The Pharma Innovation Journal 2022; SP-11(9): 1657-1661

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; SP-11(9): 1657-1661

www.thepharmajournal.com
Received: 09-06-2022
Accepted: 15-07-2022

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A study on present status of groundwater markets in northern dry zone of Karnataka

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Abstract
Groundwater is the most reliable essential source of fresh water. It is a highly scarce resource and is depleting at a faster rate than ever especially in Karnataka. Groundwater market is one of the water management strategies for efficient and equitable use of scarce water resource and it also gives access to irrigation to those who are not able to invest in bore wells or wells. Multi-stage purposive random sampling technique was used in study for selection of respondents. The sample farmers were categorized into Sellers, Self-users and Buyers based on participation in groundwater market. Collection of the primary data was done using structured, pre-tested schedule. Simple descriptive statistics, percentage and tabular analysis were used in the study. The present study results are compared with earlier one (Nayak, 2007) [2] to know what the changes are over the years. Results showed the proportion of different categories of water market participants were almost same in both studies and self-users were of highest proportion compared to others. Self-users and sellers had more land holding than buyers by default because of their capacity to invest. Buyers in present study had owned wells but in earlier they did not. Sellers had more area irrigated per well followed by self-users and buyers. Depth of bore wells which were dug in Period IV is highest in Bagalkot followed by Vijayapur and Belagavi. Widespread failure of wells and increase in cost of drilling, deepening and pumping is due to increasing depth of aquifers.

Keywords: Groundwater market, sellers, buyers, self-users, pricing

1. Introduction
Irrigation is usually carried in areas lacking sufficient rainfall to support crops. India today is world's largest groundwater economy though it was world's largest canal irrigation network during independence. Groundwater irrigation gives higher degree of control than canal irrigation to the farmers in most areas.

Groundwater marketing can be defined as informal, local, institutional setup present at village level through which water extraction machineries/tube wells/borewell owners sell water to others at a price. Though modern water marketing practices in agriculture in India have been traced back to 1920s, they had been documented systematically only after late 1960s (Saleth, 2014) [3]. Groundwater markets in India are informal, localized, unregulated. The payments could be in cash or in kind and different types of contracts like input-output sharing, output sharing, labour contracts can be seen. Agricultural groundwater markets play a significant role in semi-arid and arid areas by reallocating water from low value high volume uses to high value uses. Private water extraction machineries and groundwater markets together have brought far more land under supplemental on demand irrigation than government canals could do in more than 200 years of canal construction (Shah & Chowdhury, 2017) [4]. Though there is much scope for small group water sharing governed by social regulatory measures, there is no single policy or institutional model which can upheld as guiding success in policy formulation of groundwater (Ananda and Aheeyar, 2020) [1]. The informal water markets are widespread in states of the country like Andra Pradesh, Tamil Nadu, Gujarat, Uttar Pradesh, Punjab and West Bengal. There is also risk of rapid depletion of aquifers in absence of effective institutions in water markets along with its positive side.

It is critical to use water sustainably in India which requires participation from local communities with social and economic policies, technical and political inputs. For stabilizing local water table improving management of recharge structure and pumping of groundwater can be followed. The present study was mainly being conducted to have an overview of groundwater marketing in Northern Dry zone of Karnataka and to study change in scenario by comparing the results obtained from earlier study (Nayak, 2007) [2] which was conducted and published in 2007 titled Groundwater markets in Karnataka: Key issues in sustainability (data was collected in 2006).

2. Methodology

Farmers using groundwater for irrigation in agriculture were sample respondents. Same districts as of earlier study (Nayak, 2007) [2] were taken in present study also for comparison. Multi-stage purposive random sampling technique was used for selection of farmers. In first stage, three districts, namely Bagalkot, Belagavi and Vijayapur were chosen since they accounted for highest area under groundwater irrigation. Secondly two taluks were purposively selected from each district based on highest groundwater resource availability namely, Mudhol and Jamkhandi from Bagalkot, Sindagi and Vijayapur from Vijayapur and Gokak and Athani from Belagavi district. In third stage two villages were selected from each taluk.

The sample farmers were categorized into water Sellers (S), Self-users (SU) and Buyers (B) based on participation in groundwater market. The study depends on primary data. Collection of the primary data was done using structured, pre-tested schedule by personal interview from the sample respondents for agriculture year 2020-21. Tabular analysis, simple descriptive statistic, percentage and ratio analysis were used to analyze data.

3. Results and discussion

3.1 General characteristics of sample respondents

Table 1 presents characteristics of the sample respondents participated in water markets. The sellers' and buyers' categories included self-users cum sellers as well as self-users cum buyers along with only buyers respectively. But in the study conducted in 2007 which was taken for comparative analysis, sellers' category included self-users cum sellers and buyers' category included only buyers, not self-users cum buyers because there were no wells owners in buyers' category.

From each district forty farmers were selected as sample. Overall, the proportion of participants in different categories of water market remained almost same in both studies though it had varied slightly in individual districts. The average size of land holding had decreased compared to earlier study except in the case of buyers in Vijayapur and in general now self-users and sellers had more land holding than buyers. The number of wells per household had also decreased from 2006 and wells per household was less in number with buyers than the other two categories now. Overall, sellers had a greater number of wells followed by self-users and buyers in present study. Area irrigated per well remained almost same in both studies and now sellers had more area per well in general in different districts as well as overall, followed by self-users and buyers.

3.2 Irrigation sources of sample respondents

Information of respondents irrigation sources is given in Table 2. Open well, open-cum-borewell and borewell were the important irrigation sources in the study area among which borewells constituted major percentage followed by open-cum-borewell and open-well. The proportion of farmers irrigating with different sources remained almost same in both studies but total number of irrigation sources had decreased compared to earlier study. Among different districts the total number of irrigation sources had decreased and proportion of different sources remained same over the years. The decrease in total number of sources could be attributed to less land holding per farm household in current situation which need less wells to irrigate.

3.3 Information related to bore wells

Table 3 constitutes the information related to bore wells of sample respondents in terms of important parameters. Currently the overall age of bore well in study area was around ten years which was less by two years than earlier study. In general, the average age of well had decreased over the years except in the case of Vijayapur and it is also highest in the same case. Which shows insecurity of groundwater is increasing.

Increase in depth of bore wells over the years in the study area implies groundwater depletion. In present study Bagalkot had the highest bore well depth and Belagavi was the lowest. It was Vijayapur which had highest depth in the earlier study followed by Bagalkot and Belagavi. Since Belagavi receives good amount of rain; it is well distributed and reliable, so the bore well depth is less.

In general, present yield of borewell was lesser compared to initial yield except in Belagavi in earlier study and Vijayapur in present study. Because in present study Vijayapura had got tank filling schemes which helped in improving water table. The present yield in current study is lesser compared to present yield in the earlier study in general except in Vijayapur.

To know the changes in water yield, the difference between initial yield and present yield of bore well was computed. Overall, the water yield in present study has decreased by 0.47 inches and 12.96 per cent. Only in case of Vijayapur it has increased while in other two districts it has been decreased because of same reason as mentioned earlier, whereas in earlier study, the change was negative in all cases except Belagavi.

In present study, the percentage of failed bore wells had decreased in Vijayapur, whereas it had increased in Belagavi and Bagalkot because of better management in Vijayapur. Overall, it had remained same where almost 30 per cent bore wells out of total had failed in both studies.

3.4 Temporal groundwater depletion

Due to the over withdrawal of groundwater for irrigation purpose and also long hours of pumping in different crop seasons, the depth of water table had increased many folds over the years which was reflected by initial depth of bore well over the years. The study period (1980 to 2020) was divided into four periods, namely, Period I (1981-90), Period II (1991-2000), Period III (2001-2010) and Period IV (2011-2020) and mean depth of wells in each period was compared in order to know the temporal depletion of water table. The first two periods' data were taken from earlier study (Nayak, 2007) [2] and remaining two periods' data were added from the data collected in current study.

Overall, bore well depth in study area was 264 ft during first period which had increased to 312 ft during Period II, 391 ft during Period III and 504 ft during Period IV (Table-4). The increase in depth of bore wells from Period III to Period IV is very much higher compared to any other period shows over exploitation of groundwater in recent times. The depth of water table is increasing at increasing rate over the years. In all the three districts Period IV had highest increase in water depth followed by Period III. Depth of bore well which were dug in Period IV, the recent ones, were highest in Bagalkot followed by Vijayapur and Belagavi. Implies Belagavi is more stable.

3.5 Reasons for increase in depth of water table

From the sample farmers in the study area the reasons for increase in depth of water table were ascertained and are

presented in Table 5. Across districts a greater number of respondents attributed fall in water table to decrease in rainfall in both studies. Overall, and even across districts decrease in rainfall was the main reason for fall in water table in present study followed by increase in number of wells, increase in area under irrigation and decrease in surface water sources. No respondents from Belagavi and Bagalkot accepted that increase in area under irrigation could cause fall in water table in earlier study whereas, 13.51 per cent of respondents accepted same reason in current study from the same two districts.

3.6 Extent of groundwater marketing in study area

The proportion self-users, sellers and buyers remained almost same in both studies (Table 6). Overall, self-users were of more percentage compared to other two categories which shows more number of farmers own their own wells they neither had excess water to sell nor deficit to buy.

The total irrigated area was found less compared to the earlier study because of less average land holding in current study and overall, self-users had a greater total irrigated area than sellers followed by buyers. Same pattern was observed in all individual districts in both present and earlier studies. District wise, Vijayapur had highest total irrigated area followed by Bagalkot and Belagavi in present study because of larger land holdings in Vijayapur.

Area irrigated per household was estimated to know total area irrigated per farm household under different categories of water markets. The area irrigated was highest on self-users' farm because of self sufficiency of water followed by sellers and buyers in earlier study whereas in present study same pattern was observed in Vijayapur and Bagalkot districts. In Belagavi sellers had highest area followed by self-users and buyers. On an average, in present study respondents from Vijayapur had a greater per household irrigated area followed by Bagalkot and Belagavi because of larger landholdings in Vijaypur.

Table 1: Characteristics of households participating in water markets

S N	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.

Table 2: Sources of irrigation for the sample households

S. N.	Particulars	Bagalkot district		Belagavi district		Vijayapur district		Overall	
		2006 n=28	2021 n=37	2006 n=28	2021 n=37	2006 n=30	2021 n=35	2006 n=86	2021 n=109
1	Bore wells	72(84.00)	68(82.92)	57(75.00)	50(84.75)	67(81.00)	71(84.53)	196(80.00)	189(84.00)
2	Open-cum-Bore wells	10(12.00)	12(14.64)	14(18.00)	4(6.78)	11(13.00)	11(13.09)	35(14.00)	27(12.00)
3	Open wells	4(4.00)	2(2.44)	5(7.00)	5(8.47)	5(6.00)	2(2.38)	14(6.00)	9(4.00)
	Total	86(100.00)	82(100.00)	76(100.00)	59(100.00)	83(100.00)	84(100.00)	245(100.00)	225(100.00)

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

Table 3: Bore well related information of the sample respondents

S N	Particulars	Units	Bagalkot district		Belagavi district		Vijayapur district		Overall	
			2006	2021	2006	2021	2006	2021	2006	2021
1	Age of bore well	Years	12.00	7.05	10.00	8.49	14.00	14.30	12.00	9.94
2	Depth of bore well	Feet	327.00	516.25	315.00	467.50	377.00	495.00	340.00	492.91
3	Average initial yield of bore well	Inches	3.52	3.62	3.60	3.63	3.06	3.05	3.39	3.43
4	Average present yield of bore well	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 bore wells working	%	70.00	65.60	77.00	73.75	62.00	72.50	69.00	70.10
8	Number of bore wells failed	%	30.00	34.40	23.00	26.25	38.00	27.50	31.00	29.90

Table 4: Temporal groundwater depletion in the study area

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

Table 5: Reasons for fall in groundwater table (in per cent)

SN	Reasons	Belagavi district		Vijayapur district		Bagalkot district		Overall	
		2006 n=28	2021 n=37	2006 n=30	2021 n=35	2006 n=28	2021 n=37	2006 n=86	2021 n=109
1	Decrease in rainfall	86.00	72.99	64.00	82.85	57.00	81.08	69.00	78.89
2	Increase in number of wells	27.00	43.24	9.00	51.42	43.00	45.95	26.00	46.78
3	Increase in area under irrigation	0.00	13.51	13.00	17.14	0.00	13.51	4.00	14.67
4	Decrease in surface water sources	7.00	8.10	0.00	5.71	4.00	2.70	4.00	5.50

Note: 'n' indicates well owners.

Table 6: Extent of groundwater marketing by sample respondents

Particulars	Bagalkot district				Belagavi district				Vijayapur district				Overall			
	2006		2021		2006		2021		2006		2021		2006		2021	
	No.	%	No.	%	No.	%	No.	%	No.	%	No	%	No.	%	No.	%
S U	16	40.00	16	40.00	16	40.00	25	62.50	21	52.50	15	37.50	53	44.17	56	46.66
S	12	30.00	13	32.50	12	30.00	7	17.50	9	22.50	13	32.50	33	27.50	33	27.50
B	12	30.00	11	27.50	12	30.00	8	20.00	10	25.00	12	30.00	34	28.34	31	25.84
T	40	100	40	100	40	100	40	100	40	100	40	100	120	100	120	100
Total area irrigated (ha)																
SU	111.00	56.92	67.77	53.40	51.00	52.04	34.02	59.94	121.00	71.18	76.68	46.13	283.00	61.12	178.49	51.01
S	64.00	32.82	39.60	31.20	35.00	35.71	14.29	25.18	41.00	24.12	51.71	31.10	140.00	30.24	105.61	30.17
B	20.00	10.26	19.54	15.40	12.00	12.25	8.45	14.88	8.00	4.70	37.85	22.77	40.00	8.64	65.84	18.82
T	195.00	100	126.92	100	98.00	100	56.77	100	170.00	100	166.25	100	463.00	100	349.95	100
Area irrigated per farm household (ha)																
SU	6.94		4.23		3.19		1.36		5.76		5.11		5.34		3.18	
S	5.33		3.04		2.91		2.04		4.55		3.97		4.24		3.20	
B	1.66		1.77		1.00		1.05		0.80		3.15		1.17		2.12	

Note: SU = Self User, S = Seller, B = Buyer, T = total.

4. Acknowledgement
The authors sincerely thank the anonymous referee for providing helpful suggestions.

5. Conclusion
In Northern Dry zone of Karnataka groundwater is a highly scarce resource and it is depleting at a faster rate than ever. It is an important factor of production in agriculture economy particularly in the state. Increasing depth of water table is resulting in widespread failure of bore wells and also causing increase in cost of drilling, deepening and pumping. This increase in cost and scarcity of water has led to emergence of informal institution called groundwater market. Irrigation water access through purchase from a water seller is an alternative for own wells, given the market and socioeconomic constraints. The farmers' decision to purchase water in majority of the situations depends on water supply, cost, availability in his farm and other market forces. The water yield of bore wells had decreased (-12.95 %) over the years. Therefore, well owners have to take measures like recharging of aquifers using suitable situation specific technologies. Proper monitoring and implementation of inter well distance, depth of bore wells, mandating recharge pits for well owners in water scarce areas could be taken. Surface water resources could be retained and rejuvenated which would help in recharging aquifers and also in decreasing stress on groundwater by acting as supplement for irrigation. Farmers could be encouraged to participate in groundwater markets or share water with fellow farmers than going for new wells when there will be shortage; which will promote optimal use because of higher variable cost of water and also reduce increasing number of wells and its negative externalities.

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