# Chapter 18
# Preliminary Report on the Socioecology of Rural Groundwater Markets in the Gingee Watershed

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**Abstract** According to the latest World Bank report, India is the largest groundwater user in the world and accounts for approximately 60% of the irrigated agriculture in the country. In the hard rock and semi-arid areas of peninsular India, uncontrolled overexploitation of groundwater is leading to a continuous decline in the water table, driving farmers to participate in and increase their dependence on informal markets for irrigation water. This paper examines the existence, structure and role of groundwater markets in the Gingee river watershed in the Tamil Nadu and Puducherry region of India. The state government's policy of providing free electricity, subsidized bore installation schemes and promoting water-intensive crops has led to a drop in the water level in successive years. The large landholders have the resources to dig bores at greater depths; small landholding farmers depend greatly on surface water and rainfall, leading to exacerbation of inequalities. With changes in climate and rainfall variability during the last few years, and also the ineffectual surface water irrigation system, the whole agriculture structure has received a setback.

**Keywords** Groundwater · Water markets · Agriculture · Canal · WEMs · Tamil Nadu

## Introduction

Today, groundwater accounts for more than half of the total irrigation in India. The agriculture sector is the largest consumer of water, with 90% of the total available water being used for irrigation. Agriculture in India accounts for as much as 85%

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of the total annual withdrawals. The scarcity of water resources along with the rapid increase in the demand for water has resulted in overexploitation of aquifers. It is often stated that the availability of cheap water to the agricultural sector has tended to encourage its pre-emption for a low-value, high-volume use and has encouraged its waste and profligate consumption (Narain 1997).

Indian villages on the whole have traditionally relied on local rainfall for meeting their water requirements. When crop production was practised mostly under rain-fed conditions, the development of irrigation was mainly through exploitation of surface water and irrigation and was primarily protective and extensive. The increasing use of well and bore well irrigation has resulted in a rise in net irrigated area, but at the same time has also led to overexploitation of groundwater (Janakarajan 1993).

Water is one of the main inputs in modern agriculture and determines, to a large extent, the level of agricultural production and income. Use of groundwater in irrigation provides a higher degree of control to the farmer than canal irrigation does, in most areas. The practice of selling groundwater appears to have been prevalent in many parts of the Indian subcontinent even under traditional water extraction technology. The earliest formal reference to water-selling can be traced to the mid-1960s (Patel and Patel 1969). In many other parts of the Indian subcontinent, especially Pakistan, the Indian states of Punjab, Haryana, western and central Uttar Pradesh, West Bengal, Assam and in Bangladesh, and in some southern pockets, water transactions in some form or other have existed since the 1940s.

A water market in the Indian context is an informal arrangement in which individuals having access to water extraction mechanisms trade their water rights with each other or to outside parties. There is "renting" of water between neighbouring farmers and the seller sells some portion of his water, for a brief period of time, without any legal conditions. Although the volume of water sold is not metered, the buyer and seller have good information on the amount exchanged (Dinar et al. 1997). The key feature that distinguishes water markets from other forms of irrigation institutions such as a commonly owned tank is that water pumped is assumed to be the property of the pumper (Shah 1993). Informal water markets emerged in order to bridge the gap between the demand and supply of water, and these markets continue to exist in many parts of the country (Venkatachalam 2008).

Over the years, groundwater markets have come to play a significant role in India's groundwater economy (Bhatia et al. 1995). The rising share of groundwater in irrigation is attributed largely to its higher productivity compared with canal or tank irrigation (Shah 1993). In the hard-rock water-scarce areas of Tamil Nadu, the evidence in relation to the development of water markets is mixed. Guhan and Mencher (1983) found active and developed water markets operating in Iruvelpattu village in Ramanathapuram district of Tamil Nadu (Shah 1993). Swaminathan and Kandaswamy (1989) in their study in the Avinashi and Perianaickenpalyam taluk of Coimbatore district found the absence of water-selling; while Copestake (1986) found active water markets in the Shivaganga block near Madurai. He found evidence of water sales from wells as well as tanks.

Researchers and academics are divided on the equity and efficiency impacts of groundwater markets. In economically efficient resource allocation, the marginal benefit from the use of the resource should be equal across sectors. Equity of water allocation is particularly concerned with the “fairness” of distribution across economically disparate groups in a society or across time and may not be compatible with efficiency objectives (Dinar et al. 1997). Some favour water markets on the grounds of equity in resource distribution, in terms of access to water to farmers irrespective of their social and economic status (Rosegrant and Binswanger 1994; Meinzen-Dick and Sullins 1994). Groundwater markets make the resource accessible to those who cannot afford it. Water markets increase the use of installed pumping capacity, thereby improving the economic efficiency of private bore irrigation (Meinzen-Dick and Sullins 1994). Those who oppose water markets argue that it amounts to favouring the rich over the poor by monopoly rents, leading to worsening of income distribution (Janakarajan 1993; Singh 2002). Narain (1997) noted that in the absence of well-defined rights and an institutional structure in water, the development of groundwater markets could stimulate aquifer depletion while at the same time creating a powerful monopoly of water lords. Both arguments hold good under different situations. The former may be true in water-abundant regions and the latter in water-scarce regions.

Dwindling water tables often catalyse the process of “competitive deepening” of modern water extraction mechanisms (WEMs) as each user chases a declining water table. Over the years, the area irrigated by tanks in Tamil Nadu is decreasing while the area irrigated by wells is increasing (Palanisami and Meinzen-Dick 2001). Both underpricing of water and lack of cost recovery mechanisms in government-managed irrigation systems have resulted in poor operations and maintenance (Bandara 2005). Economic imperatives force farmers to choose “cash” crops that are generally water intensive over “food” crops which are less water-demanding, as the former provide greater economic return per unit of land. Tail-end farmers do not get canal supplies and groundwater is not recharged, which leads them to spend additional money on pumping groundwater from lower depths (Shah 2004).

Kajisa and Sakurai (2005) studied the nature of groundwater markets by examining the impacts of bargaining relationships and of output-sharing contracts on efficiency and equity, using household data from Madhya Pradesh, India. In a study conducted by Dubash (2000), in two villages in Gujarat, he concluded “that the markets are ‘informal’ should not be equated with an assumption that they are unregulated”. He also reasoned that while spatial characteristics, land patterns and water depth exert a powerful shaping influence on groundwater markets, the actual form of outcome depends on socioeconomic factors such as the distribution of land ownership, access to credit and caste. He pointed out the fact that analysis of specific village characteristics is required to understand these path-dependent outcomes.

Agriculture in Tamil Nadu and Puducherry largely depends on southwest and northeast monsoons. Taking advantage of the southwest monsoon, large-scale coverage of oilseeds, pulses and cotton crops are taken up under rain-fed cultivation. The northeast monsoon rains are also very crucial for recharge of sub-soil water. In a climate change scenario, the decreasing groundwater level and the erratic rainfall pattern will present new challenges and uncertainties to the whole irrigation system.

The purpose of this paper is to examine the presence of groundwater markets in the Gingee watershed. The paper deals with the preliminary analysis of the extent of water market development, the nature of the transactions and who participates in such transactions, with special reference to the Veedur command area in the Villupuram district of Tamil Nadu and Mannadipet commune of Puducherry. The paper attempts to document the dependence of farmers on informal water transactions for irrigation in the canal command areas.

## Study Area

The area under study forms a part of the Gingee watershed. This watershed comprises of parts of Tamil Nadu and Puducherry,[1] extending from north latitude 11° 55′ 00″ to 12° 33′ 00″ and east longitude 79° 18′ 00″ to 79° 52′ 00″. The total geographical area of the basin is 2250 $km^2$. The watershed lies on the drainage basin of the Gingee river, also known as "Varahanadi", which crosses Puducherry diagonally from northwest to southeast. The river is basically ephemeral, flowing only during rains and floods. Even during rains, due to interdiction of the flow for irrigating the upper reaches, the river flows only intermittently.

The Veedur Main Canal takes off from the saddle dam beyond the left flank of Veedur through two sluices. The channel feeds a total irrigated area of 1,280 ha, of which 400 ha are in Puducherry region. Under the Veedur dam command area, sixteen villages are officially the beneficiaries of the dam. Of these sixteen, eleven fall under Tamil Nadu and five under Puducherry.

## Methodology

Six of the sixteen villages were chosen for the study, two from each head, middle and tail end, located in the Villupuram district of Tamil Nadu state and Mannadipet commune of Puducherry Union Territory, respectively. The grounds for choosing these villages were that all of them are beneficiaries of the Veedur dam canal command area, and would have been expected to use the canal system as the main source of irrigation. The existence and extent of water transaction under such a scenario would be an indication of the dependence and importance of groundwater in irrigation. It also provides an insight on how these transactions differ along the head, middle and tail reaches within the command area.

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[1] Formerly known as Pondicherry, the name of Union territory was changed to Puducherry by an Act of Parliament in 2006.

A distinctive feature of many of the canal irrigation systems of India is that the farmers in command areas of the canal depend on pumping groundwater for irrigation (Shah 2009). Choudhury (2007) studied eight irrigation systems and found that tail-end farmers usually receive much less water than they need for growing crops. He found that even in the canal command area, less than 58% of farmers rely on canal water for irrigation.

The present study was conducted at two levels. A focus group discussion was first conducted in all the villages to get a general idea about the villages, their main source of irrigation, changes in the cropping pattern, nature of water transactions, sources of irrigation and the causes of the changes in the cropping patterns and irrigation sources. A detailed individual questionnaire survey was later conducted at households chosen randomly in all the villages. A total of 138 interviews were carried out from the six villages, taking 10% of the population subject to a maximum of 50. The survey was conducted from August 2009 till January 2010.

## Structure and Role of Groundwater Markets

Selling and buying of groundwater is a common practice in most of the villages, though the manner in which water markets function varies across different regions. A study conducted in four villages of the Banaskantha district of Gujarat concluded that groundwater irrigation is a major source of livelihood not only for well owners, but also for water buyers and farm labourers (Kumar et al. 2004).

In the present study, the existence of groundwater markets was found in all the villages except one. In all cases where water transactions occurred, it was found that the selling and buying of water has been a common practice for generations and is based on the ownership of wells. The villages surveyed under the present study had similar climates but different geologies. The main monsoon season and the major rainfall in this part of the country occur during the northeast monsoon. The geomorphology of the Puducherry region comprises mainly alluvial and flood plains, whereas the Tamil Nadu part consists of hard bedrock in the middle reaches and clay and sandstones in other parts. The farmers in the area practise irrigation, either through canal, tank or personal water extraction mechanisms (WEMs), depending on the availability of canal/tank water. Farmers without any WEMs either depend on rainfall or buy water from other farmers at an hourly basis or on an output-sharing contract basis.

Table 1 gives a comprehensive outline of the market structure of the six villages. The head and middle reaches are in the Tamil Nadu state, whereas the tail end comes under Puducherry. As can be seen from the table, the water transactions perform an important role in the irrigation of crops at the tail end and at the head end. There are few water transactions in the mid-reaches of the canal, mainly due to the geology of the area. These middle-reach villages have hard bedrock at a depth of around 40–60 m. There are no bores and existing wells do not go beyond a depth of 30–60 m in the majority of cases. Most of the existing wells do not have

**Table 1** Market structure in the study area

| | | Number of agricultural households | Number of well owners (non-sellers) | Number of well owners (water sellers) | Number of water buyers | Number of well owners who are also water buyers | % of respondents involved in water transactions |
|---|---|---|---|---|---|---|---|
| Head | Veedur | 33 | 14 | 3 | 0 | 2 | 6.06 |
| | Pombur | 30 | 13 | 5 | 7 | 1 | 26.67 |
| Mid | Nemili | 20 | 7 | 2 | 0 | 0 | 0 |
| | Thollamur | 20 | 5 | 0 | 0 | 0 | 0 |
| Tail | Lingareddy-palayam | 20 | 7 | 5 | 7 | 0 | 36.84 |
| | Suthukeny | 15 | 5 | 1 | 9 | 0 | 60 |

water during the dry season and those with water in their wells have just enough to irrigate their own fields. There is no surplus left for any water transactions to occur.

Among the six villages, Thollamur did not have any instances of a respondent selling or buying water over many years, which was also confirmed during focus group discussions. In Thollamur, the villagers depend mainly on canal and rain water and raise only one crop a year. The situation worsens during years when rains fail or rainfall is below normal. During normal monsoons the water from the canal and tank is enough for three months. For the rest of the year, villagers work as labourers in the granite mining industry in and around the area or they go to neighbouring villages or states as agricultural labourers. It was also observed that most of the respondents sold some part of their land to the granite industry, as it was more profitable than cultivating it.

The number of well owners in Veedur was higher compared to other villages. Being the first village from the dam, it also enjoys assured water availability for longer periods. The availability of free electricity to all farmers in Tamil Nadu could be one of the reasons for the proliferation of bore wells. During the survey, only five farmers were found to be using diesel pumps. Also, Table 1 shows that among the two head-end villages, there were more water transactions in Pombur than in Veedur. This is because Pombur is the first beneficiary village in line, and canal water is available for five to six months.

However, Pombur has to wait for the water to come through the canal, which passes two villages, and then fill up the Pombur tank from where it is diverted to different fields. Therefore, to reduce their dependence on canal water, people engage in informal water transactions. Also, as Varahanadi has irregular water flows, water is not available at all times. This, together with the unpredictable rainfall patterns, has generated water trading.

The tail-end villages were more active in water selling and buying, as indicated by the number of water sellers and buyers among the respondents. The lack of canal water over many years and the subsidies provided by the government to install new bore wells have played a significant role in the existing state of affairs in these villages.

**Table 2** Well ownership by land ownership

| | Land owned(acres) | 0 to ≥ 2.5 | < 2.5 to ≥ 5 | < 5 to ≥ 10 | > 10 |
|---|---|---|---|---|---|
| Veedur | well owner | 4 | 4 | 4 | 7 |
| | no well | 9 | 5 | 0 | 0 |
| Pombur | well owner | 2 | 7 | 6 | 4 |
| | no well | 8 | 3 | 0 | 0 |
| Nemili | well owner | 1 | 5 | 3 | 1 |
| | no well | 4 | 4 | 2 | 0 |
| Thollamur | well owner | 0 | 2 | 3 | 0 |
| | no well | 13 | 2 | 0 | 0 |
| Lingareddypalayam | well owner | 4 | 2 | 3 | 3 |
| | no well | 5 | 2 | 0 | 0 |
| Suthukeny | well owner | 0 | 1 | 1 | 4 |
| | no well | 9 | 0 | 0 | 0 |
| | TOTAL | 59 | 37 | 22 | 19 |

There have been cases where a water seller also became a water buyer for some parcels of land. Only three such cases were observed in the area where the WEM owner was also a buyer of groundwater from other sellers. It was observed in all these three cases that the owner's land was away from the command area of their own wells.

The ownership of water is closely associated with land ownership in India. The chances of being a well owner increases with an increase in the land owned. Table 2 provides data on well ownership by land ownership. The respondents in the area were classified under four different categories of land ownership, namely marginal (less than 2.5 acres), small (between 2.5 and 5 acres), medium (between 5 and 10 acres) and large (more than 10 acres). The majority of respondents were marginal landowners and owned the lowest number of wells. Most marginal farmers were totally dependent on the canal system and rainfall for cultivation and were also partly dependent on large well owners to provide water when there was no water from the canal. Nearly all the medium and large farmers have their own wells.

In terms of cropping patterns, although paddy still continues to be the major crop in the area, casuarina has become an important competitor in terms of acreage. As a result of the problems associated with labour availability, difficulties in getting access to water at the right time, erratic rainfall and low profit, most respondents shifted to casuarina as it required low amounts of water and labour and yielded higher income per acre. It also gives farmers a chance to earn money from other sources.

Table 3 gives a picture of the major crops in the study area and the acreage under each crop in all the six villages. Most of the farmers grow paddy just after the northeast monsoon (December to March). Where water is available through canals or private wells, paddy is grown two to three times a year. The land under paddy cultivation is higher in Veedur and Pombur compared to the other villages. According to the respondents, the main reason for this difference is the availability

**Table 3** Village-wise acreage under major crops

| Village name | Paddy | Sugarcane | Casuarina | Black gram | Cotton | Groundnut | Other crops |
|---|---|---|---|---|---|---|---|
| Veedur | 73.9 | 33 | 75 | 18 | 10 | 36 | 11.1 |
| Pombur | 67.1 | 65.3 | 22 | 15 | 4 | 14 | 16 |
| Nemili | 22.5 | | 37 | 17 | | 8 | 8 |
| Thollamur | 39 | | 22.5 | | | 2 | 2 |
| Lingareddypalayam | 17.9 | 42.5 | 72.5 | | | 3 | |
| Suthukeny | 30.9 | 46.3 | 25.7 | | | | |

of water for a longer period in the head end and the production of paddy per acre is higher from dam water than groundwater. Respondents also stated that paddy under canal irrigation produces around 25–30 quintals per acre as compared to 18–25 quintals per acre under groundwater irrigation. Though the production per acre was not as much as in the head end, it was observed that paddy was cultivated two to three times in Puducherry villages, mainly due to good-quality soil and assured water supply from bores.

Sugarcane was the third most important crop after paddy and casuarina. Sugarcane is a highly water-intensive crop and, as Table 3 shows, none of the respondents from the hard bedrock middle-reaches grew sugarcane. Focus group discussion revealed that Pombur especially leads in terms of acreage of land under sugarcane as a result of state government subsidies and encouragement of drip irrigation scheme in this village. It is generally believed that the production of sugarcane is higher per acre under drip irrigation as compared to normal irrigation. In Puducherry, the presence of a sugar mill in Lingareddypalayam since the 1980s has gradually led to a shift from paddy to sugarcane cultivation. The government schemes favouring sugarcane cropping and subsidized bore installation schemes have encouraged sugarcane production and today most farmers prefer growing sugarcane as per-acre return is higher. Both sugarcane and casuarina were found to be more profitable and less labour intensive than paddy.

Among the legumes and pulses, groundnut accounted for around 7% of the total cultivated area in the study villages, followed by black gram, sometimes used as an intercrop with casuarina or groundnuts. Many dryland crops, such as Ragi and Bajra, grown previously, were either not grown any longer or confined to a few farmers with small acreages. Cotton was grown mostly as a rain-fed crop in the head-end villages. Other crops grown included the eucalyptus tree, bananas, fodder grass and vegetables such as lady’s finger, brinjal and chillies.

Wells are the principal source of irrigation in Tamil Nadu and during 2007–2008, the net area irrigated by open wells and tube wells/bore wells accounted for about 55.6% of the total net area irrigated. The net area irrigated by wells during 2007–2008 was highest in Villupuram district, which accounted for 10.8% of the total net area irrigated by wells in the state (Season and Crop Report 2007–2008, Department of Economics and Statistics, Tamil Nadu). In Puducherry, during 2008–2009, the net area irrigated by tube wells was 64%, with canals accounting for only about 35% of the total net irrigated area (Season and Crop

**Table 4** Comparative village dependence on surface and groundwater (number of farmers)

| Village name | Surface water | GW + surface water | GW wells | Rented GW only[a] |
|---|---|---|---|---|
| Veedur | 13 | 12 | 7 | 2 |
| Pombur | 7 | 4 | 15 | 7 |
| Nemili | 10 | 6 | 4 | 0 |
| Thollamur | 15 | 1 | 4 | 0 |
| Lingareddypalayam | 0 | 0 | 12 | 7 |
| Suthukeny | 0 | 0 | 6 | 7 |

[a] These farmers depend only on water bought from well owners for irrigation. They are also included in total groundwater users

Report 2008–2009, Government of Puducherry). Table 4 gives an overview of the dependence of each study village on surface and groundwater.

The main irrigation sources in the study area were private bores and wells. The farmers in the head and middle reach of the canal irrigated with dam and tank water for three to four months after the northeast monsoons. Table 4 provides a general overview of the dependence of respondents on surface and groundwater. It shows that groundwater played a major role as a source of irrigation with surface water irrigation absent in Lingareddypalayam and Suthukeny as a result of their location at the tail end of the main canal.

The socioeconomic conditions of these villages played a major role in their well ownership and dependence on various irrigation sources. Approximately 32% of the total respondents depended entirely on surface water for irrigation and 16% used both surface and groundwater, with the major users located at the head end of the canal. Illegal withdrawal of water through pipes attached to engines in main canals and smaller channels was also observed during the field visit to the head-end villages. Such withdrawals further reduced the chances of water reaching the tail end of the canal system. Groundwater accounted for around 35% of the total water used, with 16% of the respondents depending only on rented water from well owners. Since rented water is also groundwater, approximately 50% of respondents depended on groundwater sources for their irrigation needs. Groundwater is not used if canal water is available and if rainfall is normal. However, as this was not the case most of the time, pressure on the aquifers has increased rapidly, resulting in a lowering of water tables.

In 2005, an initiative was taken up by the Tamil Nadu government to develop the basin command area and increase the efficiency of irrigation systems with the help of the World Bank. The main objective of this venture, known as the "Irrigated Agricultural Modernisation and Water Resources Management" (IAMWARM) Project, was rehabilitation and modernization of anicuts,[2] flood banks, supply channels and tanks in the Varahanadi sub-basin. Under this project, the existing irrigation facilities such as the system tanks, non-system tanks and dams of the basin are being modernized to harness the full benefit of the available water

[2] Anicut is a Tamil word meaning "dam".

**Table 5a** Details of water buyers in the study site

| | Veedur | Pombur | Nemili | Thollamur | Lingareddypalayam | Suthukeny |
|---|---|---|---|---|---|---|
| Max. no. of sellers/buyers | 1 | 3 | – | – | 2 | 1 |
| Output share[a] | (1/3) | (1/3) | – | – | (1/3,1/4) | (1/3,1/4) |
| Hourly rate[b] | – | (20–50) | – | – | – | – |
| Seasonal contract[c] | – | (1,000–7,000) | – | – | – | – |

[a] The value in brackets denotes the fraction of share of the total produce given to sellers, either in cash or crops

[b] The number in brackets denotes the hourly rate of buying water in rupees. The rate varies from 20–50 rupees

[c] The number in brackets denotes the amount in rupees paid for the whole season for a crop. The amount varies according to the type of crop from a minimum of 1,000 rupees to a maximum of 7,000 rupees

potential. This project is expected to increase agricultural productivity and provide benefits to the farmers. Work is still taking place to line the main canal with cement and stones for efficient transfer of water and reduction of seepage losses. Once the whole project is completed, we will know if there is any improvement in the efficiency of the canal system and if the benefit is passed to the tail-enders.

## Water Transactions

Three types of market contracts for water transactions were observed in the study area, namely, fixed charge per season, flat charge per application of water, and output sharing contracts. Among these, output sharing contracts were the most common. This contract type is mainly used for paddy where the water seller takes a third of the crop produce. In the case of sugarcane and casuarina, the water seller receives a quarter of the cash value of total production.

Flat charge contracts were found mainly in the hard rock areas in the middle reaches of the canal, where farmers cultivated once yearly after the north-east monsoons. Water was bought only for the last phase of the crop season and for a short period. Tables 5a and b provide data on water buyers and sellers in the six villages. In Table 5a, the first row gives the average number of sellers per buyer, which is around two. Buyers of water generally buy from the same sellers.

In the case of the tank irrigation systems of South India, the water market works in the later part of the crop season. The water is supplied on an hourly basis with rates varying from 20 to 50 rupees an hour depending on the crop period and the demand. Normally, about two to three buyers are covered under single well-owners (Palanisami and Suresh Kumar 2004). Evidence from the state of Bihar and the Ganga–Brahmaputra basin in India shows that cash transactions (Mukherji 2004; Shah 1991; Shah and Ballabh 1997; Fujita and Hossain 1995) are very common in water markets. Palanisami (2009), found the practice of non-cash

**Table 5b** Details of water sellers in the study site

| | Veedur | Pombur | Nemili | Thollamur | Lingareddy-palayam | Suthukeny |
|---|---|---|---|---|---|---|
| No. of sellers | 3 | 5 | 2 | – | 5 | 1 |
| Max. no. of buyers/sellers | 4 | 6 | 5 | – | 10 | 5 |
| Output share[a] | (1/3) | (1/4) | – | – | (1/3 and 1/4) | (1/3 and 1/4) |
| Hourly rate[b] | (50–60) | (30–50) | (25–30) | – | (50) | – |
| Seasonal contract[c] | – | (2,000–10,000) | – | – | – | – |

[a] The value in the bracket denotes the output share of the total produce with the seller
[b] The numbers in the bracket denote the minimum and maximum amount in rupees paid to the seller under the hourly rate system
[c] The numbers in the bracket denote the minimum and maximum amount paid in cash for a season. It varies according to different crops

contracts in the form of share-cropping in Tamil Nadu, particularly in tank and canal command areas. Janakarajan (1993), in his study of water markets in Tamil Nadu, found cases where water buyers offered labour services such as operating pumps and irrigating well owners' fields.

Seasonal contracts were found only in Pombur, where a fixed proportion of crops was agreed upon for the whole season, the proportion varying by crop, the highest being sugarcane and the lowest pulses and legumes. Two to three cases were observed where water sellers sold water "free of cost" but with the exception that the buyer would offer in return some other kind of service in the future. The hourly rate for water buying was used mostly for groundnuts, black gram and other legumes, as water was needed only for a short time during the last phase of cultivation. As Puducherry villages cultivated only paddy, sugarcane and casuarina, water transactions were only in the form of output-sharing contracts.

In Table 5b, water transactions are viewed from the water seller's standpoint in the study villages. The maximum number of water buyers per seller was higher than water sellers per buyer. This indirectly points to the dependence of small farmers on water transactions for irrigation purposes. Many water sellers were found to transact under all the three types of contract with their different water buyers.

The water sellers interviewed in Pombur and some sellers in Lingareddypalayam took a quarter of the total produce in terms of crops, including paddy. However, this was not common for all sellers. During personal interviews, it was found that the shares in output were increased because of competition with nearby sellers. The sellers and buyers of water had a maximum distance of 500 to 800 m between their fields. Most of the time, water was transported through PVC pipes and sometimes through small channels.

The prevalent social and ecological conditions of groundwater markets points to the fact that even though the groundwater market is not a formal institution, it plays a major role in providing access to water to marginal and small farmers, who cannot afford to have their own wells. It also points to the need to accept the existence and role of such an informal institution and to make relevant policies for both surface and groundwater use in these areas. Climate change will affect the water availability of the country. Aquifers would respond more slowly to climate change as compared to surface water systems. With a change in the climate, groundwater will become a crucial and threatened natural resource.

## Conclusions

Water scarcity is becoming one of the major areas of concern in India. With increasing demand for water, its availability is decreasing. The highly unpredictable rainfall, added to increased population expansion, has led to an increase in competition between different uses and users for the limited supplies of water in many areas. Many farmers are moving out of agriculture to find more rewarding and secure jobs in nearby towns and cities while others work as agricultural labourers in nearby villages.

Groundwater irrigation is central to India's small farmers and rural poor. In the present study, groundwater ranks as the most important source of irrigation, with both head- and tail-end farmers depending on it. Around 50% of farmers depend on groundwater for irrigation. Water-intensive crops such as paddy and sugarcane take the lead in terms of acreage. With labour shortages and decreasing water availability, there is a gradual shift towards casuarina. Many are moving out of agriculture altogether.

The majority of farmers in the study area fall into the marginal category with meagre funds to invest in their own water extraction measures. They depend on groundwater for irrigation which they rent from large farmers. Even those in the canal command area depend upon groundwater as their main source of irrigation.

The increasing scarcity and competition for water across different sectors call for a more efficient, equitable and sustainable water allocation policy. The presence of informal institutions such as groundwater markets should be officially recognized and regulated in such a way as to check the overexploitation of aquifers and to provide opportunities for small and marginal farmers to access to water. Government policies which promote water-intensive crops and provide subsidies for installing bore wells need to be changed and will require strong political will to achieve this change.

Re-formalizing India's water strategy and a change in the administrative approach towards water management issues are needed to meet the challenge of climatic change. A more holistic and long-term approach is needed to protect the region's aquifers from irreversible damage.

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