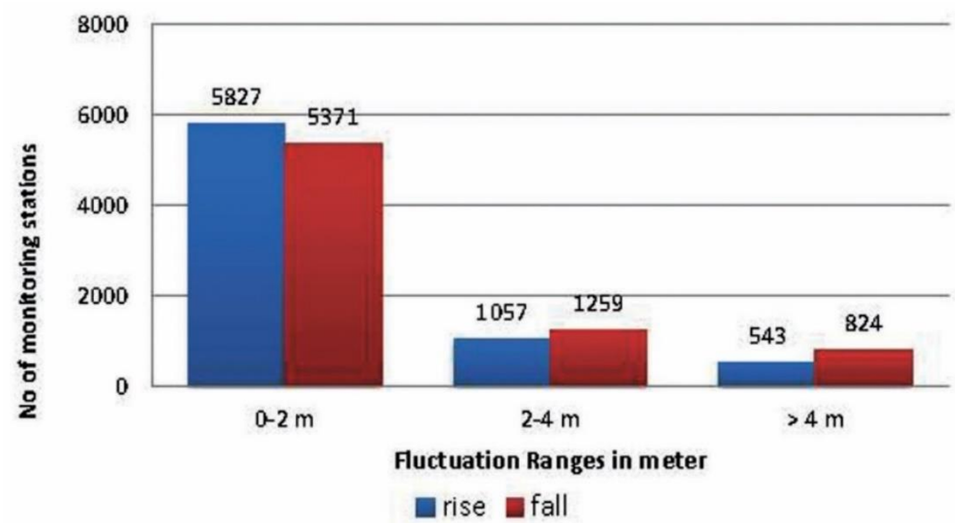
Area irrigated under groundwater has increased by 23.20 per cent to net irrigated area between 1960 and 1990 and area irrigated under canal and tank decreased by 6.90 per cent and 11.10 per cent respectively. The increased utilisation of groundwater in agriculture is mainly due to its easy access and other advantages like improved productivity by 2.5 per cent compared to dry land agriculture (Dhawan, 1995). The other noted basic advantage of groundwater over surface water irrigation is that it is relatively less sensitive to rainfall variability and enables users to obtain water more or less on demand. This has led to more secure agricultural planning and lower levels of risk and encouraged farmers to invest in inputs necessary to utilise new agricultural technologies like fertilisers, pesticides, high-yielding varieties (HYV), which in turn, has increased crop yields (Kahnert and Levine, 1993). Net area irrigated under groundwater has increased by 7.02 per cent between 1990 and 2015 and area irrigated with canal water has declined by 11.34 per cent.

3.2. *Groundwater Exploitation and Declining Water Table*

The over-exploitation of groundwater is characterised by increased depth to water table of aquifers, increased well failure, increased well deepening activities by farmers and reduced discharge from pump set. Analysis of the pre-monsoon water level data indicates that, out of 15,078 wells monitored, depth to water level in 43 per cent wells are in the depth range of 5-10 mbgl, in 23 per cent wells it is in the depth range of 10-20 mbgl. The maximum depth to water level of 134.22 mbgl is observed in Bikaner district of Rajasthan whereas the minimum was less than 1 mbgl. A comparison of depth to water level of pre-monsoon 2017 with decadal mean of pre-monsoon (2007-2016) (Figure 2) indicates that about 39 per cent of wells show rise in water level, out of which 30 per cent wells show rise of less than 2 m. About 61 per cent wells show decline in water level, out of which 43 per cent wells show decline in water in the range of 0-2 m. Around 11 per cent wells show decline in water level in 2-4 m range and remaining 7 per cent are in the range of more than 4 m.

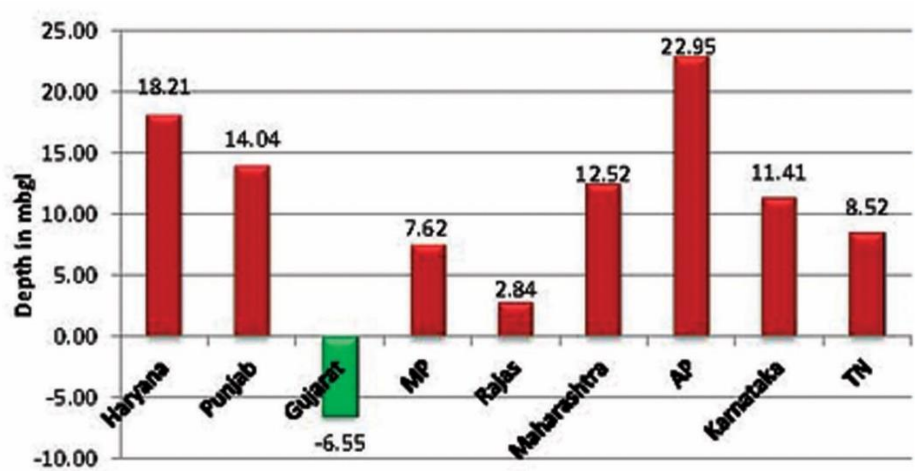
Almost the whole country was showing decline in water level, and maximum decline was observed in and around parts of Rajasthan, Haryana, Punjab, Gujarat, Telangana, and Maharashtra (Government of India, 2018).

Changes in depth to water level between TE 2008-2009 and TE 2017-2018 is given in Figure 3. The highest increase in mbgl (meter below ground level) was found in the state of Andhra Pradesh (22.95 mbgl) followed by Haryana (18.21 mbgl), Punjab (14.04 mbgl) and Maharashtra (12.52 mbgl) while there was decrease in depth by 6.55 m in Gujarat.



Source: Groundwater Year Book 2017-2018

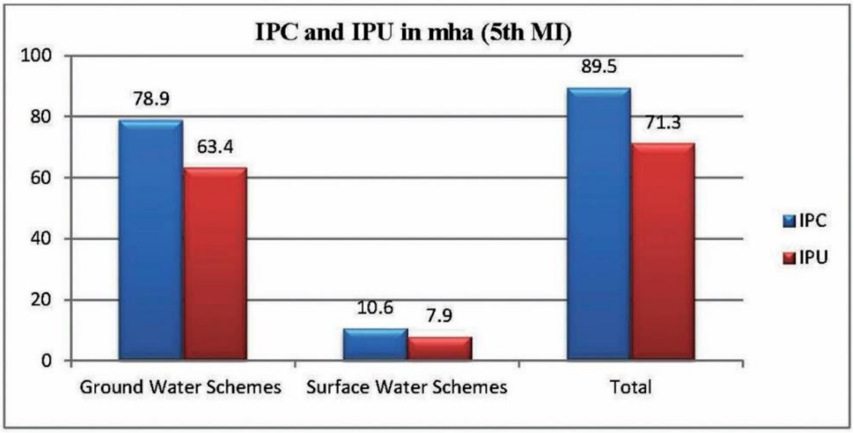
Figure 2. Decadal Water Level Fluctuation with Mean Post Monsoon (2007-16) and Post Monsoon 2017.



Source: Authors' estimate from Groundwater year book 2017-2018.

Figure 3. Change in Depth to Water Level between TE 2008-2009 and TE 2017-2018.

One of our objectives is to study the extent of groundwater exploitation across states. The total groundwater potential for irrigation purpose is 78.9 mha while the potential utilised is 63.4 mha. About 80.3 per cent of potential created is utilised for irrigation while in surface water schemes the irrigation potential utilised is 74.8 per cent of the irrigation potential created. This is shown graphically in Figure 4.



Source: *Groundwater Year Book 2017-2018*.

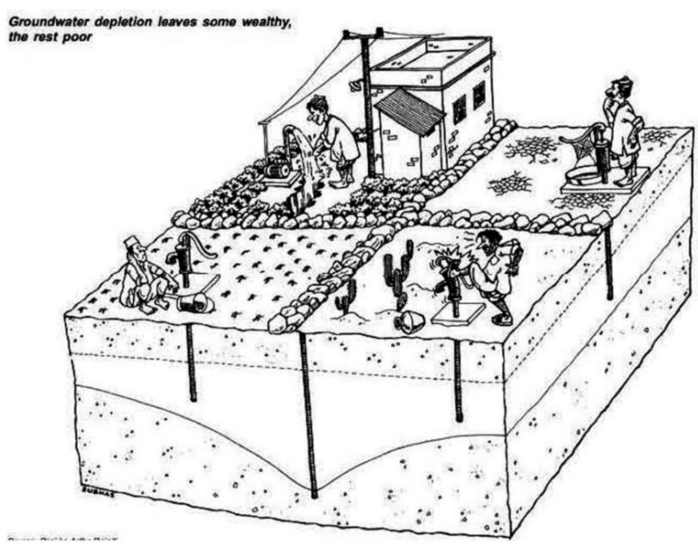
Figure 4. Irrigation Potential Created and Irrigation Potential Utilised in 5th Minor Irrigation Census.

The state of groundwater exploitation is not the same across states because of the difference in agro-economic and physical factors like recharge from rainfall, canal, etc., The stage of groundwater development is more than 100 per cent in states like Punjab, Haryana and Rajasthan while it is less than 60 per cent in states of Madhya Pradesh, Maharashtra and Andhra Pradesh. Relatively slow growth of surface irrigation, use of intensive production technologies and cultivation of water intensive crops has caused the exploitation of groundwater in these states. The intensity of exploitation of groundwater is not uniform across the states. About 80 per cent of critical blocks are accumulated in six states – Haryana, Karnataka, Andhra Pradesh, Gujarat, Uttar Pradesh and Rajasthan. When we look at the state of groundwater over exploitation at state level, it is even worse. The percentage of blocks classified as critical and over-exploited is highest in Punjab (79 per cent), Rajasthan (70 per cent) and Haryana (66 per cent) where the stage of groundwater development is more than 100 per cent. Groundwater levels have been declining more than 5 mts/year during both the pre-monsoon and post-monsoon period of 2017 in 50-64 per cent of wells belonging to states such as Andhra Pradesh, Gujarat, Haryana, Madhya Pradesh and Tamil Nadu. It is evident from the above discussion that the over-exploitation of groundwater is common in most of the regions in India.

A number of supply and demand factors which are expected to change over time and between regions determine the exploitation of groundwater. The important factors that determine the exploitation of groundwater are: the density of electric pump sets to cropped area; ratio of area under water consuming crops to cropped area; ratio of area under groundwater to total irrigated area; cropping intensity; area under surface irrigation; level of rainfall; use of horse-powered pump sets; nature and prevalence of water markets; extent of adoption of water-saving technologies (drip and sprinkler); availability of electricity supply (in terms of hours); tariff rate of electricity; availability of groundwater potential; development of modern agriculture; and the state's policy on groundwater use, etc. (Narayanamoorthy, 2010; Srivastavaa *et al.*, 2018). The groundwater extraction is influenced by many factors such as farmers' crop choice which in turn influenced by markets, prices, water availability, socio-economic and institutional factors (Suresh Kumar and Palanisami, 2019). The practice of providing power subsidies for agriculture has played a major role in the decline of water levels in India. Electricity subsidy has increased the electricity consumption in agriculture. Electricity subsidy in India increased from 4,621 crore rupees in 1990-1991 to 90,000 crore rupees in 2018. Provision of subsidy increased the demand for groundwater which in turn led to an increase in agriculture yields and agriculture revenues. This induced farmers to use more water intensive crops. Consumption of electricity for agriculture purpose has increased tremendously from 50321 GWh in 1990-1991 to 191151 GWh in 2016-2017 (Government of India, 2019) which explains the overdraft of groundwater at national level.

3.3. *Inequality in Groundwater Distribution*

Access to groundwater can be a major mechanism enabling farmers' transition out of poverty. Increased access to groundwater benefits farmers with higher yields and reduced risk in agricultural production. This enables small farmers to accumulate assets, move out of poverty and develop non-agricultural livelihoods. Farmers with better access to capital and other resources progressively benefit at the expense of those farmers with fewer resources (Moench, 2003). The conceptual relationship between groundwater access is outlined in the Figure 5.



Source: Adapted from Moench *et al*. (1999).

Figure 5. Externality in Access to Groundwater.

However, the present paper attempts to assess the inequality in access to groundwater sources among different farm size holdings across major states over a decade. It is important to examine the inequality in ownership and land holding size first as distribution of groundwater is linked with the corresponding distribution of land holding size among different class and ownership. Ownership is given by number of land holdings and area of land holding gives the size of land holding across different farm size classes.

The persistence of inequality in land ownership and distribution among various farm size classes at national level and state level was confirmed by this study. The marginal farm size class holding less than 1 ha constituted 64 per cent of the operational holdings but owned only 20 per cent of total operational area in 2005-2006 while the medium and semi-medium class together constituted 11 per cent of operational holdings but owned 44 per cent of the operational area. The large farmers owned 11 per cent of operational area even though they constitute only 0.8 per cent of operational holdings. This clearly indicates the existence of inequality in distribution of land holdings and ownership of land across different farm size class which is confirmed by Theil's inequality index of 0.153 (Table 2). Out of the total inequality at national level, 53 per cent is due to between the states inequality and 47 per cent is due to within the states inequality. The inequality in distribution of land among different size of land holders increased from 0.153 in 2005-2006 to 0.420 in 2015-2016 which indicates a consistent increase in land inequality over the decade. Within the states, inequality has decreased to 45.71 per cent and between states inequality increased to 54 per cent. Thus the hypothesis that there exists an inequality in distribution between number of land holdings and area of land holding across different farm size class has been proved.

TABLE 2. THEIL'S INEQUALITY INDEX – NATIONAL LEVEL

All India Level inequality between (1)	2005-2006 Total inequality (2)	2005-2006 Within State (3)	2005-2006 Between states (4)	2015-2016 Total Inequality (5)	2015-2016 Within State (6)	2015-2016 Between states (7)
Operational holdings and operational area [1]	0.153	0.072 (47.05)	0.0806 (53)	0.420	0.192 (45.71)	0.227 (54.04)
Operational holdings and groundwater source [2]	0.607	0.575 (94.73)	0.033 (5.4)	1.071	1.04 (97.2)	0.031 (2.8)
Operational area and groundwater source [3]	0.640	0.587 (91.71)	0.053 (8.28)	1.339	1.1100 (82.9)	0.229 (17.1)

Source: Authors' own estimates using data from All India Report on Agriculture Census 2005-2006 and 2015-2016 and 4th and 5th Minor Irrigation Census.

Notes: Figures in parentheses indicate percentage of inequality. 1- Defined as inequality between number of land holdings and size of land holdings in ha, 2-Defined as inequality between no of holdings and no of wells and tube wells owned, 3 - Defined as inequality between area of holdings in ha and no of wells & tube wells owned.

This analysis has confirmed that the highest inequality is found within the state of Haryana for both the years. However, the level of inequality is lower in the distribution of land among various categories of farmers in Tamil Nadu, Punjab and Andhra Pradesh whereas moderate level inequality is observed in Karnataka, Gujarat, Madhya

Pradesh and Rajasthan. The inequality in distribution of land among different farm size classes within the state has increased largely in Gujarat from 0.52 to 1.91 and increased marginally in Haryana from 1.32 to 1.35 (Table 3) while in other states there was decrease in inequality over the decade. The marginal decline of inequality in the distribution of land among various classes may be due to increase in the number of farm lands due to fragmentation (Singh, 2006). The inequality between operational area and groundwater sources owned has increased from 0.640 to 1.339 over the decade.

TABLE 3. STATE LEVEL INEQUALITY BETWEEN NUMBER OF OPERATIONAL HOLDINGS AND OPERATIONAL AREA

	Inequality within the state			
State	2005-2006	Rank	2015-2016	Rank
(1)	(2)	(3)	(4)	(5)
Haryana	1.32	1	1.35	2
Punjab	0.36	9	0.34	9
Gujarat	0.52	4	1.91	1
Madhya Pradesh	0.53	3	0.39	6
Maharashtra	0.39	7	0.39	7
Rajasthan	0.78	2	0.63	3
Andhra Pradesh	0.40	6	0.38	8
Karnataka	0.50	5	0.43	4
Tamil Nadu	0.36	8	0.41	5

Source: Authors' own estimates using data from All India Report on Agriculture Census 2005-2006 and 2015-2016 and 4th and 5th Minor Irrigation Census.

This study brings out that the highest inequality between area of holdings and groundwater source owned was seen in Gujarat (0.66) for 2005-2006 and in Haryana (0.62) for 2015-2016 (Table 4). The level of inequality is lower among various categories of farmers in Tamil Nadu, Punjab, Madhya Pradesh, Maharashtra and Andhra Pradesh whereas moderate level of inequality is observed in Karnataka and Rajasthan. The inequality in distribution of land and groundwater sources among different farm size classes within the state has decreased marginally in Haryana from

TABLE 4. INEQUALITY BETWEEN AREA OF OPERATIONAL HOLDINGS AND NUMBER OF WELLS OWNED ACROSS DIFFERENT FARM SIZE CLASS

	Inequality within the state			
State	2005-2006	Rank	2015-2016	Rank
(1)	(2)	(3)	(4)	(5)
Haryana	0.65	3	0.62	1
Punjab	0.17	9	0.15	6
Gujarat	0.66	2	0.36	2
Madhya Pradesh	0.37	7	0.035	9
Maharashtra	0.39	6	0.17	4
Rajasthan	0.71	1	0.15	5
Andhra Pradesh	0.46	5	0.12	7
Karnataka	0.57	4	0.23	3
Tamil Nadu	0.29	8	0.09	8

Source: Authors' own estimates using data from All India Report on Agriculture Census 2005-2006 and 2015-2016 and 4th and 5th Minor Irrigation Census.

0.65 to 0.62 and decreased to a greater extent in Madhya Pradesh from 0.37 to 0.035 and in Rajasthan from 0.71 to 0.15 while in other states there is moderate decrease in inequality over the decade.

The decrease in inequality in distribution of groundwater among different farm size class over the decade is observed in most of the states. It is due to various legislations taken at the state level. In Punjab restrictions were imposed on new electric connections in over-exploited areas and introduction of drip or sprinkler irrigation and artificial recharge. The area under water saving technologies like drip and sprinkler has increased over the years with highest area in states like Maharashtra (39.2 per cent), Karnataka (23 per cent), Rajasthan (21 per cent) and Gujarat (20 per cent) in the year 2016 (Government of India, 2017).

The analysis reveals that inequality in distribution of land among different farm size class across the state led to inequality in distribution of access to groundwater resources. As groundwater source is owned and used by farmers independently, farmers tend to overexploit the available groundwater for irrigation. Farmers owning larger area have higher access to groundwater source as they can dig more bore wells if one runs out of water. This led to inequality in the extraction of groundwater and indiscriminate exploitation of groundwater by medium and large farmers. As a result, large number of small and marginal farmers is prevented from consuming water for domestic and agriculture purposes. The role of medium and large farmers is greater in depletion of natural resources making other class of farmers to purchase water from large famers. When the scarcity of water aggravates further, the large farmers use the available water for their own purpose and sell the remaining at a higher price to marginal farmers. Thus inequality in distribution of land and groundwater sources leads to over exploitation of resources.

3.4. *Inequality and Groundwater Exploitation*

Various factors like electricity subsidy and shift in cropping pattern towards water intensive crops lead to indiscriminate pumping of groundwater resulting in decreased water table level (Palanisami *et al.*, 2008). Increased area under water intensive crops like paddy, sugarcane and electricity subsidisation to farmers are the main factors leading to groundwater depletion (Sharma, 2016). In Andhra Pradesh, the areas of groundwater depletion (both semi-critical and critical areas) has taken place because of increase in the number of bore wells or open wells and without improving proper replenishing mechanism for recharging the water table (Reddy, 2005). Large farmers have more access to groundwater as construction of bore wells is capital intensive. Hence the inequality in distribution of groundwater sources can also be a factor causing groundwater depletion.

This section explains the linkage of groundwater depletion[1] with inequality in distribution of groundwater sources. Thus analysing the correlation between distribution of groundwater sources like wells, tube wells and percentage of blocks under critical and semi critical zones gives an insight into another cause for depletion of groundwater.

There is a positive relationship between inequality in access to land with the percentage of blocks under critical and over-exploited regions in major states (Table 5). It indicates that higher the degree of inequality in access to land among different farm size class higher the percentage of blocks over exploited. But the positive correlation has decreased from 0.40 in 2005-2006 to 0.007 in 2015-2016. This brings out that correlation between distributional inequality in land and extent of over exploitation has become negligible over the decade. But the correlation between inequality in distribution of land and irrigation sources has increased from 0.30 to 0.43 explaining the over exploitation of groundwater resources is due to distribution of groundwater sources in favour of large and medium farmers.

TABLE 5. CORRELATION COEFFICIENT BETWEEN GROUNDWATER DEPLETION WITH LAND AND GROUNDWATER INEQUALITY AT ALL INDIA LEVEL

(1)	2005-2006 (2)	2015-2016 (3)
Groundwater depletion with land inequality	0.40	0.007
Groundwater depletion with no of holdings and groundwater source	0.30	0.43
Groundwater depletion with area of holdings and groundwater source	0.07	0.29

Source: Authors' own estimates using data from All India Report on Agriculture Census 2005-2006 and 2015-2016 and 4th and 5th Minor Irrigation Census.

There is a greater increase in positive correlation between inequality in distribution of land area and irrigation sources has increased from 0.07 to 0.29 over the decade which confirms the over-exploitation of groundwater resources because of increased inequality. Thus it is proven that distributional inequality can also cause groundwater depletion.

IV

CONCLUSION

The study found that there is tremendous growth in usage of groundwater for irrigation purpose after 1960 to present day and also the declining groundwater levels in many states of India. The study made an attempt to examine the relation between the inequality in distribution of land holdings and access to groundwater. It is found that substantial inequality persist in the distribution of land among different farm size classes which in turn led to inequality in accessibility of groundwater resources. The distributional inequality between number of land holdings and number of groundwater sources owned among different farm size classes has increased over the decade within the state. But the inequality between the states has decreased over the years. Thus the extraction of groundwater clearly goes in favour of the medium and large farmers. Positive correlation of inequality in access to land and groundwater resources with percentage of blocks under critical and over-exploited regions across major states of

India clearly defines that distributional inequality also causes depletion of groundwater. This analysis clearly reveals that small and marginal farmers utilise less water than their due share and they have to pay higher prices for utilising groundwater for irrigation.

According to National Water Policy 2012 - Water Framework Law, groundwater needs to be managed as community resource held by state to achieve equitable and sustainable development. The policy changes should be made in favour of the small and marginal farmers by providing subsidies to use water saving technologies like drip and sprinkler. Measures should be taken to increase the ratio of potential utilised to potential created in surface and minor irrigation schemes. Groundwater development/exploitation should be integrated with surface water bodies like tanks or canal for sustainable water resource management. Groundwater markets are helpful in increasing both efficiency and equality in groundwater distribution and usage.

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NOTE

1) Groundwater depletion in the present study is defined as the percentage of blocks classified as exploited and over exploited across the states.

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