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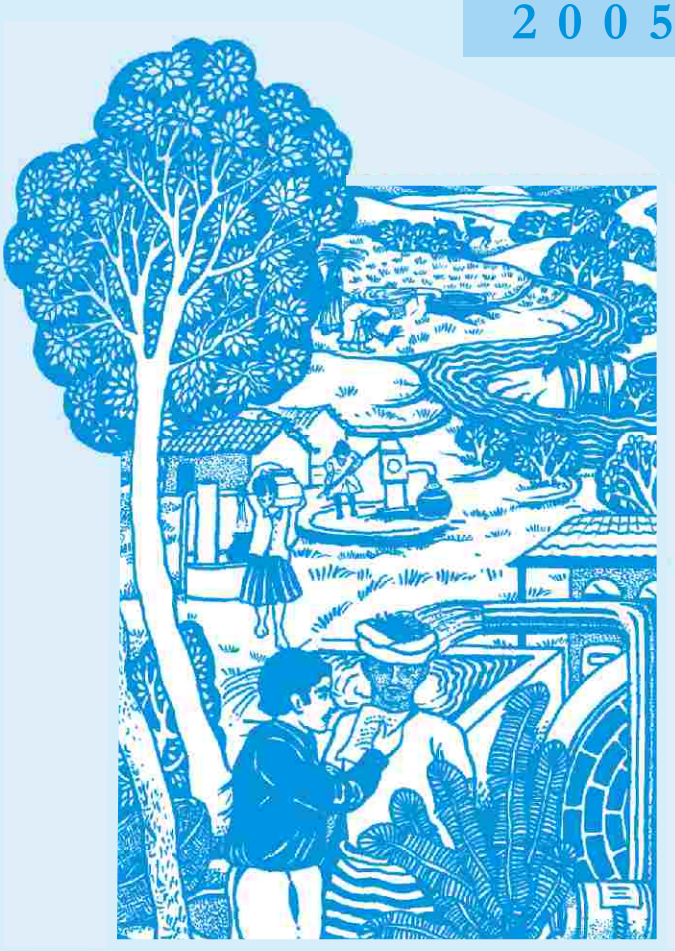
Highlight

Economic Analysis of Groundwater Markets in Central Dry Zone of Karnataka



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The functioning of groundwater markets in hard rock areas of the semi arid dry zone of Karnataka show two types of arrangements. In the first one, irrigation services are provided on demand and water charge is levied on hourly basis. In the second one, irrigation services are provided for the whole crop season, and cash equivalent of a fixed share of crop produce is paid as water charge. For water buyers, crop sharing arrangement yielded higher returns than that under hourly rates. Comparative analysis of allocative efficiencies of input use for sellers and buyers in groundwater markets show that water buyers obtain higher economic efficiency in water used for crop production than sellers, though both buyers and sellers are growing water-intensive crops such as paddy.

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Economic Analysis of Groundwater Markets in Central Dry Zone of Karnataka[1]

Research Highlight Based on a Paper with the Same Title

In the semi-arid zones of peninsular India, growth of irrigation wells has been so high that groundwater abstraction has exceeded natural recharge leading to scarcity of water. Groundwater irrigation is still the key to agricultural growth as it contributes about 56 percent to total irrigation. Since the development of groundwater is dominated by private investment, access to water is unequal in areas where well-drilling is capital intensive. Groundwater markets as informal institutions ensure access to irrigation for those who can ill afford to invest in exploiting the resource.

Groundwater markets as informal institutions provide access to groundwater irrigation benefiting resource-poor farmers who are constrained to invest on expensive and risky bore well irrigation.

Groundwater markets are important in areas which depend heavily on groundwater for irrigation. They enable many farmers to access water. The creamy section of rural society, having better access to institutional finance and large landholdings, can invest in deepening the existing wells and drilling additional ones. The ambivalence between equity and sustainability in groundwater irrigation is, therefore, becoming apparent. Groundwater markets can promote equity in access to irrigation as investment on wells is well beyond the means of small and marginal farmers. Subsidized electricity supply in the farm sector will benefit poor farmers by creating competitive water markets with lowered water charges. This study aims at analyzing the dynamics of water markets in water scarce areas with focus on functioning of groundwater markets, water pricing mechanisms, and economics.

Methodology

The study pertains to the central dry zone of Karnataka. The area is characterized by high density of bore wells and the zone in which it falls has many tehsils declared as 'dark'[2] by the Department of Mines and Geology. Annual rainfall in the zone ranges between 455 and 718 mm. Based on the intensity and functioning of water markets, four villages were taken up for detailed investigation. The selected villages were Siddapura, Thippanahalli, D. V. Halli and Kambathanahalli. A sample of 100 farmers was selected comprising 50 water sellers and 50 water buyers.

Irrigation Cost

Investment in a borewell was amortized over 10 years (the average life of bore wells), at 14 percent per annum (opportunity cost of capital) to arrive at the annual cost of selling groundwater for the well owners.

Amortized cost (A) = $CB^* [1+ i]^n * i / \{[1 + i]^n -1\}$ where CB = cost of bore well at current price.

Resource Use Efficiency

Farmers aim at allocating the available scarce resource in the most efficient manner such that

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[2]In dark areas more than 85 per cent of the recoverable recharge is being utilized, and there is no potential for further development of irrigation.

marginal benefits are equated across all uses. An attempt is made here to explore how resource use efficiency differed between water buyers and water sellers. Considering different functional forms—linear, Cobb-Douglas, quadratic and transcendental; the Cobb-Douglas model offered econometrically meaningful results. The estimated function is:

$$\text{Log } Y = \log a + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4$$

where Y = annual gross return per farm (in rupees), X_1 = volume of groundwater used per farm per year (in gallons), X_2 = irrigated area per farm (in acres), X_3 = value of farmyard manure and fertilizers applied per farm per year (in rupees), and X_4 = value of bullock and human labour services used per farm per year (in rupees). The function was estimated separately for water sellers and water buyers.

Since the production function is for the whole farm, we used gross returns from all crops irrigated with groundwater. Explanatory variables contributing to multicollinarity were deleted.

The value of marginal product (VMP) of a resource is computed at the geometric mean level of dependent (Y) and independent variable as $VMP_{xi} = b_i Y / X_i$

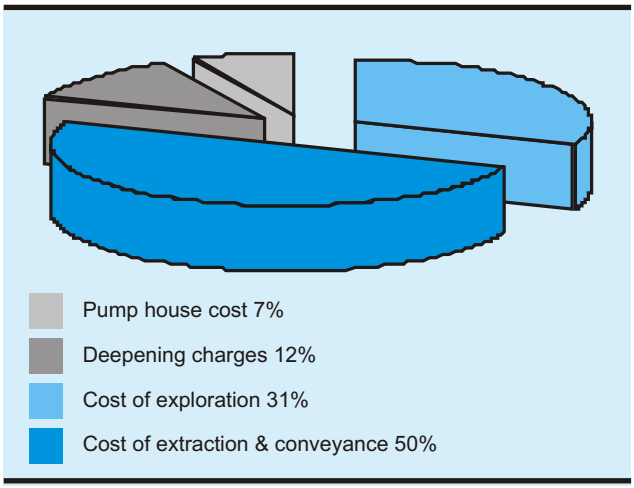
Results and Discussion

Investment in Borewells

Cost of extraction of groundwater is higher than the cost of exploration. This is because of the increasing risk of well failure. This prevents small and marginal farmers from investing in borewells

The investment in drilling a borewell is around Rs.72,202, the cost of exploration forming 31 percent of the total (Figure 1). The cost of extraction mechanism with all accessories (casing, pumpset, HDPE pipes, electricity and tank) formed a major share (50 percent) of the capital cost. Thus, extraction of groundwater is relatively more expensive than exploration even without including costs of pumping. Well drilling entails huge investment besides associated risk of well failure. This prevents resource-poor, small, and marginal farmers from investing in borewells. Majority of farmers used field channels for water conveyance and some invested in plastic pipes. Borewell owning farmers constructed an earthen farm pond to store water.

Figure 1: Investment on Borewell Irrigation by Groundwater Sellers



Source: Based on Primary Survey

Of the annual variable cost, excluding energy cost, 62 percent is for repairs of equipment and the balance for replacement of components and labor charges. The variable cost component, though negligible, adds to irrigation cost in the absence of electricity cost. The yearly amortized irrigation cost including variable cost is Rs. 16,560.

Dimension of Groundwater Market

For every groundwater seller, there were nearly two water buyers in the study area. Decision-making and pricing behavior closely resembles bilateral monopoly, with buyers and sellers dictating terms in the market. Water rent in the study area is relatively competitive since the hourly charges for groundwater are uniform irrespective of crops cultivated and type of irrigation.

Incidence of water markets is not pervasive but localized. Well owners sold water mainly during the kharif season (78 percent) and to some extent in summer. Water buyers were always at the mercy

of water sellers since the seller always had the option of not selling water.

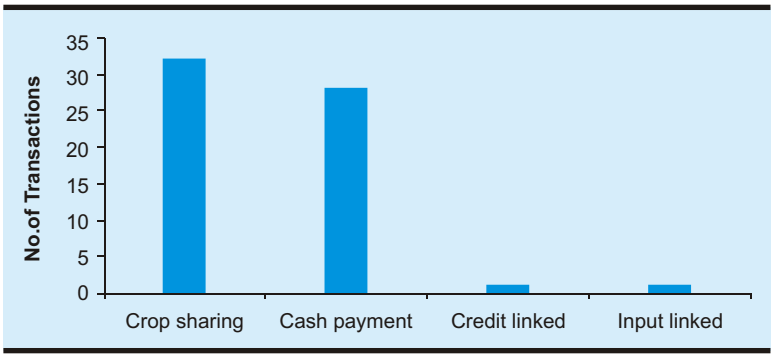
Not all the well-owning farmers were involved in water selling. Only a few well owners with surplus groundwater (after meeting their requirement) sold their water.

Functioning of Water Markets

A differential mode of payment for water existed in the area. About 45 percent of payments were through crop share contracts and cash payment was made in 39 percent of cases. About 22 percent of water buying farmers entered into contracts for more than a year. Water sellers were not ready to enter into long-term agreements or contracts owing to uncertainty in water supply/availability, as droughts were a common feature. In paddy, virtually there was no cash payment while for ragi (finger millet) and groundnut both cash payment and crop sharing prevailed. Water selling took place only after the sellers met their own requirements.

The most common sharing arrangement involved charging for water at one-third of the value of crop produce. Cash payment was preferred in 39 percent of water buying cases on hourly basis (Figure 2). Water sellers insisted on part payment of cash ranging between 25 and 50 percent of the approximate water rent at the beginning of the crop season. This was done to avoid default in the event of crop failure and the balance amount was paid at the end of the season.

Figure 2: Type of Water Markets



Source: Based on Primary Survey

A few groundwater sellers exchanged water for labor to perform agricultural operations. Thus, interlocking the water market with the labor market. However, these interlocked markets were not conspicuous. There were two cases of interlocked markets: (i) water market linked with credit and inputs where groundwater was exchanged for interest free loan, and (ii)services of animal power were exchanged with groundwater. In such markets, in addition to payment of water rent, water buyers were expected to render certain free services (participating in agricultural operations such as weeding, inter-cropping, and so on) to the seller. Water buyers opined that irrigation provision was timely and adequate, as area irrigated by buyers was small. In addition to physical proximity of land, social relations between buyer and seller influenced the sale and purchase of groundwater as the percentage of kith and kin in total transaction was modest 30 and neighbors constituted around 40 percent.

Comparison of Crop Share and Cash Payment Basis

In groundwater markets, water charge is levied in terms of either crop share or hourly basis. The crop-sharing arrangement usually leads to an assured market for water since water sale/purchase is for the entire season. Water charge is usually levied on the basis of the market value of one-third or one-fourth of the crop yield. Here the bargaining power rests with the seller even though the risk of crop loss is almost equally shared between the seller and buyer. The higher bargaining power of the seller is because of higher rate charged for water on per acre and on per acre-inch basis compared with the rate charged on hourly basis. Charging of water on hourly basis usually leads to an ad hoc market since the buyer has the option to buy water only as and when needed. Here the buyer has greater freedom and hence greater bargaining power. In water-scarce areas, crop-share based pricing of water prevails, and in relatively less scarce areas, hourly water rates rule.

The price of water estimated in both acre (area) and "acre-inch (volume) terms was found to

Table-1: Comparison of Water Price on Crop Share and Per Hour Basis for Different Crops

Crop	Water used per acre (acre inches)	Water price on crop share basis			Water price on per hour basis		
		Basis and bargaining power	Rs per acre	Rs per acre - inch	Basis and bargaining power	Rs per acre	Rs per acre - inch
Paddy	35.66	One-third of the value of crop yield. Bargaining power rests with seller	3750	105.15	Does not exist for paddy in the study area	Does not exist for paddy in the study area	Does not exist for paddy in the study area
Ragi	4.69	One-fourth	1350	288	Rs. 6 to Rs. 10 per hour Bargaining power rests with buyer	680	145
Groundnut	5.32	One-fourth	1466	276	Rs. 6 to Rs. 10 per hour Bargaining power rests with buyer	772	145

Note: Hourly charges of water varied between Rs. 8 to Rs. 12 depending on the crop
Source: Based on Primary Survey

be higher in crop-sharing arrangement than under ad hoc market with hourly water charges (Table 1). The price differential in the crop share market is 98 percent for ragi and 90 percent for groundnut. This is the reason for prevalence of crop share based water market in 65 percent of the cases of water selling, with water sellers enjoying bargaining power over the buyers. This pricing mechanism, however, belies the hypothesis that water prices are usually lower in assured markets compared with ad hoc markets. Groundwater markets operating in scarcity areas vest bargaining power with water sellers.

Cropping Pattern and Intensity

The cropping pattern is more or less uniform among water buyers and water sellers, though water buyers devoted marginally higher proportion of area for paddy (60 percent) compared to water sellers (55 percent). Groundnut dominated the crop pattern of both water buyers and water sellers during summer. In kharif, paddy was dominant among water sellers while paddy and ragi dominated the crop pattern among water buyers. During kharif, availability of groundwater is relatively higher than in other seasons. Hence, the volume of water sale was higher in kharif than other seasons. About 60 percent of groundwater use was for paddy by both the groups. In spite of access to groundwater, cash crops like vegetables and fruits have not been raised because of lack of market in the region. The cropping intensity of water sellers was higher (231 percent) than that of water buyers (159 percent) as own source of irrigation enabled water sellers to increase cropping intensity.

Economics of Water Markets

Productivity of water use in paddy was 25 percent higher on water sellers' farms than on water buyers' farms, as sellers had greater control over irrigation water. Volume of groundwater used by

water sellers for paddy per acre (51 acre-inches for paddy) was marginally higher than that used by water buyers (48 acre-inches). Water buyers paid 0.83 *paise* per gallon of water (or Rs 189 per acre-inch) and realized a return of 2.6 *paise*. After deducting the water charges, buyers realized a net return of 1.75 *paise* per gallon of water. Water sellers incurred 0.48 *paise* per gallon of water sold and realized a return of 0.84 *paise,* a net return of 0.36 *paise* per gallon of water after meeting water rent (Table 2). Water charges are the highest for ragi (Rs. 270/acre-inch) followed by groundnut (Rs. 122/acre-inch) and paddy (Rs. 78/acre-inch).

Water Use Efficiency

In case of water sellers, per acre costs and returns were higher for paddy and groundnut compared to water buyers. There was a gap in productivity between water buyers' and water sellers' farms owing to the differential reliability of irrigation water supplies. The variable cost component was higher for water sellers than for water buyers owing to use of higher doses of inputs. For water buyers, water rent formed 20 to 30 percent of the cost of production. Water sellers realized higher yield of paddy (25.30 quintals) than water buyers (20 quintals). In the case of other crops, water buyers had higher productivity than water sellers owing to higher water use efficiency. There is a sharp difference with respect to irrigation cost. For sellers, amortized irrigation cost per acre of gross irrigated area was higher (45 percent of total cost in paddy, 9 percent in ragi, and 18 percent in groundnut). For buyers, irrigation cost per acre (actual rent paid to water seller) formed 31 percent of cost of production of paddy. This

Table 2: Economics of Water Markets

Particulars	Crops		
	Paddy	Ragi	Groundnut
1. Actual water used per acre (in gallons) by			
Water Seller	1160848 (51.34)	120290 (5.32)	309544 (13.69)
Water Buyer	1085328 (48.00)	113055 (5.00)	271332 (12.00)
2. Recommended water requirement	1062717 (47.00)	106271.7 (5)	264548.7 (12)
3. Crop Productivity realized (in quintals) per acre by			
Water Seller	25.0	11.0	6.0
Water Buyer	20.0	11.4	6.0
4. Cost per gallon of water purchased (in Rs.)	0.00276	0.0143	0.0081
5. Water rent paid per acre (in Rs.)	3750	1350	1465
6. Imputed water rent paid on per acre inch basis (in Rs.)	78	270	122
7. Return per gallon of water purchased (in Rs.)	0.00829 (187.45)	0.0453 (1024.28)	0.0243 (549.45)
8. Cost per gallon of water sold (in Rs.)*	0.00479 (108.31)		
9. Return per gallon of water sold (in Rs.)*	0.00838 (189.48)		

Note: Figures in parentheses are acre-inches of water [* Pooled data]
Source: Based on Primary Survey

shows that the imputed water rents are lower whereas market rents are relatively higher, reflecting a higher opportunity cost of irrigation.

Resource Use Efficiency

The Cobb-Douglas production function estimated separately for water sellers and water buyers gave the following results:

Annual gross return per farm of water sellers =

$5.3535 + 0.180^{*} X_1 + 0.386^{*} X_2 + 0.249^{*} X_3 + 0.019^{*} X_4$

(0.052) (0.086) (0.097) (0.191)

R^2 =0.49, n=50

Annual gross return per farm of water buyers =

$2.4457 + 0.322^{*} X_1 + 0.273^{*} X_2 - 0.01 X_3 + 0.339^{*} X_4$

(0.121) (0.108) (0.468) (0.137)

R^2 =0.51, n=50

* significant at 1 percent level of significance

The elasticity of gross return for volume of water used was 0.32 for water buyers and 0.18 for water sellers. Thus, water buyers realized higher elasticity of gross return for water compared with water sellers. Since buyers paid the marginal cost of water, they were relatively more efficient in water use than water sellers.

Allocative Efficiency

Irrigation water was used more efficiently by water buyers than water sellers, as their marginal product value/marginal factor cost ratio (0.81) was closer to unity compared to that of water sellers, who had a ratio of 0.58. Water buyers took care in utilizing the purchased water as they were paying rent for the resource.

Major Findings

Since agriculture is heavily dependent on groundwater irrigation in the central dry zone of Karnataka, informal water markets are playing a prominent role by expanding access to groundwater for small and marginal farmers and other peasants who cannot afford owning wells. Water markets have, thus, become a key source of irrigation for many farmers sustaining their incomes.

Crop sharing prevailed in 45 percent of water sales while cash payment prevailed in 39 percent. For semi-dry crops, which have low water requirement (like ragi and groundnut), both crop sharing and cash payment type of contracts existed. But for water intensive paddy crop, only the crop share method was prevalent. The price for water is charged on the basis of the market value of crop output (one-third or one-fourth). In water scarce areas, crop share basis of water pricing prevails and in relatively less scarce areas, per hour charges rule.

Comparison of crop economics of farmers who buy water on crop-sharing basis and those who buy water on hourly rates showed that crop-sharing arrangement yielded higher returns. Both the groups used more water than recommended. Groundwater use facilitated multiple cropping, and contributed to higher cropping intensity for water sellers (231 percent) than water buyers (159 percent), since purchased water is unreliable and fraught with risk. The imputed water rents are lower than the market rent.

Conclusions

Groundwater, unlike surface water, is expensive and relatively scarce and hence should be used to grow crops that are responsive to protective irrigation, require less water and are remunerative.

Sellers and buyers of groundwater have put large areas under paddy, a water-intensive crop. This needs to be disciplined through effective groundwater institutions. Groundwater literacy has to be promoted by educating farmers on the pros and cons of overexploitation. For farmers who do not own wells, one way to enable access to water is through group investments in well irrigation. This would require provision for institutional credit for such groups and energization of pumpsets. This will provide an environment of sharing available groundwater and the associated costs.

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IWMI-Tata Water Policy Program

The IWMI-Tata Water Policy Program was launched in 2000 with the support of Sir Ratan Tata Trust, Mumbai. The program presents new perspectives and practical solutions derived from the wealth of research done in India on water resource management. Its objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations.

Through this program, IWMI collaborates with a range of partners across India to identify, analyse and document relevant water-management approaches and current practices. These practices are assessed and synthesised for maximum policy impact in the series on Water Policy Research Highlights and IWMI-Tata Comments.

The policy program's website promotes the exchange of knowledge on water-resources management, within the research community and between researchers and policy makers in India.

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