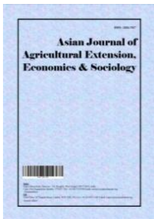

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The Impact of Groundwater Irrigation Development on Cropping Intensity and Crop Productivity in Krishnagiri District

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The study is done with the objective of assessing the impact of groundwater irrigation development on cropping intensity and crop productivity in Krishnagiri, Tamil Nadu, India.
Study Design: Purposive random sampling
Place and Duration of Study: Krishnagiri district, Tamil Nadu, India during 2019-20.
Methodology: The data on irrigation sources and area under various irrigation sources in Krishnagiri, Tamil Nadu and India is subjected to growth analysis using trend studies and CAGR (Compound Annual Growth rate) to study the ground water irrigation development. Whereas, regression analysis was done with the primary data collected from 120 farming households in Krishnagiri on agricultural land use and irrigation to study the impact of groundwater irrigation on cropping intensity and crop productivity.
Results: As the net tube wells and other well irrigated area to net sown area (GWA) increases, there has been a corresponding increase in cropping intensity and crop productivity. The rise in

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percent of net tank and canal irrigated area to net sown area and percent of fertilizer applied area to net sown area have also increased cropping intensity and crop productivity whereas the increase in percent of net rainfed area to net sown area have decreased the cropping intensity and crop productivity.
Conclusion: The ground water utilization through tube well construction have increased the cropping intensity and crop productivity.

Keywords: Irrigation; groundwater development; tube well; cropping intensity; crop productivity.

1. INTRODUCTION

Water is a vital input for agriculture which determines the yield potential of any crop. Precipitation every year provides 4000 billion cubic meters of water across India, out of which only 48% of the precipitation is stored in India's surface and ground water bodies indicating improper rainwater management. About 75% of India's annual rainfall of 1183mm happens during the monsoon within four months; this rainfall fills up the water reservoirs however it may lead to runoff if not properly stored. These reservoirs act as a source for irrigation water supply and domestic water supply. The groundwater and surface water irrigation in combination recorded a utilized irrigation potential of 87 Mha when compared to total irrigation potential of 140 Mha in 2019 which contributed to the rise in the net irrigated area from nearly 18 per cent to 48 per cent in the recent times [1]. This is made possible through the government interventions at various levels. Contemporarily, canal irrigation is found to be a viable source for the farmers living near the canals but not for those who are far away thereby leading to the inequality in water accessibility which is reduced in the case of wells [2]. To prevent the yield loss due to uncertainty of surface water availability, farmers started exploring the option of groundwater irrigation. Between 1960-61 and 1990-91, the number of wells in Tamil Nadu was observed to be doubled [3]. The well irrigation had many benefits including less conveyance loss, more flexibility in timing and quantity [4,5]. A rise in the number of wells allowed the farmers to cultivate multiple crops in a single year increasing the cropping intensity. Groundwater irrigation is found to improve the cropping intensity when compared to the intensity obtained with canal irrigation in the same area [6]. On the other hand, crop productivity per hectare of net sown area has been found to be higher for groundwater irrigated areas of Punjab and Tamil Nadu by 1.5 to 2 times than the canal irrigated areas [4]. This explains the potential of groundwater irrigation in ensuring quality irrigation with stability and reliability. In Krishnagiri, the total net irrigated area increased at the rate of 30% from 2006-2007 to 2017-2018 despite the decreasing trend of net area irrigated through canal and tanks and this increase is attributed to the area irrigated through wells. The advent of groundwater irrigation has changed the agricultural scenario in developing nations around the globe. The rise in groundwater irrigation also found to positively impact the economic status of farm households and their standard of living in Nepal [7]. This study aims at understanding the impact of groundwater irrigation development on the cropping intensity and crop productivity in Krishnagiri district of Tamil Nadu, India. The 'impact' herein implies the extent to which the availability or unavailability of groundwater irrigation for farming affects the cropping intensity and crop productivity. The major objectives of the study are i) To understand the growth and development of groundwater irrigation in Krishnagiri district in comparison to the groundwater irrigation development of the state Tamil Nadu and India as a whole ii) To analyze and observe the impact of groundwater irrigation on cropping intensity and crop productivity in Krishnagiri district.

2. METHODOLOGY

2.1 Study area and Duration of study

Krishnagiri district is located in north-western zone of the state Tamil Nadu in India. Geographically, it is located between 11º12'N to 12º49'N Latitude,77º27'E to 78º38'E Longitude with a total land area of 5143 Sq. Kms. The total cultivated area is 224767 ha and net cultivated area is 180902 ha within total geographical area of 5,14,325 ha. The study took place in Krishnagiri district during the year 2019-20. The maps representing the location of Krishnagiri district with its taluks / tehsils is included for better understanding of the study area.

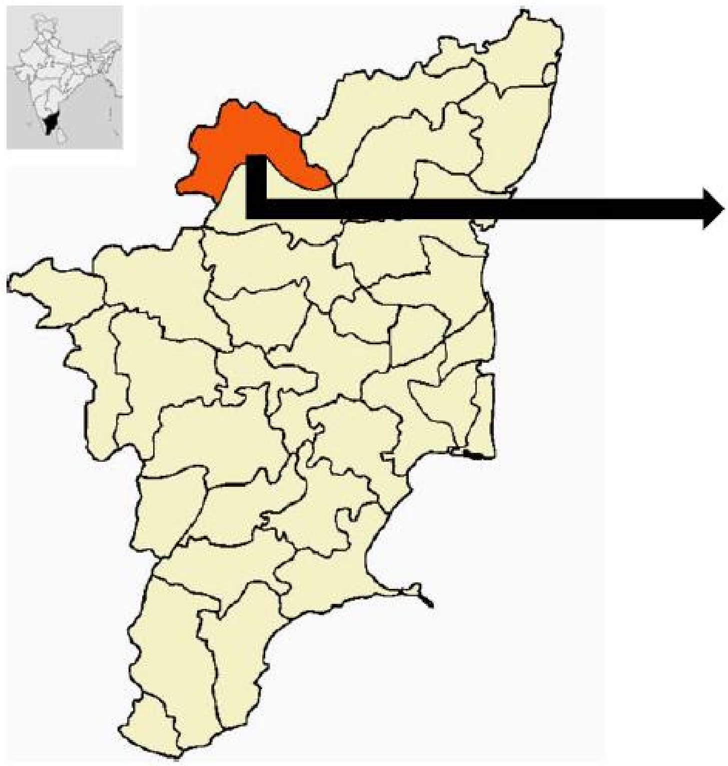


Fig. 1a. Map of Tamil Nadu highlighting the study area (Krishnagiri district)

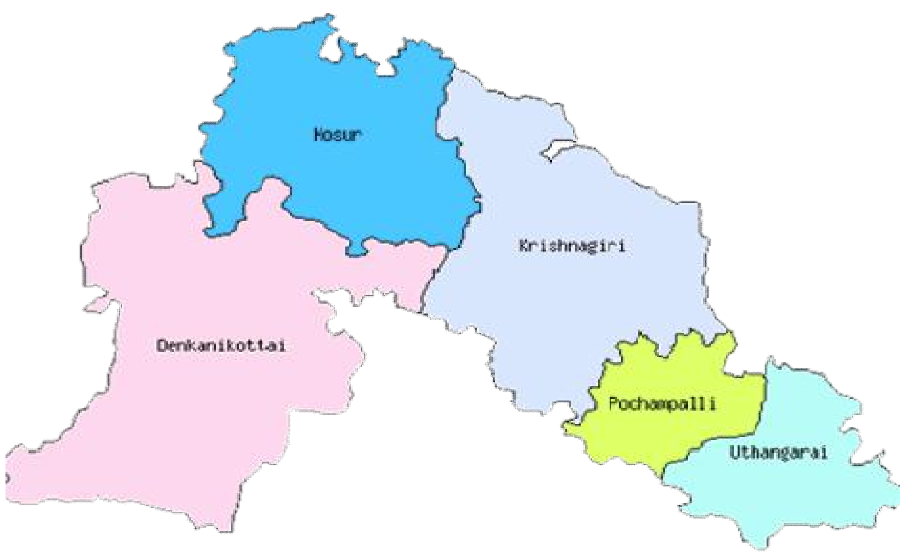


Fig. 1b. Taluk/Tehsil Map of Krishnagiri district

Fig. 1c. Map showing surface water bodies in Krishnagiri District

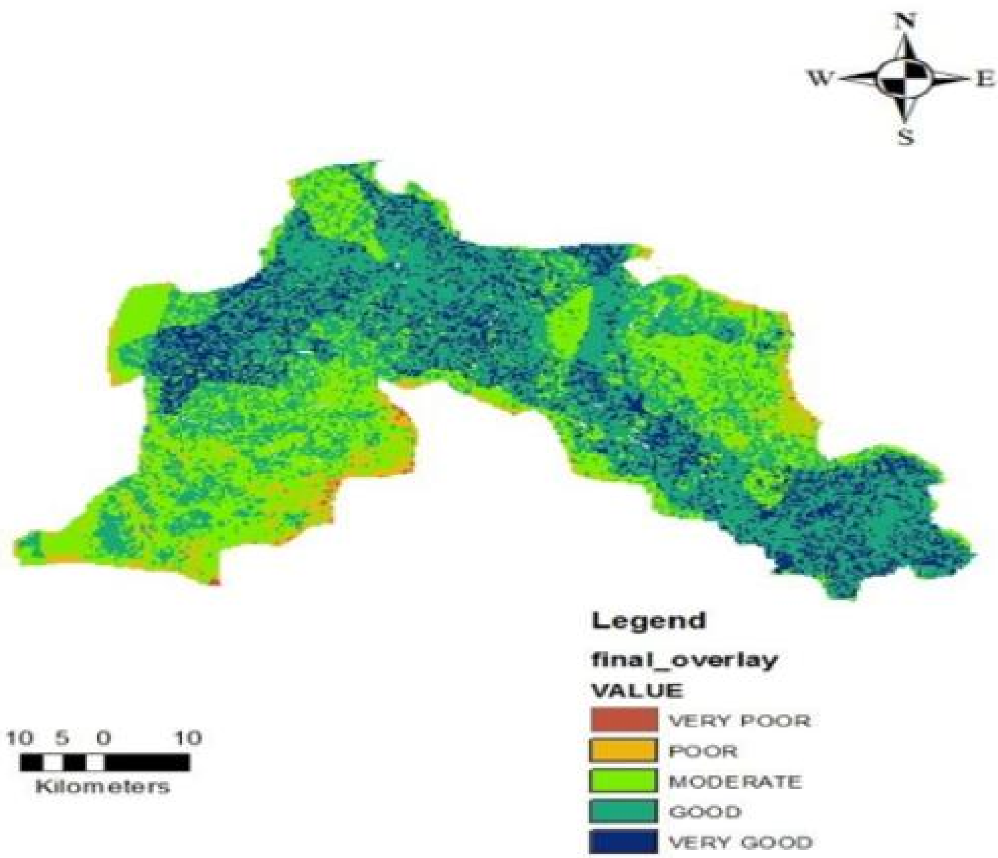


Fig. 1d. Map representing the groundwater potential of Krishnagiri District

2.2 Data Collection and Sampling Design

Secondary data on irrigation sources and source wise net irrigated area was collected from state and central statistical resources and websites to study the trends and development in ground water irrigation in comparison with the other irrigation sources.

The Primary data on agricultural land use and irrigation sources were collected by sampling among the farm households in Krishnagiri district. Krishnagiri district is purposively selected owing to the larger area under groundwater irrigation as compared to other irrigation sources. In Krishnagiri district two taluks viz., Uthangarai and Pochampalli were randomly selected from the District. Further, two villages from each taluk were randomly selected and 30 farmers per village were randomly sampled making the total number of samples 120.The following data were collected from the sample households in the study area using personal interview method. i) Net sown area, ii) Gross cropped area, iii) Total Yield iv) Net area irrigated by surface water sources viz., tank and canal, v) Net area irrigated by groundwater sources viz., open well, tube well and bore well vi) Net rainfed area vii) Net area under fertilizer implication. Thus, purposive random sampling technique was used and the sampling framework is illustrated below.

2.3 Compound Growth Rate

To estimate growth in irrigation development, trend lines were fitted using the exponential function as mentioned below.

$$Y_t = ab^t e^{Ut}$$

Where,

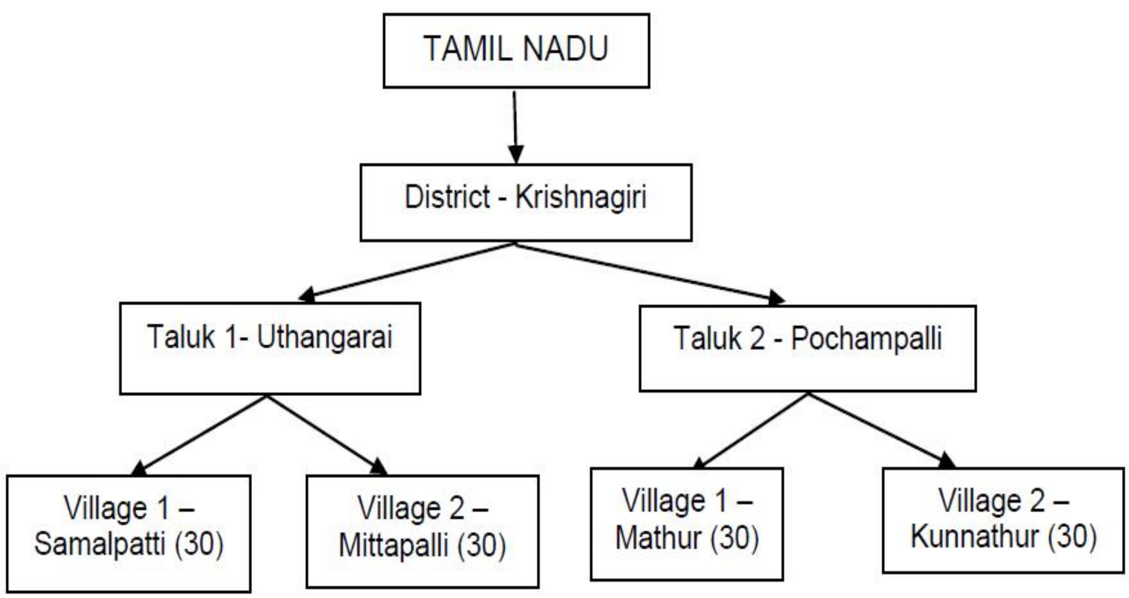
Y_t = Value of dependent variable for which growth rate is to be estimated at time t
a = Intercept
b = Regression coefficients
t = Time variable
u_t = Error term corresponding to t^{th} observation

The equation is estimated after transforming it to logarithmic form as given below.

$$\ln Y_t = \ln a + t \ln b + u_t$$

The relationship used to compute compound growth rate is

CGR= [antilog (ln b)-1] X 100



Flow Chart 1. Sampling framework

2.4 Multiple Linear Regression Analysis

To study the impact of groundwater development on cropping intensity and crop productivity two multiple linear regression models are built, one with CI as the dependent variable and the other with CP as the dependent variable and the empirical model is fitted as follows.

1. $CI = \beta_0 + \beta_1 (SWA) + \beta_2 (GWA) + \beta_3 (RFA) + \beta_4 (FIA)$

2. $CP = \alpha_0 + \alpha_1 (SWA) + \alpha_2 (GWA) + \alpha_3 (RFA) + \alpha_4 (FIA)$

Where,

SWA = Percentage of net tank and canal irrigated area to net sown area
GWA = Percentage of net tube wells and other well irrigated area to net sown area
RFA = Percentage of net rainfed area to net sown area
FA = Percentage of fertilizer implicated area to net sown area
CI = Cropping Intensity (%) CP = Crop Productivity (Kg/ha)

Cropping intensity is calculated as ***(Gross cropped area / Net sown area) * 100%***, whereas the formula for crop productivity is ***Yield / Gross cropped area*** *(Kg/ha)*

The above regression models are tested to satisfy the **Fisher's criterion** for model adequacy using the F-test. The hypothesis statements for F-test are

Null Hypothesis, H_0: The model is not fit

Alternate Hypothesis, H_a: The model is fit

If the probability value of F-Statistics i.e., prob(F-statistics) is less than 0.05 the null hypothesis is rejected and the model isacceptedto be a fit one.

3. RESULTS AND DISCUSSION

The data on irrigation sources and area under various irrigation sources in Krishnagiri, Tamil Nadu and India is subjected to growth analysis using trend studies and CAGR (Compound Annual Growth rate) to study the ground water irrigation development. Whereas, regression analysis was done with the primary data collected from 120 farming households in the study domain on SWA(Percent of net tank and canal irrigated area to net sown area), GWA (Percentage of net tube wells and other well irrigated area to net sown area), RFA(Percentage of net rainfed area to net sown area), FA(Percentage of fertilizer implicated area to net sown area), CI(Cropping Intensity) and CP(Crop Productivity) to study the impact of groundwater irrigation on cropping intensity and crop productivity. The above data were compiled, analyzed and the results are discussed below.

3.1 Trends of Different Sources of Irrigation in India

The net irrigated area has been substantially increasing since 1960's from 25 million hectares in 1960 to 67 million hectares in 2016. Initially, during 1960 the major source of irrigation was canals. However, there was a shift in the share of different sources over the years. The canal's contribution to net irrigated area was on an increasing trend until 1990, then its share started declining (Fig. 2a). Starting from 1960, tube well's contribution to the net irrigated area has been on a constant increasing trend. It overtook canal and became the major source of irrigation from 1990's.

In the decade 1960-70, the growth of canal irrigation was only 1.74 per cent whereas tube well irrigation recorded a prolific rise at rate of 38.06 per cent for the same period. Contemporarily, tank irrigation declined at rate of 1.63 per cent and the growth rate of other sources was a meagre 0.51 per cent. This data clearly implies the increase in the groundwater utilization over the years in India. In the recent years, during 2010-17, canal growth rate was about 0.02 per cent and tube well recorded a growth rate of about 2.41 per cent. The growth rate of tube well fell from 38.06 per cent in 1960-70 to 2.41 per cent in 2010-17 (Table 1). In this wise tube well construction for irrigation purpose went on increasing since 1960s.

3.2 Trends of Different Sources of Irrigation on Net Irrigated Area in Tamil Nadu

Open wells have been the major source of irrigation in Tamil Nadu since 2006 till now. Even though the net area irrigated by open wells have started to decrease since 2012, open wells still remains as the major contributor to net irrigated area. The share of tube wells to net irrigated area have shown an increasing trend since 2012. Both canals and tanks have recorded a declining trend in contribution to net irrigated area (Fig. 2b). This emphasizes that open wells and tube wells are the major contributors to the net irrigated area in Tamil Nadu.

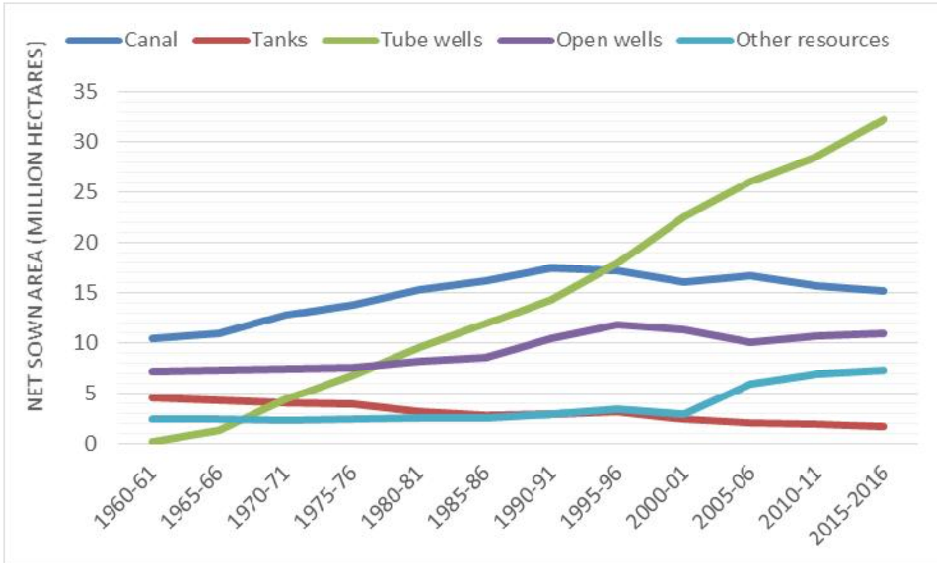


Fig. 2a. Share of different sources of irrigation to net irrigated area of India

Table 1. CAGR (%) of different sources of irrigation in India

Year	Canal	Tank	Tube well	Others	Net irrigated
1960-70	1.74	-1.63	38.06	0.51	2.01
1970-80	1.86	-0.38	8.22	1.20	2.57
1980-90	0.80	-1.93	4.25	1.66	1.77
1990-00	-0.06	-1.93	4.94	1.79	2.02
2000-10	1.77	-1.33	2.71	2.15	2.13
2010-17	0.02	-3.18	2.41	1.24	1.26

Source: Ministry of Agriculture, GOI [8]

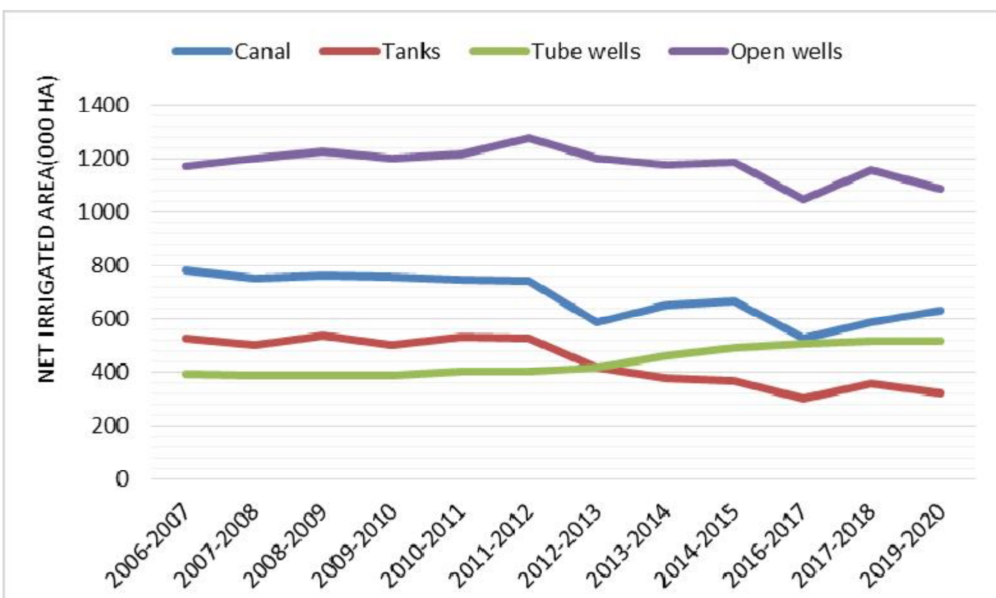


Fig. 2b. Contribution of different sources of irrigation to net irrigated area of Tamil Nadu

3.3 Trends of Different Sources of Irrigation on Krishnagiri

In Krishnagiri district the major source that contributes to the net irrigated area from 2006 till 2018 are open wells. Tube wells have been showing an increasing trend in its share to the net irrigated area. The contribution of the tanks have been gradually decreasing and the share of canals to net irrigated area have plateaued over the years (Fig. 2c). This clearly depicts that Krishnagiri is largely dependent on groundwater for agriculture and there is a high chance that it can lead to groundwater over exploitation if not checked. Suitable measures have to be taken to ensure efficiency in canal and tank water utilization.

Among the ground water sources used in Krishnagiri viz., open wells and tube wells, open wells are comparatively high in number. However, in the study domain between 2006 and 2017, it is observed that open wells have been decreasing in number and tube wells were still on an increasing trend (Fig. 2d). This can further be emphasized by looking into the growth rate. Tube wells have shown an increasing growth at a rate of 5.7 per cent whereas open wells had declined at a rate of 3.5 per cent.

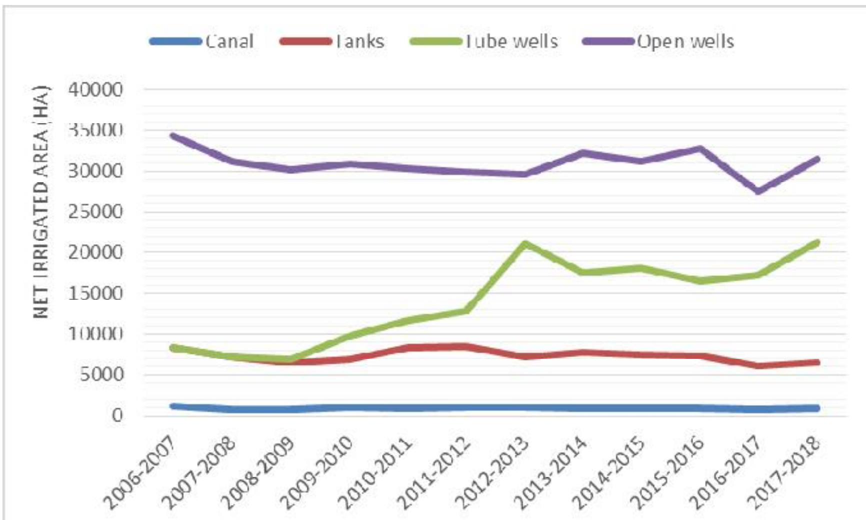


Fig. 2c. Contribution of different sources of irrigation to net irrigated area of Krishnagiri

Fig. 2d. Trends of different groundwater sources of irrigation in Krishnagiri

The CAGR (%) of tube wells in Krishnagiri district is 5.7 per cent and that of the open wells is -3.5 percent. This indicates the disparity in the development of these two groundwater irrigation sources. The dominance of tube wells in the study domain over the open wells may be attributed to a feasibility approach. The deepening of groundwater tablein the study area further complicates the establishment of open wells which unlike tube wells cannot be used to extract irrigation water from deeper aquifers. Also, open wells in the regions with deep water table depends on rainfall for recharge which is highly seasonal and irrigation in summer and dry winter becomes difficult with such open wells. Economically, the cost required for establishing and maintaining the open wells as compared to the tube wells under deep water table areas is higher and further deepening of wells when the declining water table becomes unreachable is very difficult in the case of open wells. Thus, tube wells are more feasible than the open wells as far as Krishnagiri is concerned.

3.4 Growth Rate of Different Sources of Irrigation on Net Irrigated Area in Krishnagiri

The compound growth rate of net area irrigated with different sources of irrigation in Krishnagiri district is estimated and tabulated below.

During 2006 to 2017, canal irrigated area recorded a declining growth rate of -2.79% and -1.85% in Tamil Nadu and Krishnagiri respectively. Similarly, tank irrigated area also documented a declining growth rate in both Tamil Nadu and Krishnagiri (-3.86% and -2.25% respectively). In Tamil Nadu, tube well irrigated area witnessed an increase in growth rate at 2.84%. This indicates the increased dependence of famers on groundwater compared to surface water. The growth rate of tube well irrigated area in Krishnagiri (8.93%) was higher than Tamil Nadu (Table 2). Thereby, share of tube well irrigated area in Krishnagiri is found to be more than the state average. The study domain is greatly dependent on groundwater for irrigation due to insufficiency of water supplied by the surface water sources. However, the over dependency of the farming community in the study domain on the groundwater irrigation has greatly depleted the water table and resulted in its deepening. In addition, the subsidized free electricity provided by the government to the farm households in the study for irrigation purposes has resulted in the injudicious utilization of groundwater resources [10]. Such over exploitation has been recorded around the globe in areas where free electricity for irrigation water extraction mechanisms is prevalent. Thereby, policies changes are required to curtail the depletion of ground water through proper regulation and monitoring of water extraction under free electricity tariff.

3.5 The Impact of Groundwater Irrigation on the Cropping Intensity and Crop Productivity

The influence of groundwater irrigation on the cropping intensity and crop productivity was studied by fitting the regression models. The variables chosen to assess the variation in Cropping Intensity (CI) and Crop Productivity (CP) are percent of net canal and tank irrigated area to net sown area (SWA), percent of net tube wells and other well irrigated area to net sown area (GWA), percent of net rainfed area to net sown area (RFA) and percent of fertilizer implicated area to net sown area (FIA).

Table 2. CAGR (%) of different sources of irrigation on net irrigated area in Tamil Nadu and Krishnagiri between 2006 and 2017

Different sources	Tamil Nadu	Krishnagiri
Canal	-2.79	-1.85
Tanks	-3.86	-2.25
Tube wells	2.84	8.93
Open wells	-0.14	-0.80
Other sources	-13.59	-100.00
Total	-0.95	1.31

Source: Department of Agriculture, Tamil Nadu [9]

Table 3. Impact of irrigation development on cropping intensity

Variable	Coefficient	Std Error	t-stat	*P* value
Intercept	142.830	16.015	6.488	1.87152
SWA	0.315**	0.212	2.383	0.00076
GWA	0.849*	0.256	3.320	0.00734
RFA	-0.645*	0.235	-2.744	0.02912
FIA	0.355**	0.146	2.434	0.00083
R^2	0.646**			0.00001

*.Note: ** and * indicate significance at 1and 5 per cent respectively*

Table 4. Impact of irrigation development on crop productivity

Variable	Coefficient	Std Error	t-stat	*P* value
Intercept	5.587	1.059	5.2749	2.29621
SWA	0.022**	0.010	2.189	0.00064
GWA	0.033*	0.012	2.742	0.00285
RFA	-0.019**	0.013	-2.127	0.00095
FAA	0.017**	0.007	2.489	0.00089
R^2	0.622**			0.00002

*Note: ** and * indicate significance at 1 and 5 per cent respectively.*

The probability of F-statistics is given by the *P* value of the R^2. Since, the value of prob(F-statistics) is less than 0.05 the model satisfies the Fisher's criterion for model adequacy. For the dependent variable cropping intensity, the results revealed that SWA, GWA and FIA had positive regression coefficients of 0.315, 0.849 and 0.355 respectively. The *P* values of SWA, GWA and RFA are <0.001, <0.05 and <0.05, thereby they show statistical significance at 1 percent, 5 percent and 5 percent respectively (Table 3). RFA had a negative coefficient of -0.645 at 1 per cent significant level. It was observed that 1 per cent increase in percent of net tube wells and other well irrigated area to net sown area (GWA) increased the cropping intensity by 0.85 percent when the other independent variables are held constant. As for as per cent of net rainfed area to net sown area (RFA), there was a 0.65 per cent decline in the cropping intensity for 1 percent increase in RFA when other independent variables are held constant. The Rainfed area (RFA) is found to have a detrimental effect on the cropping intensity which means it decreases chance of the same land being cultivated more than once in an agricultural year. This may lead to a substantial decline in the farm income.Also, it has been found that improving the irrigation infrastructure increases the cropping intensity and crop diversification towards high value crops [11].Thus, cropping intensity can be increased by bringing more area under irrigation.

Similar trend was observed for the dependent variable crop productivity. The value of Prob(F-statistics) is less than 0.05 which indicates that the model is fit and it satisfies the Fisher's criteria for model adequacy.SWA, GWA and FIA had positive regression coefficients of 0.022, 0.033 and 0.017 respectively whereas RFA had a negative regression coefficient of -0.019. The *P* values of SWA, GWA and RFA are <0.001, <0.05 and <0.001 and they showed statistical significance at 1 percent, 5 percent and 1 percent respectively (Table 4). It was observed that 1 per cent increase in percent of net tube wells and other well irrigated area to net sown area (GWA) increased the crop productivity by 0.033 percent when other independent variables are held constant. As far as the percent of net rainfed area to net sown area (RFA), there was a 0.019 percent decrease in crop productivity for 1 percent increase in RFA when other independent variables are held constant. The results of the regression analysis suggest that the irrigation either groundwater or surface irrigation has an incremental effect on the crop productivity. The crop productivity is found to increase with the increase in groundwater irrigation potential [12]. Rainfed area is characterized by lack of water supply and also faces the bottlenecks of uneven precipitation. Thereby, crop productivity is found to be negatively influenced by the it. Crop productivity is closely associated to irrigation water productivity [13]. The Fertilizer implicated area (FIA) on the other hand increases the crop productivity. The fertilizers have been found to be one of the key drivers in increasing the crop productivity in additional to other inputs [14]. Thus, the groundwater irrigation has a positive impact on the productivity of crops which is also supplemented by surface irrigation sources and fertilizer application but it is led down by the rainfed area.

The following policy implications were made based on the discussion of the study which can address the irrigation problems under similar conditions worldwidei) Regulation of water exploitation in the areas with free electricity tariff and rationing of electricity can be made on pro-rata basis to ensure judicious utilization of groundwater irrigation resources [15], ii) infrastructure development is needed ensure equity in water supply by surface irrigation sources such as canals and tanks to cover more area to reduce the pressure on groundwater irrigation sources [16], iii) reducing the rainfed area bringing more area under irrigation by government intervention and subsidizing group ownership of tube wells among rainfed farmers [17].

4. CONCLUSION

The major source of irrigation water supply has taken a turn around 1960's from canals and tanks to wells. This may be due to a variety of reasons such as uncertainty of water released from canals, incomplete irrigation projects, below par maintenance of existing surface irrigation infrastructure. This in fact increased the farmers' dependency on ground water leading to increase in tube well numbers since the installation of tube wells is more decentralized than the large-scale canal projects [18]. Over the years, this has resulted in an upsurge in the well irrigated area with simultaneous decrease in the tank irrigated areas in Krishnagiri. Groundwater is highly reliable and efficient due to its private ownership. Furthermore, the tube well construction was encouraged by power subsidy and fairly easy availability of credits, especially in those areas where water availability is already scarce. However, agricultural advancement in areas under free electricity tariff is achieved at the cost of groundwater over-exploitation [19]. The construction of tube wells has resulted in increase in the number of crops grown in a year by the expansion of the number of seasons when crops are planted in a given year. This spread out the production period into summer and dry winter seasons. These uncertainties have caused a decline in the area irrigated by canals and tanks over the years. However, enhancing the canal management and improving the infrastructure to supply both the head and tail of the canal system equitably can increase the efficiency of canal systems [20]. This study showed a positive influence of supplying ground water, surface water and fertilizers on both the dependent variables, cropping intensity and crop productivity. Meanwhile, rainfed condition exhibited a negative impact on cropping intensity and crop productivity. In order to maintain sustainability of irrigation, emphasis has to be given to both surface and groundwater and to maintain maximum irrigation efficiency.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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