

Original Research Article
**Potential and Determinants of Groundwater Use
in Coimbatore District of Tamil Nadu**

ABSTRACT

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Aims: To study the potential and determinants of groundwater use

Study design: Purposive random sampling.

Place and Duration of Study: The study was conducted in the Coimbatore district of Tamil Nadu and the survey was conducted during July 2021 and September 2021.

Methodology: The sample size selected for the study is 480 which includes 160 sample farmers from each region. Mean and simple regression analysis with regional dummy was used for the study.

Results: The groundwater was highly developed in the overexploited region. Among the farmers, it was highly developed among the medium farmers. The determinants of groundwater use on the farm are the overexploited region, farm size and cultivating water-loving crops of expecting higher income.

Conclusion: The groundwater is highly tapped in the overexploited region and mostly by the medium farmers of all the region. Sustainable groundwater management is essential for addressing the developing water scarcity problems.

Keywords: groundwater, wells, groundwater development, groundwater use, groundwater over-extraction, regional dummy

1. INTRODUCTION

Groundwater is an important source of freshwater that supplies nearly half of the world's population's household needs [16]. Groundwater meets around 38 per cent of global consumptive irrigation water demand [12]. Groundwater depletion is a major issue in most of the world's irrigated regions, where millions of people live [8]. [2,13] report that groundwater abstraction accounts for 33 per cent of total withdrawals globally and provides water for agricultural (42 per cent), home (36 per cent), and industrial (27 per cent) demands. The rapid growth of irrigated farmland to fulfil the needs of the growing population has resulted in the exploitation of groundwater [4,15]. More than half of the population relies on groundwater for food production [3,12]. According to [5], the current global groundwater footprint is 3.5 times the actual aquifer area, posing a threat to about 1.7 billion people, even though 80 per cent of aquifers have footprints smaller than their area, implying that only a few overexploited aquifers are responsible for the net global footprint. Groundwater depletion is primarily concentrated in isolated overexploited aquifer systems, such as those in Northern India [11,15].

Irrigated agriculture is suited more in the water scare region than rainfed agriculture [1,9,10]. Even in rainy regions, mismanagement of water resources can lead to a greater dependency on groundwater due to uneven rainfall distribution [11]. India is mostly reliant on the Indian summer monsoon rain, and lower monsoon rain might lead to drought [6]. During such dry periods, water extracted from groundwater causes a drop in groundwater level, worsening drought conditions even more [14].

As a result, groundwater is a critical resource for the sustainability of ecosystems and lives in the world's second-most populous country. Groundwater can also help to mitigate the negative effects of climate change on water availability. Rapid groundwater depletion is still one of the most serious long-term sustainability issues. In the present and expected future climates, groundwater sustainability is critical for satisfying food and water needs.

Hence groundwater is the most utilizable resource, it is essential to study the potential of groundwater and the determinants of groundwater use on the farm. It will help us to manage the problematic renewable resources in future.

2. METHODOLOGY

2.1 Selection of study area and sampling design

The study was carried out in the Coimbatore district, which is located in the western part of Tamil Nadu, between the latitudes of 10° 10' N and 11° 30' N, and the longitudes of 76°40' E and 77° 30' E, with an annual average rainfall of

1215 mm. The southwest and northeast monsoons cater to rain to the district. The northeast monsoon brings the most rain to the area, and summer showers are rare. The Palghat Gap on the Eastern side of the Western Ghats had a profound impact on the climate and agriculture of the district. This gap delivers a huge amount of rain to Pollachi Taluk during the southwest monsoon. The district's temperature ranges from 18.6⁰ to 35.7⁰ Celsius. The district is the hard rock type which is composed of rocks such as charnockite, sillimanite, genesis, granite, pyroxenite calc. granulites quartzite and alluvium.

As per the recent GO Dynamic groundwater resources assessment for Tamil Nadu dated 23.10.2019 categorization, there are 38 firkas in the district. Firkas are classified into over-exploited, critical, semi-critical, safe, and saline, or poor quality firkas based on their percentage of exploitation. The firkas which are exploited more than 100 per cent are overexploited firkas, between 90 to 100 per cent are critical firkas, between 70 to 90 per cent are semi-critical firkas, and less than 70 per cent are safe firkas. Over-exploited, critical, semi-critical, and safe firkas were purposively selected for the study since it critically shows the negative externalities of the groundwater. Of the 38 firkas, 26 firkas are overexploited five firkas are in critical, six firkas are in semi-critical, and one falls in safe firka.

Among 38 firkas in the district, two firkas from each category that critically shows the externality were purposively selected for the study. Four villages from each firka were purposively selected for the study. The villages selected for the study from the overexploited firka were Kunnathur, Pachapalayam, Naranapuram, and Kattampatti from Annur firka, Thondamuthur, Narasipuram, Alandurai, and Booluvampatti from Thondamuthur firka. From critical firka, the villages selected were Madukkarai, Ettimadai, Seerapalayam, and Pichanur from madukkarai firka and the villages from saravanampatti firka were Kalapatti, Vilankurichi, Vellaikinaru and Chinnavedampatti. The two firka selected from semi-critical firka were Kuniyamuthur firka and Karamadai firka. The villages were Kurinchi, Kulathupalayam, Pulakadu, and Kuniyamuthur from Kuniyamuthur firka and the villages under Karamadai firka were Sikkarampalayam, Bellathi, Kemmarampalayam and Maruthur. The total sample size was 480 which constitute twenty members from each village.

Primary data was collected from the sampled respondents through personal interviews with the aid of a pre-tested interview schedule designed specifically for the purpose. The personal interview method was adopted to ensure that the data obtained from the respondents were relevant, comprehensive reasonably correct, and precise. Detailed information of the respondents like the number of open wells or bore wells and their usage in their farm. The data collected were tabulated, processed, and subjected to statistical analysis.

2.2 Analytical framework

2.2.1 Determinants of groundwater use on the farm

Groundwater is highly developed in the Coimbatore district of Tamil Nadu. The groundwater use on the farm was determined by the factors such as depth to the water table, farm size, the area under water-loving crops, non-farm income and adopter or non-adopter of water management practice. The adoption of drip irrigation is mentioned in the study.

The linear regression model was used for analysis. Water pumped per hectare is a dependent variable and depends on the factors such as regional dummy which are overexploited region, critical region and semi-critical region, depth to water table, farm size, area under water-loving crops and adoption of water management practices.

The linear regression model used is,

$$W = \beta_0 + \beta_1 R2 + \beta_2 R3 + \beta_3 D + \beta_4 FSIZE + \beta_5 AWLC + \beta_6 NFI + \beta_7 ADOPT$$

Brief accounts of a priori of the explanatory variables are discussed hereunder:

FIRKA : It is expected that overexploited region may have a positive influence on the volume of water pumped since groundwater has highly developed in the overexploited region and the other firkas may have a negative influence on the dependent variable. The groundwater has less development in the other regions.

D : Depth to water is the distance between the surface of groundwater and the water availability in the well. Depth to the water level in feet may negatively influence the dependent variable. As the distance increases the volume of water pumped may decrease.

FSIZE : The increase in farm size increases the volume of water pumped. The increase in farm size forces the farmer to extract more water. It is expected that it may positively influence the volume of water pumped.

AWLC : Area under water-loving crops may have a positive sign on the dependent variable. If the farmer has a larger area under a water-loving crop, there is a need for a large volume of water.

NFI : It is expected that non-income may have a negative influence on the dependent variable (volume of water pumped). The increase in non-income will decrease the interest of the farmers to cultivate more areas simultaneously decreasing the volume of water pumped per hectare.

ADOPT : Adoption or non-adoption of water management activities may negatively influence the volume of water pumped. Installation of drip irrigation in the farm may decrease the volume of water pumped.

Table 1. Variables and units of measurement

| Variable | Definition | Expected sign |
|----------------------|---|---------------|
| Dependent variable | | |
| W | The volume of water pumped (in m ³) | |
| Independent variable | | |
| R1, R2, R3 | Dummy for different firkas such as overexploited, | +/- |

| | | |
|-------|--|---|
| | critical and semi-critical firkas | |
| D | Depth to water table (in feet) | - |
| FSIZE | Farm size (in hectares) | + |
| AWLC | The area under water-loving crops (in hectares) | + |
| NFI | Non-farm income (in rupees) | - |
| ADOPT | Adoption of water management practices; 0 for non-adopter and 1 for an adopter | - |

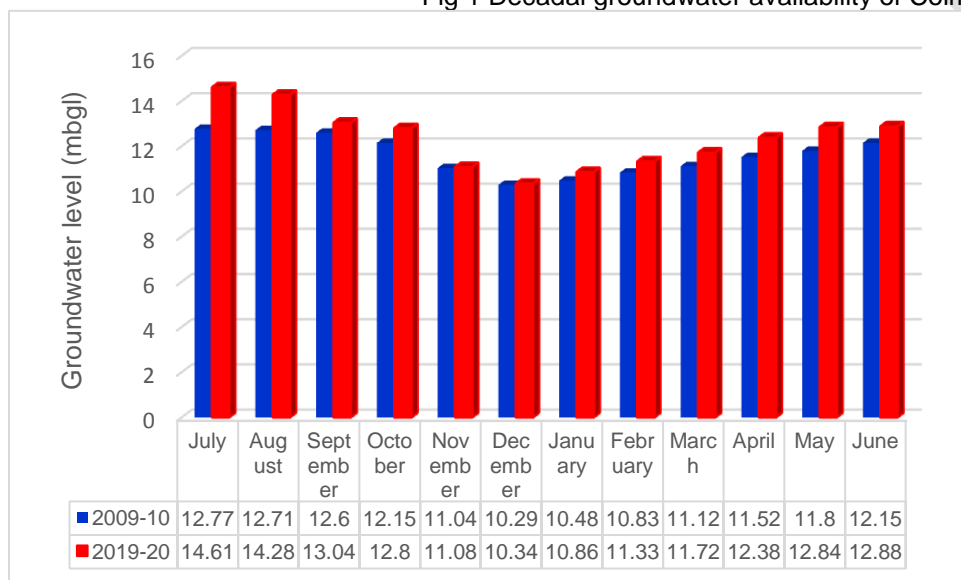
3. RESULTS AND DISCUSSION

3.1 Groundwater development in the district

Groundwater is the major source of irrigation in the Coimbatore district. The groundwater level is high in July followed by August and it was very low in the cold month of December. The groundwater is highly correlated with groundwater availability [7]. The yearly average groundwater availability is 12.35 meters. The month-wise decadal groundwater availability is shown in figure 1.

Figure 1 shows that groundwater availability increased over the years. The difference is very high during July followed by August. The difference is low during the cold month of December. It could be inferred from the figure that groundwater is highly developing over the years and it may increase widely in near future.

Fig 1 Decadal groundwater availability of Coimbatore district



Source: Assistant director of statistics, Coimbatore

3.2 Distribution of functioning wells and failed wells in the district

The number of wells in the study area critically shows the groundwater development, exploitation and interferences. The increase in number results in increased exploitation. The increased dried wells show the negative externality in the sense of increased well investment.

Table 2 shows that the sample farmers had a large number of open wells followed by borewells and dug cum bore wells. Mostly all the sample farmers had age-old open wells in the district as well as bore wells. The proportion of dug cum bore wells is very low because the rate of failure is very high. Instead, farmers prefer new bore well in a different place.

The number of borewells is high in the critical region followed by the semi-critical region. The number of borewells and dug cum borewells is in the overexploited region. Similarly, the number of dried wells is high in the overexploited region followed by the critical region.

It could be concluded that groundwater is highly developed in the overexploited region compared to the other regions of the Coimbatore district.

Table 2. Total number of wells and failed wells

| Firkas | Open wells | Borewells | Dug cum bore wells | Total | Dried wells |
|----------------|------------|-----------|--------------------|-------|-------------|
| Over exploited | 150 | 168 | 54 | 372 | 260 |
| Critical | 173 | 121 | 51 | 346 | 232 |
| Semi critical | 153 | 83 | 42 | 278 | 195 |
| Total wells | 476 | 372 | 147 | 996 | 687 |

3.3 Distribution of wells across the different categories of farmers

The distribution of wells among the farmers will explain the development of groundwater among the farmers and those who extract more for irrigation.

In the overexploited region, the dug wells are more compared to open wells. Medium and large farmers have a large number of open wells similarly dug wells. Medium farmers have a large number of dried wells. It could be found that groundwater was highly developed among the medium farmers of overexploited firka.

In the critical region, the number of open wells is higher than dug wells. Among the farmers, medium farmers have a large number of wells. The total wells of marginal farmers of semi-critical regions are very high than marginal farmers of the overexploited region. The groundwater was highly developed by the medium farmers of the critical region than medium farmers of the overexploited region. The number of dried wells is 232 wells.

In the semi-critical region, marginal farmers had a larger number of wells followed by medium farmers. The number of open wells is higher among the farmers followed by dug wells.

Table 3. Distribution of wells across landholding sizes

| Firkas/ Landholding size in ha | Over exploited firka | | | | | Critical firka | | | | | Semi-critical firka | | | | |
|--------------------------------------|----------------------|-----------|--------------------|-------------|-------------|----------------|-----------|--------------------|-------------|-------------|---------------------|-----------|--------------------|-------------|-------------|
| | Open wells | Dug wells | Dug cum bore wells | Total wells | Dried wells | Open wells | Dug wells | Dug cum bore wells | Total wells | Dried wells | Open wells | Dug wells | Dug cum bore wells | Total wells | Dried wells |
| Marginal | 18 | 20 | 7 | 45 | 39 | 24 | 16 | 8 | 48 | 58 | 70 | 38 | 20 | 128 | 29 |
| Small | 36 | 41 | 14 | 91 | 26 | 42 | 29 | 12 | 83 | 35 | 18 | 10 | 5 | 33 | 23 |
| Medium | 48 | 54 | 17 | 119 | 91 | 74 | 53 | 22 | 149 | 35 | 50 | 27 | 13 | 90 | 64 |
| Large | 48 | 53 | 16 | 117 | 104 | 33 | 23 | 10 | 66 | 104 | 15 | 8 | 4 | 27 | 79 |
| All categories | 150 | 168 | 54 | 372 | 260 | 173 | 121 | 52 | 346 | 232 | 153 | 83 | 42 | 278 | 195 |

Source: Primary data collection (2021)

3.4 Distribution of ownership of wells

The distribution of ownership of wells explains clearly the wells of different classes of farmers. The total and average extent of irrigated area from well explains the relationship between irrigation and well investment. The more the area, the more water is needed which forces more well investment across different farmers of the study area.

It could be seen from table 4 that large farmers of overexploited firka, owns 117 wells and irrigate 282.35 ha of land. The average extent of irrigated area per well is 2 ha which is due to the higher extraction of 10 HP motor pumps. The marginal farmers have 119 wells with a total irrigated area of 162.03 ha and the average extent of irrigated area per well is 1.50 ha. Marginal and small farmers have 45 and 91 wells respectively with a total irrigated area of 16.87 ha and 66.19 ha. The average extent of irrigated well is 0.75 and 1.50 ha per well which may be due installation of 3 and 5 HP motor pumps which abstract a low volume of water. The average extent of irrigated area per well of semi-critical firka is 1 ha for large farmers which is very low compared to other regions.

Table 4. Ownership of wells across the size of landholding farmers

| Firkas/ Landholding size in ha | Over exploited firka | | | | | Critical firka | | | | | Semi-critical firka | | | | |
|--------------------------------------|----------------------|--------------------|-------------------|--------------------------------------|---|--------------------|--------------------|-------------------|--------------------------------------|---|---------------------|--------------------|-------------------|--------------------------------------|---|
| | No. of well owners | Total no. of wells | Functioning wells | Total extent of land irrigated in ha | Average extent of irrigated area per well | No. of well owners | Total no. of wells | Functioning wells | Total extent of land irrigated in ha | Average extent of irrigated area per well | No. of well owners | Total no. of wells | Functioning wells | Total extent of land irrigated in ha | Average extent of irrigated area per well |
| Marginal | 45 | 45 | 45 | 16.87 | 0.75 | 91 | 91 | 91 | 66.19 | 1.50 | 119 | 119 | 119 | 162.03 | 1.50 |
| Small | 91 | 91 | 91 | 66.19 | 1.50 | 117 | 117 | 117 | 282.35 | 2.41 | 117 | 117 | 117 | 117 | 1.50 |
| Large | 117 | 117 | 117 | 282.35 | 2.41 | 117 | 117 | 117 | 117 | 1.50 | 117 | 117 | 117 | 117 | 1.50 |
| All categories | 253 | 253 | 253 | 465.35 | 1.84 | 325 | 325 | 325 | 455.57 | 1.40 | 325 | 325 | 325 | 325 | 1.50 |

| | | | | | | | | | | | | | | | |
|----------------|-----|-----|-----|--------|------|-----|-----|-----|--------|------|-----|-----|-----|--------|------|
| Marginal | 24 | 39 | 45 | 16.87 | 0.75 | 33 | 58 | 48 | 20.48 | 0.75 | 90 | 29 | 128 | 38.51 | 0.50 |
| Small | 45 | 26 | 91 | 66.19 | 1.50 | 49 | 35 | 83 | 71.56 | 1.00 | 26 | 23 | 33 | 29.24 | 0.75 |
| Medium | 52 | 91 | 119 | 162.03 | 1.50 | 56 | 35 | 149 | 136.11 | 1.00 | 35 | 64 | 90 | 79.84 | 0.75 |
| Large | 39 | 104 | 117 | 282.35 | 2.00 | 22 | 104 | 66 | 109.08 | 1.50 | 9 | 79 | 27 | 48.45 | 1.00 |
| All categories | 160 | 260 | 372 | 527.44 | 1.43 | 160 | 232 | 346 | 337.23 | 1.06 | 160 | 195 | 278 | 196.04 | 0.75 |

Source: Primary data collection (2021)

3.5 Determinants of groundwater use on the farm

3.5.1 Groundwater use on the farm

A simple regression model with regional dummies was used to capture the factors involved in groundwater use on the farm. The factors responsible for groundwater extraction were the different regions, depth of the wells, farm size, the area under water-loving crops, non-farm income and adopter or non-adopter of water management practices. Regional dummies were used to differentiate different regions. R1 is the regional dummy for the overexploited area, R2 is the dummy for critical firka and R3 is the dummy for the semi-critical firka. To avoid the dummy variable trap, two dummies (R2 and R3) were used for estimation with all other factors.

Table 5 reveals groundwater use on the farm with the volume of groundwater extracted. R square is 0.63 which means 63 proportion of variance in the dependent variable is explained by the independent variables. The farm size (FSIZE) and the area under water-loving crops (AWLC) significantly influence the groundwater use on the farm. The increase in farm size and the area under water-loving crops increases groundwater extraction. The negative sign of the regional dummies implies less dependence of the regions on groundwater use compared to the overexploited firka. The sign of depth to water level is negative as expected which shows as the depth to water level increases groundwater use increases and vice versa but the influence is very negligible (0.003). The water table near the surface motivates the farmer to cultivate more crops which in turn consumes more water. The income from a non-farm source drives the farmers to participate in non-farm income activities than agriculture which is the reason for the negative sign of non-farm income source. The dummy variable is used for the qualitative variable adopter or non-adopter of water management practices like drip irrigation and sprinkler irrigation. The adoption of water management practices forces to bring the larger area under cultivation which in turn consumes more water.

It could be concluded that groundwater is highly developed in the overexploited region. The farm size of the farmers and area under water-loving crops significantly influence the groundwater use on the farm.

Table 5. Parameter estimates of groundwater use on the farm

| Variables | Co-efficient |
|---------------------|------------------------|
| Constant | -4.21 (10.82) |
| R2 | -1.89 (1.65) |
| R3 | -0.66 (2.46) |
| D | -0.003 (0.012) |
| FSIZE | 1.62*** (0.40) |
| AWLC | 5.98*** (0.95) |
| NONFARM | -0.000011 (0.00003) |
| ADOPT | 0.59 (0.72) |
| R square | 0.63 |
| No. of observations | 480 |

Note: Figures in the parenthesis indicates standard error

*** indicates a 1 per cent significance level.

4. Conclusion

The study revealed that the groundwater has highly developed in the overexploited region of the Coimbatore district compared to other regions of the district. Mostly the medium and small farmers are affected due to high groundwater development. Farm size and area under water-loving crops significantly influence the groundwater use on

the farm. Even the large farmers could reduce groundwater extraction by adopting water management practices while cultivating water-loving crops, particularly in the overexploited region. One could conclude that our policy focus may be tilted towards the water management practices and particularly in the regions of overexploited firka.

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