Groundwater MarketingDynamics in Northern Dry Zone of Karnataka: A Comparative Study over Time

Abstract

Groundwater is an essential resource, but it is becoming increasingly scarce and depleting rapidly, particularly in the state of Karnataka. As a result, the groundwater markets have emerged as an alternative strategy to manage this limited resource more efficiently and equitably. These markets enable farmers who cannot afford water extraction machinery to access irrigation. In this study, a multi-stage random sampling technique was used to select farmers, who were then categorized into water sellers, self-users, and buyers based on participation in the market. Primary data was collected through a structured, pre-tested schedule and analysed using descriptive and logit regression analysis. The results were then compared with an earlier study conducted in 2007,in the same study area to determine any changes over years. It allows us to see how changes in technology, societal norms, or environmental conditions have influenced groundwater marketing. The study found that self-users made up the highest proportion of market participants in both studies (more than 50%). Unlike the earlier study, buyers in the present study owned wells. The depth of borewells has increased in all cases (overall by 44%), resulting in increased drilling, deepening, and pumping costs. Very few people (8%) acknowledged that over-extraction from their own farms could also contribute to groundwater insecurity. While studying the economics it was found that perennial crops had the highest economic rents (260, 610Rs/hr for sellers and buyers respectively) for market participants. The reasons for participation in the water market has shifted from investment capacity to water scarcity compared to the earlier study.So farmers can be motivated to participate in water markets or share water with fellow farmers,

instead of relying on new wells during water shortages. This encourages the optimal due to higher variable cost and reduces negative externalities associated with increasing number of wells.

Keywords: Groundwater market, Sellers, Buyers, Self-users, Pricing

1 Introduction

India's irrigation system was once the world's largest canal network, but it has now become the world's largest groundwater economy. Indiscriminate groundwater extraction is a major concern due to its easy access, lack of regulation, and free or subsidized electricity for irrigation(Patel, 2020).According to the Central Groundwater Board of India, approximately 17% of groundwater blocks are being overexploited. This means that the rate at which water is being extracted is higher than the rate at which the aquifer can recharge. Additionally, 5% and 14% of blocks are at critical and semi-critical stages, respectively. The situation is particularly concerning in three major regions: north-western, western, and southern peninsular.Based on a World Bank project report, groundwater pollution and climate change, particularly unpredictable rainfall in dry regions, are putting extra pressure on groundwater resources. These resources provide around 85% of rural domestic water supply, 45% of urban domestic water supply, and over 60% of irrigated agriculture. The current rate of overexploitation is endangering livelihoods, food security, climate-induced migration, sustainable poverty reduction, and urban growth(Shiferaw, 2021).Groundwater markets provide an alternative water management strategy for efficient and equitable use of scarce water resources. These markets are defined as informal, local, institutional setups present at the village level through which water extraction machinery owners sell water to others at a price. Groundwater markets in India are unregulated, but they promote equity, efficiency, and sustainability benefits(Varughese and Prasad 2012). Agricultural groundwater markets play a significant role in reallocating water from low-valuehigh-volume uses to high-value uses. Private water extraction machinery and groundwater markets have brought far more land under supplemental on-demand irrigation than government canals(Shah and Chowdhury, 2017).Sustainable groundwater use requires participation from local communities with social and economic policies and technical and political inputs. Improving the management of recharge structure and pumping of groundwater can assist in stabilizing the local water table. This study is unique of its kind because it aims to assess the utility of groundwater markets as an economically viable alternative and studies the changes in the scenario in the Northern dry zone of Karnataka by comparing the results obtained from an earlier study conducted in 2007 by Mahantesh R Nayak titled 'Groundwater Markets in Karnataka: Key issues in sustainability'. It allows us to see how changes in technology, societal norms, or environmental conditions have influenced groundwater marketing. We can integrate new insights that have emerged in the interim and identify any long-term effects or trends. Additionally, having a historical record of development is beneficial.

2 Methodology

The study focuses on groundwater marketing in the Northern Dry Zone of Karnataka and compares the results with an earlier study conducted by Mahantesh R Nayakin 2007. The goal is to determine the suitability of groundwater marketing and analyze any changes in the scenario. The sample respondents were farmers who used groundwater for irrigation. The survey involved a multi-stage purposive random sampling technique. Three districts with the highest area under groundwater irrigation were selected, namely Bagalkot, Vijayapur, and Belagavi. From each of these districts, two taluks with the highest groundwater resource availability were chosen, and two villages were selected from each taluk. The sample farmers were categorized into water sellers, self-users, and buyers based on their participation in the groundwater market. The primary data was collected through personal interviews using a structured, pre-tested schedule from the sample respondents for the agriculture year 2020-21 and data from Nayak (2007) study was used to comparison.

Tabular, descriptive statistics was used to examine the general socio-economic conditionof the sample respondents, their investment in irrigation infrastructure, and the cost and returns per hectare from irrigated cropping, opinions of farmers on insecurity of water supply and groundwater depletion. The logistic regressionisemployedto study the factors that affected farmers' decisions to participate in groundwater marketing. The logit model used in the study is provided below.

$\ln [\{P(m/x)\}/\{P(t/x\}] = XB + E$ … (1)

$\ln [\{P(m/x)\}/\{1\text{-}P(m/x)\}] = XB + E$ … (2)

Where,

P(m/x) = Probability of individual farmer being a participant in groundwater market,

where, level of X is given

P(t/x) = Probability of individual farmer being a non-participant in groundwater market, where, level of X is given

= 1-P(m/x)

$[\{P(m/x)\}/\{P(t/x)\}] = [\{P(m/x)\}/\{1\text{-}P(m/x)\}]$

= Relative odds of a farmer’s participation versus non-participation in groundwater market.

X = Explanatory variables

B = Response coefficients vector and

E = Random disturbances vector

The logit model estimated to find the logarithm of "relative odds of farmer's participation versus non-participation in groundwater market" is specified as follows.

$$\ln [P_i/(1-P_i)] = \beta_0 + \beta_1 AGE_i + \beta_2 EDN_i + \beta_3 FMSZ_i + \beta_4 NWW_i + \beta_5 NFW_i + \beta_6 YOW_i + \beta_7 LHD_i + \beta_8 AREAFC_i + \beta_9 AREAHC_i + \beta_{10} IRRIGFUR_i + \beta_{11} IRRIGDRP_i + \beta_{12} IRRIGSPR_i + \beta_{13} AREAKH_i + \beta_{14} AREARB_i + \beta_{15} AREASM_i + \beta_{16} AREAPE_i + U_i$$

Where,

P_i = Probability of the i^{th} farmer being a participant in the water market

$(1-P_i)$ = Probability of the i^{th} farmer being not a participant in the water market

AGE = Age of the farmer (years)

EDN = Education of the farmer indicated by the number of schooling stages, taking values 0 (indicating illiterate), 1 (completed primary education), 2 (secondary education), 3 (matriculation), 4 (higher secondary), and 5 (college)

FMSZ	=	Family size (number)
NWW	=	Number of working wells owned by farmer
NFW	=	Number of failed wells
YOW	=	Yield of working wells (inches)
LHD	=	Land holding of farmers (ha)
AREAFC	=	Area under field crops (ha)

AREAHC	=	Area under horticultural crops (ha)
IRRIGFUR	=	Area under furrow irrigation (ha)
IRRIGDRP	=	Area under drip irrigation (ha)
IRRIGSPR	=	Area under sprinkler irrigation (ha)
AREAKH	=	Area under kharif crops (ha)
AREARB	=	Area under rabi crops (ha)
AREASM	=	Area under summer crops (ha)
AREAPE	=	Area under perennial crops (ha)
β_j	=	Logit coefficients (j = 0,1...16) and
U_i	=	Random disturbances (i= 1…120)

3 Results and discussion

In the study area, there were three categories of market participants: buyers, sellers, and self-users. An additional category was included in the present study - self-user-cum-buyer with in buyers because of the presence of buyers who owned wells.

The proportion of each category of water market participant was nearly the same in both studies, to ensure fair comparison (Table 1). Self-users were the largest proportion of participants in both studies(44 - 46%). However, in the study conducted by Singh et al. (2007), sellers were the most prevalent. The average size of land holding has decreased from the earlier study, due to the fragmentation amongst children over generations. In general, self-users and sellers had more land holdings than buyers, as they had sound financial status. This result issupported with the study of Acharyya et al. (2018), where more than 75% of buyers were marginal farmers. The number of wells per household was less for buyers (1.02) than the other two categories in the present study because they had lesser land holdings, and were financially not so stable. Area irrigated per well remained almost same in both studies and in the present study, sellers had more area per well(2.66 ha), because sellers irrigate their farms as well as the buyers.

With respect to borewell related information (Table 2), the age of wells was found to be lower than earlier study due to frequent borewell failures and recent construction of wells, except in Vijayapur where it washighest(14 years).The exception is due to adoption of water conservation strategies such as drip irrigation and groundwater recharge. The depth of water table in Bagalkothas surpassedVijayapur and it also hadhighest number of well failures(34.40%) due to increase in water-intensive commercial crops and inadequate water supply management. In Vijayapur, the sustainability status has improved, leading to an improvement in the yield of wells(+1.47) and decrease in well failures (10%).

To assess depletion over time (from 1980 to 2020), the study period has been divided into four phases (Table 3). The most significant increase in borewell depth occurred during Period IV compared to any other period(28.90%), due to increased drilling and easier financial access, improved economic conditions of farmers, and greater availability of drilling machinery and electricity. Commercialized agriculture with water-intensive cash crops has also contributed to the depletion of the water table. Kulkarni et al (2015) found that unsustainable groundwater pumping for irrigation was the primary reason for the significant depletion of the water table, with 60% of districts in India either depleted or contaminated. The increasing rate of watertable depth represents a growing stress on groundwater resources, highlighting the need for integrated resource management and improved recharge facilities.

More than 70% of respondents expressed feelings of insecurity when it came to the sustainability of groundwater supplyin both studies (Table4). Interestingly, some respondents

did feel secure about the supply. In fact, in the current study, there were more farmers who cited an increase in the number of wells as a reason for their insecurity about water supply than in the previous study(65%).Increase in wells, with less distance between them, has also led to an almost two-fold increase in the number of respondents who feel insecure (37 to 61% because of the fear of neighbor farmers drilling borewells). Only a few people acknowledged that over-extraction from their own farms could also contribute to this insecurity (only 8%).
The amount of irrigation per hectare was highest for perennial crops(158 Hrs/ha) as they require year-round irrigation (Table 5). Perennial crops also had the highest economic rent from water selling (260 R/ha). The economic benefit for buyers in terms of extra income obtained through irrigation was highest for perennial crops (610 R/ha).Increase in operational and maintenance costs for buyers has increased much higher (almost 5 folds)than for sellers in the present study, as buyers now own wells, unlike in the earlier study. Khan and Brown (2019) found that trading permits between farmers increased economic benefits and, in some cases, reduced environmental violations.

A logit model was used to determine factors affecting participation in the water market (Table 6). The study initially had sixteen dependent variables, but three variables were removed due to multicollinearity in the present study (2021). Out of the total sixteen variables included in the model age, area under kharif crops, number of working wells, land holding, and furrow irrigation were significant in the earlier study. In the present study, the yield of wells, area under rabi crops and area under summer crops were significant. This indicates a shift in the reasons for farmers' participation in water markets, from investment capacity on wells to water scarcity. The exponential value of regression coefficients indicates the amount by which participation in water markets will change if the corresponding explanatory variable changes by one unit. If the value is more than one, the corresponding variable has a positive influence on participation, otherwise negative influence. In a different study, Manjunatha *et al.* (2014) found that water buying was positively influenced by well failures and agricultural credit.

4 Conclusion

The study reveals a shifting trend in groundwater markets in Karnataka, indicating increased reliance on market participation due to water scarcity. Self-users remain predominant, but buyers now own wells, reflecting changes in market dynamics and ownership patterns. The escalating depth of borewells and associated costs highlight the intensifying struggle to access groundwater. Despite this, a minimal acknowledgment of individual over-extraction suggests a need for heightened awareness. Economic gains from perennial crops drive market participation, influencing motivations from investment capacity to addressing water scarcity. Policy implications suggest a shift towards incentivizing water sharing over excessive well drilling. Encouraging optimal resource utilization and reducing negative externalities through measures promoting water market participation, cooperative sharing, and sustainable farming practices will be crucial in managing groundwater resources.

The groundwater market in Karnataka reflects a notable shift, primarily driven by water scarcity. Understanding changing motivations for market participation and ownership patterns is crucial. Policy initiatives to incentivize water sharing, promote sustainable practices, and manage escalating drilling costs are imperative for effective groundwater resource management in the region.

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Table 1: Characteristics of households participating in water markets

SN	Particulars		Bagalkot district n=40			Belagavi district n=40			Vijayapur district n=40			Overall n=120		
			SU	S	B	SU	S	B	SU	S	B	SU	S	B
1	Number of households (No.)	2006	16 (40.00)	12 (30.00)	12 (30.00)	16 (40.00)	12 (30.00)	12 (30.00)	21 (52.50)	9 (22.50)	10 (25.00)	53 (44.17)	33 (27.50)	34 (28.33)
		2021	16 (40.00)	13 (32.50)	11 (27.50)	25 (62.50)	7 (17.50)	8 (20.00)	15 (37.50)	13 (32.50)	12 (30.00)	56 (46.66)	33 (27.50)	31 (25.84)
2	Avg. size of land holding (ha)	2006	9.56	10.12	2.76	14.09	3.44	1.42	9.46	6.12	2.72	11.03	6.56	2.3
		2021	4.23	3.04	1.77	1.36	2.04	1.05	5.11	3.97	3.15	3.56	3.02	1.99
3	No. of wells per household	2006	3.94	3.17	-	3.25	3.08	-	3.45	3.32	-	3.54	3.19	-
		2021	2.75	2.30	0.72	1.52	2.14	0.75	2.06	2.61	1.58	2.11	2.35	1.02
4	Area irrigated per well (ha)	2006	2.45	2.76	-	2.02	1.86	-	3.29	3.05	-	2.58	2.55	-
		2021	2.34	2.59	1.77	1.35	2.12	1.13	3.03	3.26	1.67	2.24	2.66	1.52

Note: SU = Self-User, S = Seller, B = Buyer; Figures in parentheses indicate percentages to total.

No buyers did own wells in 2006

Table 2: Borewell related information of the sample respondents

SN	Particulars	Units	Bagalkotdistrict		Belagavidistrict		Vijayapur district		Overall	
			2006	2021	2006	2021	2006	2021	2006	2021
1	Age of borewell	Years	12.00	7.05	10.00	8.49	14.00	14.30	12.00	9.94
2	Depth of borewell	Feet	327.00	516.25	315.00	467.50	377.00	495.00	340.00	492.91
3	Average initial yield of borewell	Inches	3.52	3.62	3.60	3.63	3.06	3.05	3.39	3.43
4	Average present yield of borewell	Inches	3.09	2.92	3.70	2.87	2.54	3.09	3.11	2.96
5	Changes in water yield-Absolute [(4)-(3)]	Inches	-0.43	-0.70	+0.10	-0.76	-0.52	+0.04	-0.28	-0.47
6	Changes in water yield-Percentage [(4)-(3)/ (3)] *100	%	-12.22	-19.31	+2.78	-21.03	-16.99	+1.47	-8.26	-12.95
7	Number of borewells working	%	70.00	65.60	77.00	73.75	62.00	72.50	69.00	70.10
8	Number of borewells failed	%	30.00	34.40	23.00	26.25	38.00	27.50	31.00	29.90

Table 3: Temporal groundwater depletion in the study area

	Period	Years	Belagavi district			Vijayapur district			Bagalkot district			Overall		
			Mean depth (ftbgl)	Increase over previous period (ft)	% Increase over previous period	Mean depth (ftbgl)	Increase over previous period (ft)	% Increase over previous period	Mean depth (ftbgl)	Increase over previous period (ft)	% Increase over previous period	Mean depth (ftbgl)	Increase over previous period (ft)	% Increase over previous period
Past study	I	1981-90	201	-	-	305	-	-	285	-	-	264	-	-
	II	1991-00	268	67	33.33	350	45	14.75	318	33	11.58	312	48	18.18
Present study	III	2001-10	360	92	34.32	415	65	18.57	397	79	24.84	391	79	25.32
	IV	2011-20	490	130	36.11	503	88	21.20	519	122	30.73	504	113	28.90

Table 4: Opinions of sample respondents on groundwater security

SN	Particulars	Belagavi district		Vijayapur district		Bagalkot district		Overall	
		n = 28	n = 37	n = 30	n = 35	n = 28	n = 37	n = 86	n = 109
		2006	2021	2006	2021	2006	2021	2006	2021
a.	Respondents 'secure' with respect to groundwater	9 (32.00)	12 (32.44)	1 (3.00)	9 (25.72)	8 (29.00)	7 (18.92)	18 (21.00)	28 (25.69)
b.	Respondents 'insecure' with respect to groundwater	19 (68.00)	25 (67.56)	29 (97.00)	26 (74.28)	20 (71.00)	30 (81.08)	68 (79.00)	81 (74.31)
Reason for 'insecure' feeling of the respondents with respect to groundwater									
1	Depletion of water table	14 (74.00)	22 (59.45)	29 (100.00)	26 (74.28)	18 (90.00)	29 (78.37)	61 (90.00)	77 (70.64)
2	Low rainfall	16 (84.00)	25 (67.56)	26 (90.00)	26 (74.28)	12 (60.00)	30 (81.08)	54 (79.00)	81 (74.31)
3	Continuous drought	10 (53.00)	7 (18.91)	20 (69.00)	11 (31.42)	12 (60.00)	9 (24.32)	42 (62.00)	27 (24.77)
4	Increase in number of borewells	12 (63.00)	21 (56.75)	19 (66.00)	25 (71.42)	10 (50.00)	25 (67.56)	41 (60.00)	71 (65.13)
5	Lack of ponds, tanks and streams near to his farm	11 (58.00)	18 (48.64)	13 (45.00)	21 (60.00)	8 (40.00)	19 (51.35)	32 (47.00)	58 (53.21)
6	Fear of the neighbouring farmers drilling borewells adjacent/very near to his own	9 (47.00)	19 (51.35)	10 (34.00)	22 (62.85)	6 (30.00)	26 (70.27)	25 (37.00)	67 (61.46)
7	Over extraction of groundwater from aquifer	3 (16.00)	2 (5.40)	8 (28.00)	4 (11.42)	9 (45.00)	3 (8.10)	20 (29.00)	9 (8.25)

Note: Figures in parentheses indicate percentages to total; 'n' indicates number of well owners.

Table 5: Economic rents to sellers and buyers of groundwater market

	Particulars		Belagavi district				Vijayapur district				Bagalkot district				Overall			
			K	R	S	P	K	R	S	P	K	R	S	P	K	R	S	P
1	Extent of irrigation (Hrs/ha)	2006	51	80	95	142	47	82	86	105	50	83	85	170	49	82	89	139
		2021	67	95	116	156	55	92	93	170	68	78	96	148	63	88	101	158
2	Economic rent to seller[1] (Rs/hr)	2006	63	36	35	132	74	40	42	281	-	-	-	115	68	37	39	162
		2021	89	58	58	256	119	70	42	254	93	72	65	272	100	66	55	260
3	Economic rent to buyer[2] (Rs/hr)	2006	188	107	104	396	221	119	127	844	-	-	-	344	204	112	117	487
		2021	304	186	141	575	426	235	262	610	373	302	260	646	367	241	221	610
4	Operational and maintenance cost to seller (Rs/hr)	2006	10				13				12				12			
		2021	32				35				34				34			
5	Operational and maintenance cost to buyer (Rs/hr)	2006	2				4				3				3			
		2021	16				15				17				16			
6	Net income to seller (Rs/hr)	2006	53	26	25	122	61	27	29	268	-	-	-	103	56	25	27	150
		2021	57	26	26	224	84	35	7	219	59	38	31	238	67	33	21	227
7	Net income to buyer (Rs/hr)	2006	186	105	102	394	217	115	123	840	-	-	-	341	201	109	114	484
		2021	288	170	125	559	411	220	247	595	356	285	243	629	352	225	205	594

Note: K=*Kharif*; R=*Rabi*; S=Summer; P=Perennial.

1: Amount paid by buyer to seller

2: Additional gross returns to the buyer due to ‘irrigated farming’ (through purchase of water) over ‘rainfed farming’

Table 6: Factors determining farmers' decision to participate in groundwater market

Explanatory Variable	Coefficient (Bj)			SE (Bj)			Significance Level			Exp (B)	
	2006	2021		2006	2021		2006	2021		2021	
Constant	-0.0620	0.886	1.207	3.442	1.767	1.723	0.986	0.616	0.483	2.426	3.345
Age	-0.0640*	0.002	0.003	0.037	0.025	0.024	0.085	0.932	0.890	1.002	1.003
Education	-0.2600	0.335*	0.266	0.328	0.192	0.183	0.427	0.081	0.146	1.398	1.305
Family Size	-0.0100	0.124	0.065	0.151	0.210	0.197	0.949	0.553	0.742	1.132	1.067
Number of Wells Working	-0.7500***	-0.043	-0.014	0.284	0.315	0.297	0.008	0.892	0.964	0.958	0.987
Number of Wells Failed	-0.2870	0.573	0.380	0.273	0.413	0.385	0.294	0.165	0.323	1.774	1.463
Yield of Well	-0.1250	-0.903***	-0.887***	0.300	0.272	0.258	0.676	0.001	0.001	0.405	0.412
Land Holding	0.7520***	-0.484	-0.455	0.226	1.048	0.991	0.001	0.644	0.647	0.616	0.635
Area under Field Crops	0.0260	-5318.911	-	0.059	2915022.777	-	0.655	0.999	-	0.000	-
Area under Horticultural Crops	0.4000	-5318.392	-	0.335	2915022.777	-	0.233	0.999	-	0.000	-
Furrow Irrigation	-0.5360***	0.600	0.645	0.137	1.048	0.991	0.000	0.567	0.515	1.822	1.907
Drip Irrigation	0.0170	0.760	0.820	0.308	1.044	0.986	0.955	0.467	0.406	2.137	2.270
Sprinkler Irrigation	-0.0560	-22.222	-	0.096	49620.951	-	0.561	1.000	-	0.000	-
Area under *kharif* crops	2.3810**	5319.222	0.401	1.025	2915022.777	1.258	0.020	0.999	0.750	0.000	1.494
Area under *rabi* crops	-0.3880	-1.441***	-1.577***	1.313	0.542	0.526	0.767	0.008	0.003	0.237	0.207
Area under summer crops	1.3590	-1.288	-1.411*	1.754	0.851	0.835	0.438	0.130	0.091	0.276	0.244
Area under perennial crops	0.3640	5318.314	-0.263	0.579	2915022.777	1.086	0.529	0.999	0.809	0.000	0.769
	2006				2021						
-2 Log likelihood	132.136				125.499			129.983			
% Correct Classification	90.800				73.333			71.700			
Sensitivity[#]	94.000				73.437			71.900			
Specificity[$]	86.800				73.214			71.400			
No. of observations (n)	120.000				120.000			120.000			

Note: ***, ** and * indicates significant at 1, 5 and 10 per cent probability levels, respectively.

[#]Proportion of participators who were predicted correctly; [$]Proportion of non-participators who were predicted correctly.