Groundwater markets under the water scarcity conditions: The upland Balochistan region of Pakistan

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Abstract:

The study documents comprehensive analysis on informal groundwater marketing in upland Balochistan, Pakistan. Informal groundwater markets are emerging a feasible option to manage increasing water scarcity and declining water tables as a result of poor groundwater policies. First we evaluated the groundwater trading mechanism and later we empirically examined factors affecting the groundwater trading using logit econometric models. We did not observe any permanent groundwater transactions; only temporary groundwater exchange takes place. Two common transactions methods were noted – water in exchange for given crop share and cash payment per hour (flat rate per hour). In all, 60% respondents reported selling water for crop share. This form of transaction method intensifies as we move from high altitude areas to low altitude areas because water and land are relatively scarce at higher uplands. In general, the crop sharing rates were 33% of the crop output. Water trading in cash transactions was practiced by 40% of respondents. The charges per hour depend on the altitude, with an average price of Rs.[2]100, Rs.112, and Rs.205 per hour were reported at low, medium and high altitudes, respectively. This form of water marketing intensifies as we move from low to high altitude areas, mainly because of relatively abundant water and land in low altitude areas.

The results of empirical models indicates that among others, cropping intensity, area under high value fruits, decline in watertable, tubewell reliability, alternate source of irrigation, and soil quality are important variables influencing water buying and selling decisions. Importantly, personal attributes such as kinships, age, and education were also found important factors affecting water buying and selling decisions. In the upland Balochistan water markets appears to provide cushions against increasing water scarcity by averting damages to high value horticultural crops and also proving useful in enhancing water efficiently as it helps overcome the problem of over irrigation/miss use of water by facilitating selling the surplus/extra water and using purchased water more sparingly and efficiently. It is envisaged that groundwater play key role in sustaining high value crops and will continue to contribute in upland Balochistan.

Keywords: informal groundwater markets, Balochistan, logit model, groundwater decline, sustainable cropping system.

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[2] USD = Pakistan Rupees (Rs) 85 and AUD = Rs 91 as of June 2011

1. Introduction

Pakistan is facing unprecedented water shortage; owing to climate change and poor water management that has resulted exploitation of water at a rate faster than it is replenished, directly contributing to the growing water scarcity crisis. Particularly, in upland Balochistan where water scarcity problem even more worrisome as watertables are falling at the rate more than three to six meters per annum, threatening the viability of agricultural communities (Ahmad, 2007).

The upland Balochistan is characterized by tubewells as the main source of irrigation. Government's past and current groundwater development policies such as electricity subsidy[3], to encourage farmers to use groundwater for increased agricultural production and support farmer's incomes, has resulted in massive draw down of watertables (Mustafa, et, al. 2007; Van Steenbergen, 2007; Ahmad, 2006; GoB, 2006; IUCN, 2000). Farmers of upland Balochistan have made massive investments in planting fruit orchards with tubewell irrigation. The most promising growth has been seen in the production of high value fruits since 1970's.

However, as a result of increasing water scarcity and over exploitation of groundwater resources, tubewells are now drying in upland basins of Balochistan. Drying tubewells, as a result of declining watertables, have dispossessed a large number of tubewell owners from their source of irrigation. The groundwater availability has reached to its threshold limits where small and medium farmers are increasingly opting to buy water to avoid damages to high valuable fruit crops. Importantly, increasingly, many small to medium farmers prefer to buy water instead of installing new tubewells to avoid increased risks of tubewell failure.

Informal groundwater markets are emerging in upland Balochistan to manage impact of water scarcity and groundwater decline. Groundwater markets provide a useful mechanism of utilizing water efficiently, since it overcomes the problem of over irrigation/miss use of water by facilitating selling the surplus/extra water and using purchased water more sparingly and efficiently (Shah, 1993). According to Meinzen Dick (1996), water markets, in which farmers buy and sell irrigation water, present promising mechanism for increasing access to irrigation with private groundwater, and for increasing the productivity and efficiency of water use in irrigation system.

Informal water markets are reported in many countries including India, Pakistan, China, and Nepal. In Nepal, groundwater markets are also considered the only appropriate way to provide peasant farmers access to groundwater in Nepal (Bahadur, 2004). Zang et al. (2008) concluded

[3] Under the electricity subsidy policy, government covers 80% of the electricity charges. The subsidy policy costs US$ 82 million (Pakistan Rupees 5 billion) per year to Balochistan government (Ahmad, 2006)

that groundwater markets in northern China are competitive, do help the poor/small farmers through increasing their access to a more reliable source of irrigation that help reduce income inequalities. In areas dependent on irrigated agriculture, the reliability of groundwater sources have made possible the high crop yields generally achieved as a result often enable farmers with small landholdings to increase income. In India water markets are catering to the needs of very small farmers to a great extent, something that other modes of irrigation cannot offer and have significant feature in India's agricultural landscape (Pant, 1992; Mukherjee, 2008).

Groundwater markets in Pakistan are informal, not officially recognized, the sale of water from private tube wells is a growing form of water allocation in all the four province of Pakistan (Meinzen-Dick, 1996). Water markets are a medium for informal water sale from private wells but does not involve in the exchange of permanent water rights (entitlement) in Pakistan (Meinzen-Dick, 1996; Hussain et al. 2005). Balochistan is no exception as far as groundwater marketing in Pakistan is concerned, where water marketing is as old as the history of the area when markets would involve mainly in exchange of *karezes*[4] and springs water.

Informal groundwater markets are playing an essential role in water scarce and poor managed groundwater systems in Balochistan. However, little attention is paid to characterize the emergence of groundwater markets and their significant role, particularly their functioning in less favourable environments of depleting groundwater. Importantly, quantification of key water buyers and sellers attributes affecting the groundwater markets is vital for further enhancing the functioning of groundwater markets. Employed with robust econometric models using a sample of 328 water buyers and sellers, the study aims to comprehensively document informal groundwater trading mechanism and trends, and empirically examine factors affecting the groundwater trading.

2. Study area: an overview of the Upland Balochistan region

Balochistan is one of the four provinces of Pakistan, and biggest in terms of area among other provinces, with an area of 347,190 km^2. The provincial plateau is mostly comprised of hilly terrains. Balochistan is divided into four agro-climatic zones – uplands, coastal, planes and desert

[4] *Karezes* are manmade sub-surface horizontal tunnels/galleries constructed to tap groundwater in the upper limits of the valley floor/piedmont plan and eventually deliver it at lower level lands by gravity. A well called the mother well is dug near the foot of the mountain where groundwater is available. This is followed by a series of wells at intervals of 60 to 100 meters; all of these wells are connected by an underground tunnel (WAPDA, 1993).

due to its wide agro-ecological diversity. Uplands of the province are famous for the production of deciduous fruits and different vegetables. The upland Balochistan can be classified as arid in terms of rainfall, they receive an average rainfall of 200 to 250 mm annually, which emphasise the need of irrigation water for high value crops. The upland comprises Ziarat, Kalat, Quetta, Pishin, Killa Abdullah, Mastung, Zhob and Loralai districts of Balochistan (Figure 1). The upland Balochistan was further divided into three locations on the basis of altitude above the sea level – low altitude areas (1050-1550 meter), medium altitude areas (1551-2050 meters), and high altitude areas (2051 and above meters) – due to climatic conditions, water availability and cropping systems.

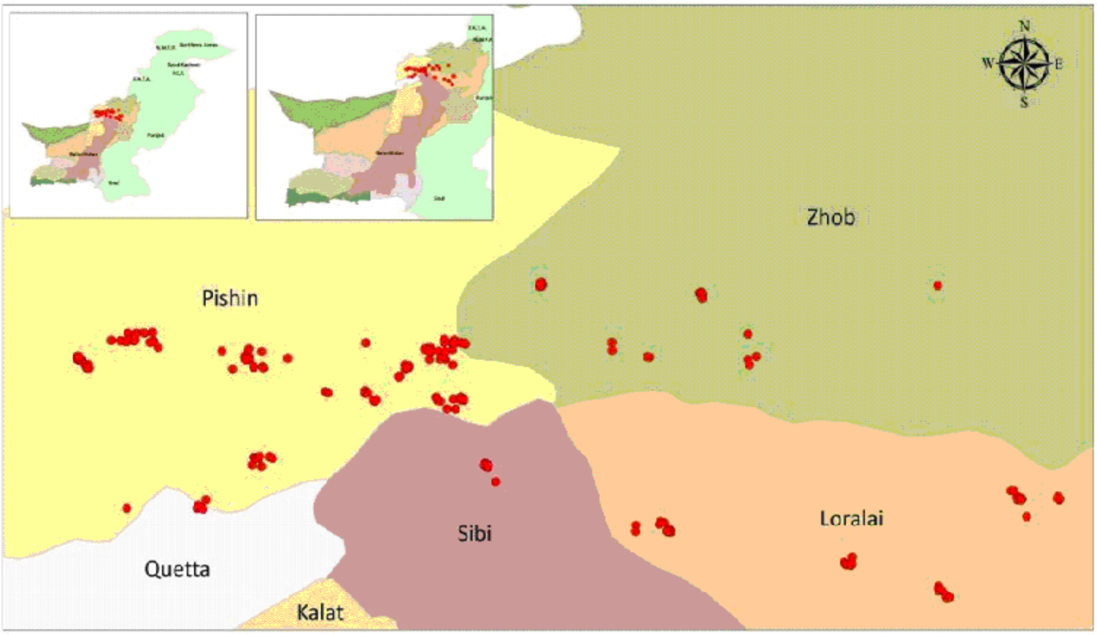

Figure 1: The Study Area of Upland Balochistan Region of Pakistan

Groundwater is the main source of irrigation in upland Balochistan, which is mainly obtained through tube wells, dugwells, *Karezes* and springs. Overtime tubewells numbers have increased significantly, from 2,500 in 1971 to 21,231 in 2008 (Figure 2). This growth has also been accelerated by the drought during 1998-2005 and sub-optional groundwater management policies, which caused a large number of groundwater sources like *Karezes*, springs and tube wells dried (Steenbergen, 1995; IUCN, 2000).

Unplanned groundwater exploitation through various ill-formed and invalidated polices has alarmingly resulted decline in groundwater tables (Figure 3). Neither under customary law nor under government jurisdiction were the rules to control the decline in groundwater tables. No government organization had a mandate to handle the crisis (Steenbergen, 1995).

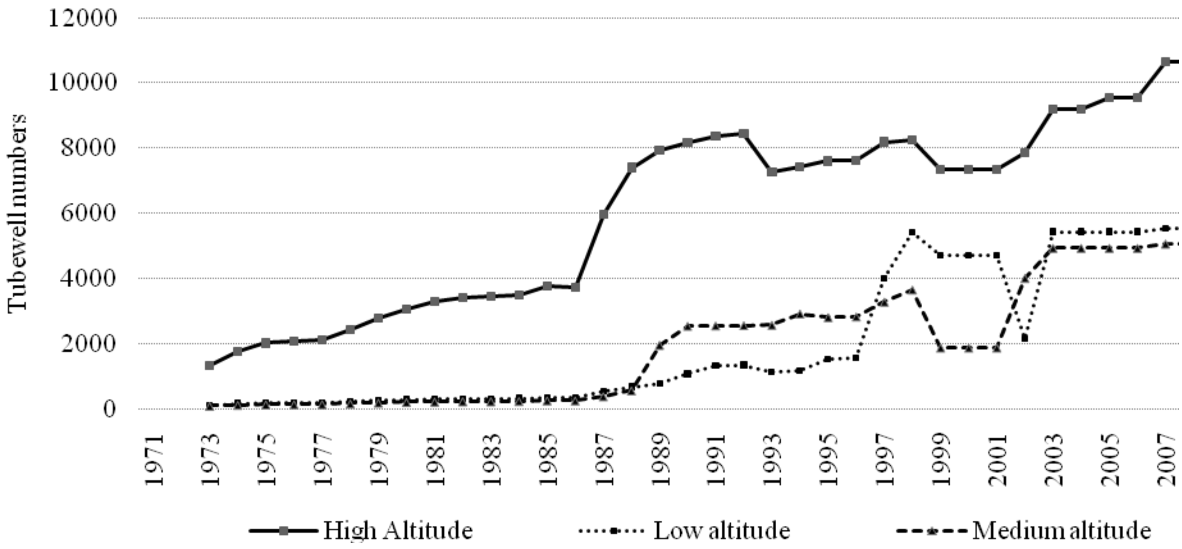

Figure 2: Tubewell growth in upland Balochistan

(Source: Agriculture Statistics, Balochistan 1970-2008)

The decline in watertables in the three uplands was 75, 60, 57 meter in high, medium, and low altitude areas respectively, from 1980 to 2008 (Survey, 2009).

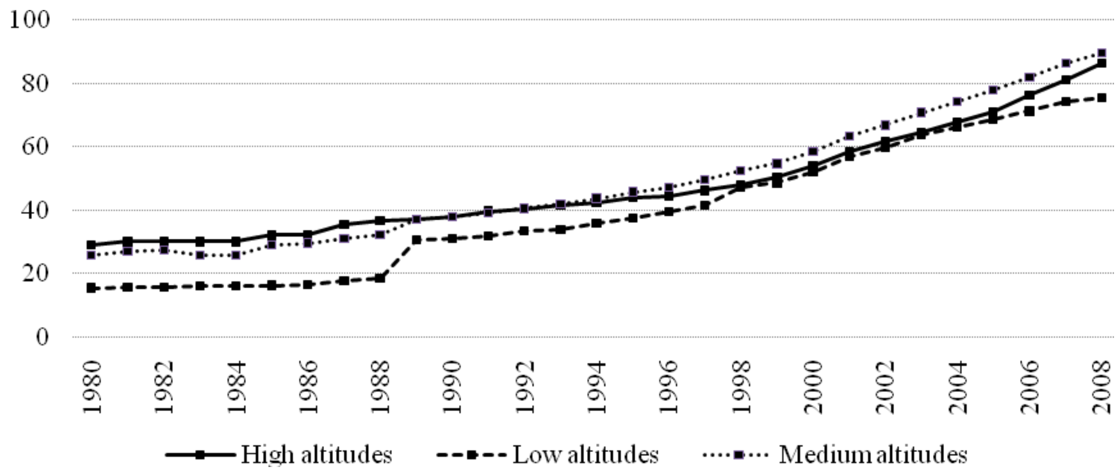

Figure 3: Average decline in watertable (meter/yr) in upland Balochistan

(Source: Agriculture Statistics, Balochistan 1970-2008)

3. Methodology

3.1 Survey methodology

A well structured questionnaire was developed to collect data from the sample respondents. The sample of 328 water sellers and buyers, consists of tubewell owners and non-owners, were face- to-face interviewed. Multistage sampling technique was used for the selection of sample farmers for interview. In the first stage, 3 key upland basins were purposively selected out of eighteen basin in Balochistan, located at different altitudes (meters) from the sea level – Low altitude (1050-1550), Medium altitude (1551-2050) and High altitude (2051 and above). In the second stage, 6 sample villages within each upland basin were selected randomly. In the third stage, farmers were selected using proportionate stratified random sampling technique based on the proportion of respondents in the population – tubewell owners and non-owners in the overall population (Table 1). The location of the respondent was identified using GPS as shown by the small red dot points in Figure 1. The distribution of the sample respondent is shown in Table 1.

Table 1: Distribution of sample respondents on the basis of altitude

Location & altitude (meters)	TW Owners	TW Non-owners	Total
Low (1050-1550)	83	2	85
Medium (1551-2050)	96	64	160
High (> 2050)	58	25	83
Total	237	91	328

Source: Survey 2009

3.2 Econometric modelling

Based on the dichotomous nature dependent variable (water selling and buying), we propose the following econometric model to analyse the factor affecting groundwater market buying and selling decision:

$$W_{jt}^{S,B} = \alpha + \beta X_{jt} + Z_{jt} + \varepsilon_{jt} \qquad (1)$$

In Equation 1, $W_{jt}^{S,B}$ represent water selling and buying decision in upland basin village *j* in time *t* years. The variable on the right side of the equation is measured as 1 if involved in water selling and buying, otherwise 0, not involved. The term on the left side of the equation X_{jt} represent vector of physical variables such as location, farm size, reliability of the water, high value crops that are assumed to influence water buying and selling decision. The term Z_{jt} represents vector of personal attributes that like to impact water buying and selling decision and ε_{jt} is an error term, which is assumed to be uncorrelated with the explanatory variables.

We used logit econometric model to derive the maximum likelihood (MLE) estimates and marginal effects. The marginal effects are the partial derivatives of probabilities with respect to the vector of independent variables and are computed at the means of the explanatory variables. The value of marginal effect coefficient implies the changes in decision to sell/buy water brought about by one unit change in the independent variables, *ceteris paribus.* The detail of the empirical model, definitions and measurement of variables are given in Appendix 1. The descriptive statistics of water seller and buyer is given in Table 2 and 3.

Table 2: Descriptive statistics of water seller

Var. Code	Variable name	Low altitude		Medium altitude		High altitude	
		Mean	STD	Mean	STD	Mean	STD
Twnum	Tubewell number	1.89	1.26	1.39	1.12	1.33	0.79
Age	Age of water seller	44.33	13.41	43.04	12.14	39.92	11.54
Edn	Education of the water seller	5.67	5.53	7.76	5.31	6.75	5.26
Family	Family size of water seller	26.42	14.37	27.06	16.95	16.64	8.42
Area	Farm area	40.98	36.17	25.71	25.85	6.31	6.62
Depthb	Depth of tubewell	470	189	493	210	326	260
Sellcash	Dummy variable for sell in cash	0.05	0.23	0.43	0.50	0.81	0.40
Sell	Dummy for decision to sell water	1.00	0.00	1.00	0.00	1.00	0.00
Cropint	Cropping intensity	95.66	18.65	94.62	15.57	101	8.16
Frthiwat	Area of fruits high delta	11.77	13.64	14.98	16.98	5.62	6.47
Vegkhf	Area Vegetable Kharif	11.80	16.67	5.65	6.79	8.36	13
Reliab	Dummy for reliability of tubewell	0.11	0.31	0.31	0.47	0.25	0.44
Wtselkin	Dummy for kinships in water sales	0.00	0.00	0.11	0.32	0.25	0.44
Decwtab	Decine watertable	160	111	98	100	94	102
Twophrs	Tubewell operation	6119	4689	4177	3554	2678	2553
Twown	Dummy for tubewell ownership	0.95	0.23	0.85	0.36	0.89	0.32
Plotsno	Number of irrigated plots	3.71	1.76	3.35	1.58	2.50	1.32
Pipedia	Diameter of delivery pipe	2.89	0.85	2.59	1.04	2.67	0.96

Source: Survey 2009

Table 3: Descriptive statistics water buyers

Var. Code	Variable name	Low altitude		Medium altitude		High altitude	
		Mean	STD	Mean	STD	Mean	STD
Age	Age of water buyer	45.6	12.30	42.98	13.74	40.76	12.68
Edn	Education of the water buyer	8.4	7.13	5.21	7.50	7.33	5.27
Family	family size of water buyer	22.6	12.93	19.71	10.98	20.98	10.68
Area	Farm area	37.4	25.67	14.90	13.95	6.89	8.04
Cropintensity	Cropping intensity	125.9	44.06	98.32	28.30	104.0	19.96
Fuitshighwater	Area of fruits high delta	16	15.17	13.75	20.14	6.52	8.12
Vegkhf	Area Vegetable *Kharif*	7.4	8.41	3.45	8.60	9.00	15.94
Twown	Dummy for tubewell ownership	0.8	0.45	0.55	6.34	0.54	0.50
Plotsno	Number of irrigated plots	4.2	2.17	2.48	6.18	2.22	1.38
Expyears	Experience of water buyer	25	14.14	23.07	11.40	23.28	10.85
Reliab	Dummy for reliability of tubewell	0.8	0.45	0.76	6.30	0.72	0.46
Watbuykinship	Dummy for kinships in water purchasing	0.4	0.55	0.12	6.39	0.28	0.46
Driedtwown	Dummy for dried tubewell ownership	0	0.00	0.07	6.40	0.00	0.00
Soilquality	Dummy for quality of soil	0.8	0.45	0.81	6.29	0.63	0.49
Powerconection	Dummy for power connection	0.8	0.45	0.55	6.34	0.50	0.51
Lackalter	Dummy for Lacking alternative source of irrigation	1	0.00	0.88	6.28	0.65	0.48
Buy	Dummy for decision to buy water	1	0.00	0.98	6.26	0.91	0.28

Source: Survey 2009

4. Results and Discussion

4.1 Characteristics of water seller and buyer

4.1.1 Cropping Pattern

The decision to sell or buy water hugely relied on the type of crops grown on the farm. Apple and major *Kharif* vegetables are driving the decision to buy and sell water. Figure 4 shows the distribution of crops in terms of altitude, whereas Figure 5 shows the distribution of farm income, associated with cropping systems in high, medium and low altitude. Apple is the major fruit grown in the high altitude (87%) due to its suitability to produce high quality apple as a result of favourable climate. Superior quality of apple attracts higher prices and as a result yields higher cash income in high altitude area (Figure 5). However, myopic behaviour to plant additional area under apple to higher returns in upland has alarmingly declined the groundwater tables. Vegetables are key crops grown in the low altitudes primarily due to mild weather compared with high altitude. Medium altitude has both vegetables and high value orchard such as apricot, grapes, peach, and plum.

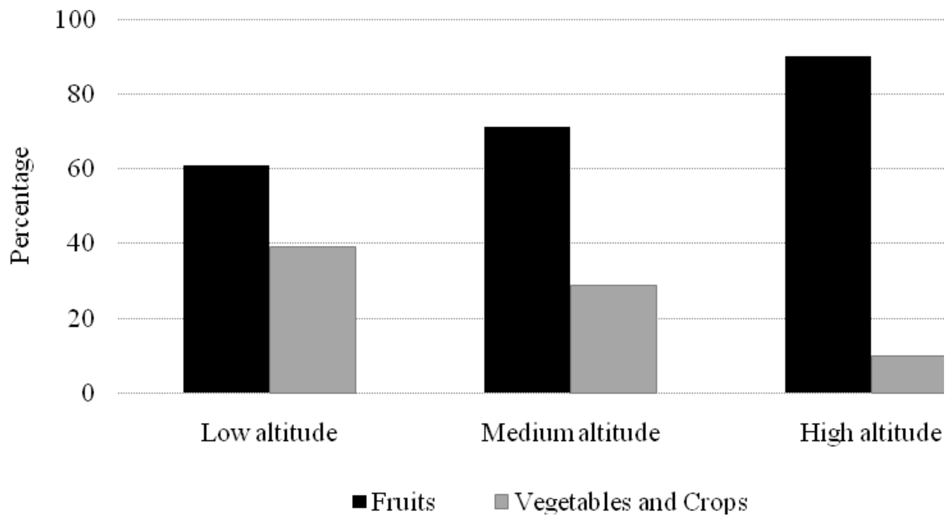

Figure 4: Distribution of cropping areas in upland Balochistan

(Source: 2009 survey)

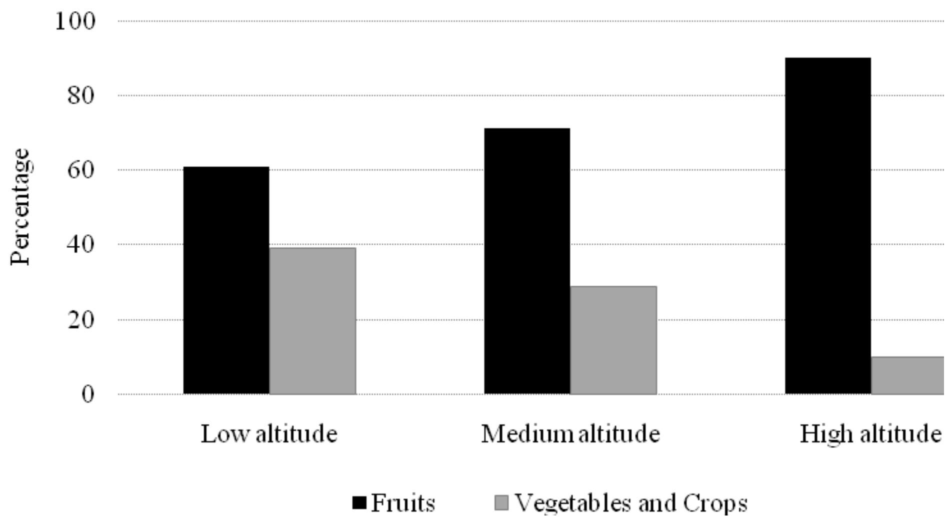

Figure 5: Distribution of farm income in upland Balochistan

(Source: 2009 survey)

4.1.2 Typology of water buyers and sellers

Water seller types**:** Three types of water seller were identified:

- Tubewell owners having excess water of their self managed irrigated area needs usually sell surplus water for cash and/or crop share. The water rate is charged mostly per hour basis through negotiation. The price also depends on the discharge flow of tube well, measured in terms of the delivery pipe size.
- Tubewell owners who do not undertake self cultivation but rather sell the tubewell water pumping rights to others for a specific period of time;
- Land owners who lease their piece of land for the development of tubewell to other farmers under certain terms and conditions. Under such type of agreement; a piece of land is sold to another willing person, who installs tubewell on it bearing all the development costs (vary from 500 to 700 thousands rupees). In case of successful installation and starting of pumping, the tubewells installer pay the monthly compensation rent for water extraction (Rs.5000), provide a job of tubewell operator to the land owner (Rs.3000 per month) and will have the water pumping rights until the water exist. In case of drying of water, the agreement stand cancelled.

Table 4 presents the distrubition of water sellers in upland Balochistan. Majority of sellers (around 90%) in all locations of the study area sold the water in excess of their self managed irrigated farm area either for crop share or cash.

Table 4: Typology of water seller in upland Balochistan

Seller Type	Altitude					
	Low		Medium		High	
	Number of sellers	Percent of total sales	Number of sellers	Percent of total sales	Number of sellers	Percent of total sales
Tubewell owners having excess water of their self managed irrigated area needs	50	89.28	70	88.6	58	92.06
Tubewell owners who don't undertake self cultivation	1	1.78	5	6.33	-	-
Land owners who sell a piece of land for tubewell boring	5	8.93	4	5.06	5	7.94
All	56		79		63	

Source: 2009 survey

Water buyer types**:** Four key types of water buyer were identified:

- Tenants: are those landless small farmers who undertake crop cultivation for certain share of crop in return for their management and labour inputs. They are mostly involved in water buying for crop share.
- Dry tubewell owners: are those farmers used to have own tubewells but due to drought and over pumping, their tubewells dried out and are out of any irrigation source, relying on water markets.
- Fellow tubewell owners: are neighbouring farmers, mostly preferred at the time of water sales.
- Relatives: Relatives are farmers who have some sort of association with the tubewell owners. They are also usually preferred at the time of water sale or purchase.

The table 5 presents the distribution of water buyer types. Tenants, who usually lease land for the return for their labour inputs are major water buyer. About 60% of the water is currently bought by the tenants alone while the rests (dry tubewell owners, fellow water deficient tubewell owners, land owners having no tubewell and relatives) makes the other 40%.

Table 5: Water sales (percent) to different users

Buyer Type	Altitude					
	Low		Medium		High	
	Number of buyers	Percent of total sales	Number of buyers	Percent of total sales	Number of buyers	Percent of total sales
Tenants	30	54.54	40	31	8	9.41
Dry tubewell owners	9	17	25	19.17	24	28.24
Fellow tubewell owners	13	24	28	21.53	22	26
Land owners having no tubewell	2	2.46	34	26	31	36.35
Relatives	1	2	3	2.3	0	0
All	55	100	130	100	85	100

Source: Survey 2009

The tenant number was found higher in low and medium altitudes because they usually do not own the land, and therefore cannot have tubewell, managing small sized land, and undertake relatively short term contracts for vegetable and other crops. Therefore, they are better off buying water to supplement their cash crops. On the other hand, at higher altitudes due to nature of high value permanent planting, dry tubewell owners, fellow water deficient tubewell owners, land owners having no tubewell were major water buyers.

4.1.3 Methods of groundwater transactions

Three groundwater transactions methods were observed. The timeframe of the groundwater transaction were made based on the crop type and tenancy arrangements. The short term groundwater transactions agreements were made for one season, mainly for vegetable crops, either in cash or in kind. Medium term groundwater transactions were agreement made for more than one season to two years, also mainly for vegetables. The longer term groundwater transactions agreements, over numbers of years, were made for high value perennial orchard crops. In general there are three common groundwater transaction methods in Pakistan as documented by Meinzen-Dick (1995) as listed:

- Flat rate per hour: The hourly rate is the payment for an hour of tubewell water used. This is most commonly used method in all the three locations of the study area with relatively more intensity in water scarce areas of high altitudes.
- Payment in kind as share cropping is the payment made for irrigation water used in the shape of the crop output. It rates from vary from locality to locality and from enterprise to enterprise.
- Area-based rates: Area based rates are used for specific crops or seasons in order to minimize monitoring costs, especially under flat rates for power. Area-based rates, especially with crop-sharing arrangements, are more appealing with severe water scarce areas, power shortage and breakdowns and greater production risk.

Another type of agreement observed where one party, the land owner, provides the land for installing tubewell in water rich downstream area and supply the water through long pipelines to the upstream orchards of the affected person. The payment is made to land owner on yearly basis, besides paying for everything else for the development, maintenance and operation of tube well. The amount may vary depending on the bargaining position of the affected person.

The distribution of groundwater transaction methods in upland Balochistan is given in the Table 6. The flat rate payment for water arrangement intensifies as we move from low lands to high lands showing the relative scarcity of water in the high altitudes. Moreover, relatively smaller farm size, highest per unit returns from fruits and colder climatic conditions ideal for horticulture commodities make this method workable in high altitudes. While the payment in kind type of arrangement intensifies as we move from high uplands to low lands mainly due to relative water abundance, larger farm size, comparatively low returns and warmer climatic conditions. Area based rates were mainly used when the frequent power interruptions makes the monitoring of hourly arrangement agreement difficult, few water buyers were able to get area based arrangement from the water seller.

Table 6: The distribution of groundwater transaction methods in upland Balochistan

Transaction Methods	Altitude					
	Low		Medium		High	
	Number of transactions	Percent of total transactions	Number of transactions	Percent of total transactions	Number of transactions	Percent of total transactions
Flat rate (Rs/hour)	3	5.4	25	31.64	40	63.5
Payment in kind (% crop share)	50	89.2	46	58.22	11	17.46
Area based payment	3	5.4	8	10.14	12	19.04
All	56	100	79	100	63	100

Source: 2009 survey

Some additional special arrangements also were observed. They were made to cater for exceptional circumstances such as drought and failure of tubewells. They are:

***Water sold for a share in fruit orchard output*:**

Share output arrangements also exist for fruits orchards, about 17-33 percent share in orchard was given to tube well owners in return for irrigating their orchards throughout the year/s. Under this type of arrangement, the tubewell owner takes the responsibility of irrigation for a certain output share for a certain period of time (usually 1-5 years). Overall, 7 responded using this transaction method – one in low upland, 5 in medium upland and one in higher upland.

***Sale of land for Tubewell Installation*:**

This type of arrangement is the growing form of water sale agreement between a land owner and water buyers. This is prevalent in all the locations of upland Balochistan, especially where tubewells are drying. In search of new sources of water, more tubewells are installed far away

(500 meters to 3000 meters) from its earlier location (wherever water is available). Under such type of agreement; a piece of land is sold to another willing person who installs tubewell on it bearing all the development costs (vary from 500 to 700 thousands rupees). In case of successful installation, the tubewells installer pay the monthly compensation rent for water extraction (Rs.5000), provide a job of tubewell operator to the land owner (Rs.3000 per month) and will remain the owner of tubewell until the water is there. In case of drying of water, the agreement stand cancelled.

4.1.4 Price determination

Prices are determined mainly through negotiations in all the locations of the study area. However, current market prices and price prevalent in area from the previous transactions were also used. Table 7 shows the distribution of respondents who use different types of water pricing mechanism. A trend that can be seen in the Table 7, as we move from low uplands to medium to high, the ratio of buyers and sellers setting/determining price through negotiation increases showing the shortage of water in the higher uplands. Also showing greater competition among water buyers. The previous season prices were also used to determine water prices being highest in low altitudes, followed by medium and high altitudes of the study area showing relative water abundance and less competition among water buyers.

Table 7: Groundwater price determination in upland Balochistan

Price determination methods	Altitude		
	Low	Medium	High
	Percent	Percent	Percent
Current market	3.2	14.0	21.4
Negotiation	39.7	52.3	50.0
Price prevalent in area from previous season	57.1	30.2	11.9
Current market and negotiation	-	3.5	16.7

Source: 2009 Survey

4.1.5 Groundwater prices trend overtime

Figure 6 and Figure 7 shows historical trends in average groundwater sale and purchase prices. There are no published groundwater prices. These prices were collected using respondends recall method during interview. As shown in the figures, the prices have remained stable overtime; have not shown greater fluctuation, during 1999 to 2008 due to subsidized electricity that has kept the pumping cost low. However, groundwater prices varied significantly with regards to altitude. The groundwater prices in high altitude were two times higher prices than medium and low altitudes reflecting water scarcity and its high value use for orchard crops. The average purchase price per hour for low, medium, and high altitude was Rs.93, Rs.103, and Rs.199, respectively.

The average sale rices show a decline after 2003, due to mainly the relatively wetter weather that prevailed during 2003 to 2006 in the area. The average sale price per hour of groundwater during the ten years was Rs.107, Rs.137, and Rs.212, respectively, in low, medium, and high altitudes.

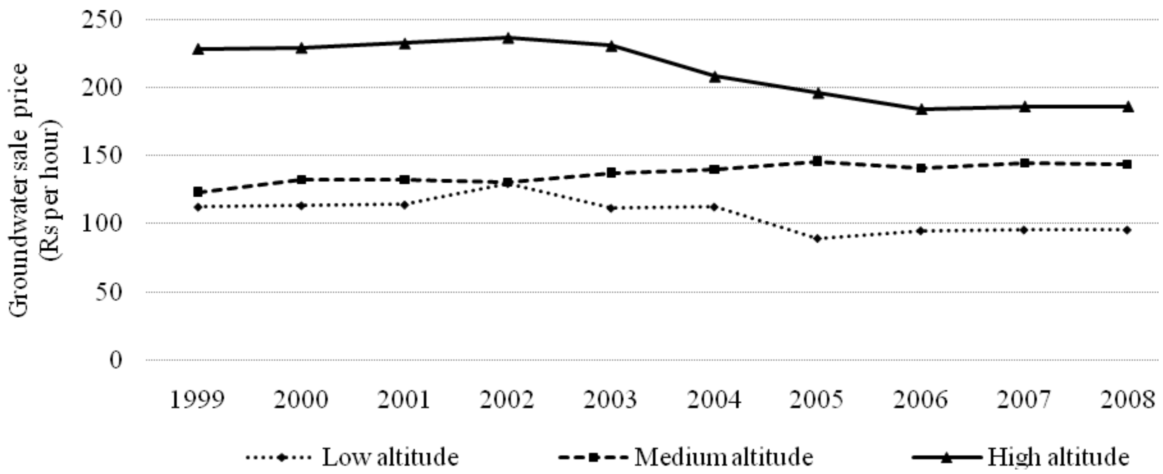

Figure 6: Groundwater sale price trend in upland Balochistan

(Source: 2009 survey)

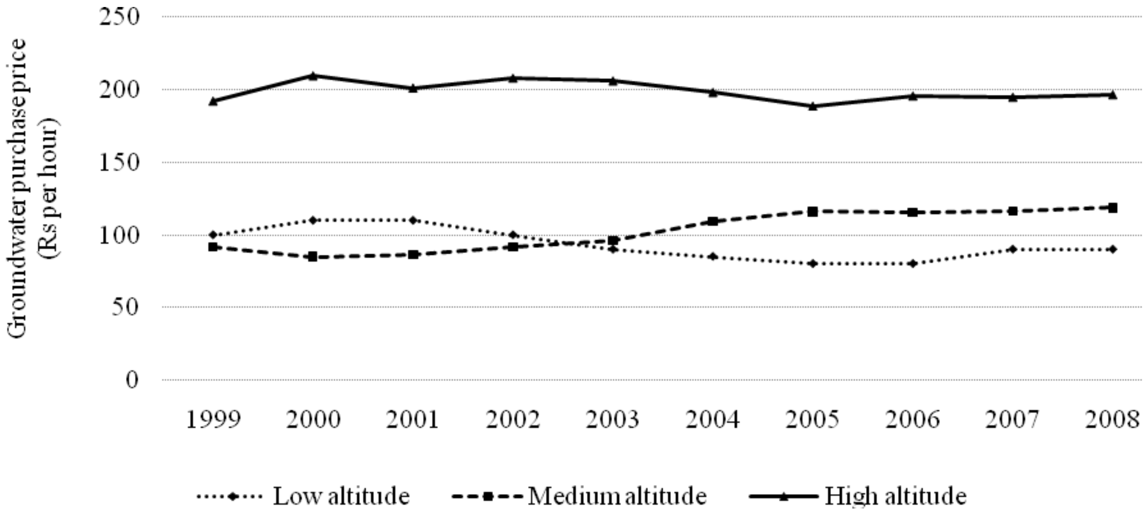

Figure 6: Groundwater purchase price trend in upland Balochistan

(Source: 2009 survey)

Empirical evidence of water selling and buying

4.1.6 Ground water selling

The logit regression model was used to examine the effects of a number of quantitative and qualitative independent variables on the probability of tubwell water selling. This logit model estimates the likelihood of and extent of water selling decision. It takes the value of 1 if the farmer sells the tubewell water and 0, otherwise. The location of the farms at different altitudes enters the decision to sell water as a shift variable – measuring the difference in the decision to sell water between the low and high altitude tubewell owners, and the tubewell owners located at medium altitude. Location specific dummies capture the influence of location specific factors other than those included in the function (such as rainfall, land quality, other socio-economic factors). The multicollinearity test showed that multicollinearity problem doesn't occur. The results from the logit model in terms of index level, marginal effect and elasticity are presented in Table 8.

The index values are bit difficult to interpret, unless they are transformed into probabilities. For example, the 0.014 MLE estimate of age indicates that a one year increase in age of the respondent would lead to an increase of a farmer's underlying index Z_i by 0.014 units, *ceteris paribus*. Similarly, the 1.91 estimated value of dummy variable for cash sell indicates that a change in the type of payment from deferred to cash would increase a logarithm of odds (Z_i) that the farmers will sell the water 1.91 units, *ceteris paribus*. The same interpretation holds true for the remaining variables.

The results show that crop intensity (CROPINTENSITY) and decline watertable (DECLINEWTAB) and dummy variable; sell for cash (SELLCASH) significantly influenced the decision to sell water. In addition, the coefficient of site dummy of high altitudes (SITE3HIGH) was also significant. Variables such as age (AGE), education (EDN), depth of bore (DEBTHBORE), area under high delta fruits (FRUITSHIWATER), area vegetables kharif (VEGKHARIF), kinships in water sales (KINWATSALE), decline in watertable (DECLINEWTAB), pipe diameter (PIPEDIA), tubewell number (TWNUMB), and site 1 dummy (SITELOW) were not significant, although they showed *a priori* relationship with the decision to sell water. Therefore, to evaluate the effect of each explanatory variable on the probability of selling water, partial derivatives of probabilities (marginal effects) were estimated.

Table 8: Logit Estimates for the Likelihood of Water Selling Decision in Upland Balochistan, Pakistan 2009-2010[a]

VARIABLE	MLE ESTIMATES		MARGINAL EFFECTS[b]		Elasticity[c]
	Coeff.	Std. error	Coeff.	Std. error	
Constant	0.373	1.185	0.085	0.270	
AGE	0.014	0.012	0.003	0.002	0.209
EDN	0.039	0.029	0.008	0.006	0.090
DEPTHBORE	0.001	0.001	0.001	0.001	0.121
CROPINTENSITY*	-0.016	0.009	-0.003	0.002	-0.551
FRUITHIWATER	-0.008	0.010	-0.002	0.002	-0.033
VEGKHARIF	0.002	0.012	0.005	0.002	0.006
KISHIPSWATERSALE	1.012	0.713	0.194	0.107	0.022
SITE1LOW	0.466	0.376	0.103	0.080	0.047
SITE2HIGH***	-1.074	0.396	-0.254	0.093	-0.107
DECLINEWTAB*	-0.002	0.001	-0.001	0.001	0.115
PIPEDIA	0.135	0.150	0.030	0.034	0.120
SELLCASH***	1.914	0.417	0.361	0.059	0.155
TWELLNUMBER	0.149	0.177	0.034	0.040	0.072
Farms correctly predicted (%)			73.46		
Goodness of fit (pseudo R-squared)			62.28		
Log-likelihood function (unrestricted)			-155.07		
Log-likelihood function (restricted)			-186.21		
P-value			0.088		
Degrees of freedom			13		
Number of observations			279		

Dependent variable: Decision to sell water

[a] Source: Survey data 2009

[b] Marginal effect (dEy/dx) is the partial derivatives of the expected values with respect to the vector of characteristics. They were computed at the mean of the independent variable.

[c] elasticity is computed by multiplying the marginal effect coefficient by the ratio of mean of the concerned explanatory variables to the mean of the dependent variable.

- ***, **,*, refers to significance at 1, 5, and 10%

The partial probability of water seller age was estimated to be 0.003. It implies that, *ceteris paribus*; a one year increase in household age will increase the probability of selling water by 0.003 (Table 8). The partial probability of household education was estimated to be 0.009 points. It implies that, *ceteris paribus*; a one year increase in household education will increase the probability of selling water by 0.009 points. The partial probability of cropping intensity was estimated to be -0.003 points. It implies that, *ceteris paribus*; a one percent increase in the cropping intensity will decrease the probability of selling water by 0.003 points. Similarly, the partial probability of area under kharif vegetables was estimated to be 0.001. It implies that, *ceteris paribus*; an acre increase in the area under kharif vegetables will increase the probability of selling water by 0.001 points. The site 1 (SITE1LOW) gave a marginal effect of 0.10, which means the as compare to site 2 (medium altitude) the control, the probability of selling water is more by 0.10. The effects of other variables on the probability of selling tubewell water can be interpreted in the same way.

The elasticity coefficient indicates that a 1% change in the explanatory variable will change the probability of tubewell ownership equal to the respective percentage of elasticity coefficient. As presented in Table 8, the sign of respective elasticity coefficient explains the direction of change between the dependent and the independent variable. The elasticity of age on tubewell ownership was computed to be 0.21. This implies that a 1% increase in household age would increase the probability of selling water by 21%, *ceteris paribus*. The remaining variables can be interpreted in the same way. The interpretation of the elasticity of binary variables is somewhat different. For example, the elasticity coefficient of sell for cash (SELLCASH) was 0.15 which implies that the probability to sell water would increase by 15 percent if the method of selling changes to cash method (Table 8).

4.1.7 Groundwater buying

Water buyers are mostly tenants and small farmers to whom water is sold on cash or as crop share, however, many medium and large size farmers having fragmented land holdings were also reported buying water. The results from the logit model in terms of index level, marginal effect and elasticity are presented in Table 9. However, since the index function only describe the directions and hard to interpret unless translated into probabilities therefore they are not discussed in this section.

The result show that, among other variables, tubewell ownership (TWOWN), reliability of tubewell (RELIABILITY), soil quality (SOILWHCAP) age (AGE), were influencing significantly on water buyers decision. Similarly, between the two site dummies, site 1 (low altitude) and site 3 (high altitude) were significantly different from medium altitude (control). Site 1 (low altitude) areas being less dependent on water markets than the medium altitude, because here the crops share arrangements are common and water is also in abundance make this area farmers less dependent on water markets as compare to medium altitude areas, hence as compare to medium altitude, less water buying in cash takes place. Although the other variables such as education level of water buyer (EDN), farm area (FARMAREA), crop intensity (CROPINTENSITY) showed *a priori* relationship with the decision to buy water they were not found significant.

Table 9: Logit Estimates for the Likelihood of Water Buying Decision in Upland Balochistan, Pakistan[a]

VARIABLE	MLE ESTIMATES		MARGINAL EFFECTS		Elasticity
	Coeff.	Std. error	Coeff.	Std. error	
Constant	-1.92	1.69	-0.293	0.252	
AGE	0.021	0.020	0.003	0.003	0.701
EDN	0.012	0.045	0.0018	0.007	0.065
TWOWN	-2.61***	0.773	-0.537	0.159	-2.376
FARMAREA	-0.022*	.013	-0.003	0.002	-0.409
RELIABILITY	4.448***	0.668	0.778	0.071	1.280
CROPINTENSITY	-0.008	0.0105	-0.001	0.001	-0.710
FRUITHIWATER	0.006	0.024	0.001	0.003	0.064
VEGKHARIF	0.006	0.0222	0.009	0.003	0.038
KISHIPWATERBUY	-0.534	0.854	-0.070	0.096	-0.033
DRIEDTWOWN	0.459	0.917	0.076	0.169	0.064
SOILWHCAP	1.119***	0.500	0.155	0.066	0.529
SITE1LOW	-2.401***	0.763	-0.280	0.066	-0.451
SITE2HIGH	1.052	0.647	0.184	0.130	0.267
POWERCON	-0.226	0.667	-0.036	0.112	-0.149
LACKALTER	0.179	0.777	0.026	0.109	0.121
PLOTSNO	0.154	0.199	0.023	0.0305	0.377
Farms correctly predicted (%)			89.96		
Goodness of fit (pseudo R-squared)			0.600		
Log-likelihood function (unrestricted)			-69.44		
Log-likelihood function (restricted)			-173.91		
P-value			0.0248		
Degrees of freedom			18		
Number of observations			279		

Dependent variable: Decision to buy water
[a] Source: Survey data 2009
[b] Marginal effect (dEy/dx) is the partial derivatives of the expected values with respect to the vector of characteristics. They were computed at the mean of the independent variable.
[c] elasticity is computed by multiplying the marginal effect coefficient by the ratio of mean of the concerned explanatory variables to the mean of the dependent variable.
- ***, **,*, refers to significance at 1, 5, and 10%

The value of marginal effect coefficient implies the changes in decision to buy water brought about by one unit change in the independent variables, *ceteris paribus*. The partial probability of water buyer's fruits area (FRUITSHIGHWATER) was estimated to be 0.001. It implies that, *ceteris paribus*; a one acre increase in the area under fruits will increase the probability of buying water by 0.001 points. Because fruits are the major profitable enterprise and source of income; fulfilling the water requirement of fruits is of foremost importance. To save the long term investment in fruits and hence source of livelihood; farmers go for water from wherever they find it.

The marginal effect of the dummy variable dried tubewell ownership (DRIEDTWOWN) was 0.08, implying that *ceteris paribus*; a change in water buyer to a dried tubewell owner will increase the probability of buying water by 0.08 points. Tubewells drying is a common phenomenon in the wake of declining watertables in some of the aquifers. Those farmers who lose their source of irrigation (tubewell dried) definitely look for water markets for water to save their hard established high value fruits orchards. The effects of other variables on the probability of selling tubewell water can be interpreted in the same way.

The elasticity of crop intensity had the significant elasticity coefficient (-0.56) with respect to the decision of water buying which implies that a 1 percent increase in cropping intensity will decrease the probability of water buying by 56 %. Similarly, the elasticity coefficient of plots number was (0.21) which implies that the probability to buy water would increase by 21 percent if the number of plots increases by 1 percent (Table 9).

5. Summary and conclusions

In the groundwater dependent areas of upland Balochistan, with increasing water scarcity and prevailing drought, informal groundwater markets emerged as proficient institutions for providing access to water deficient farmers. Water selling is common in the area; there are two major types of water recipients were common – the tenants and non tenants.

Payment for water is made to buy the water for fruits, vegetables, and crops in the following two ways; (i) payment on hourly basis, (ii) payment in kind as share cropping (exist in a variety of forms). The ratio of water sales for crop share decreases as we move from low uplands to medium to higher uplands. Water sales mostly in cash to other users such as dry tubewell owners, fellow tubewell owners, and fellow land owners having no tubewell and relatives/friends increases as we move from low to medium to high uplands. Prices are determined mainly through negotiations in all the locations of the study area; however, current market prices and price prevalent in area from the previous transactions are also used.

The logit regression model was used to examine the effects of a number of quantitative as well as qualitative independent variables on the probability of tubwell water selling. The results showed that variables such as, tubewell ownership, reliability of tubewell, soil withholding capacity and farm area significantly affect the water buying decision. While the variables such as age, education, cropping intensity, area under high delta fruits, area vegetables *kharif*, water buy kinships, dried tubewell ownership, power connection, lack of alternate source of irrigation, and plots number showed the expected effect on the decision to buy water. Site 1 (low altitude) and site 3 (high altitude) were both significantly different from medium altitude (control) in terms of water buying most probably because site 1 (low altitude) areas relatively less dependent on water markets in terms of water buying on cash than the medium altitude, because here the crops share arrangements are common and water is relatively abundant.

The results of regression analysis shows that groundwater marketing (water selling and buying) is the result of a combined effect of a number of climatic, socio-economic, and environmental factors. Among them, many factors are related to water and its use under the scarcity conditions. On the seller's side, it shows that groundwater markets help tubewell owners to sell water in excess of their own use on self managed farm area. These markets are also bound in a number of social associations (kinships) which are being regarded while selling water. On the buyer's side, its shows that groundwater markets are helping those farmers who don't have any source of irrigation or those who have got dried their tubewells, hence showing the welfare effects of water markets. Water use efficiency is encouraged in such a way that instead of installing own tubewells, farmers buy water from the nearby tubewells hence ensuring full utilization of pumping capacity of existing pumps. Groundwater markets are also helping giving employment, and increasing incomes thus reduce poverty as well. To further enhance their effective role, the arrangements for the provision of real time price information for the better functioning of informal groundwater markets and better institutional arrangements to govern both tubewell installation and groundwater arrangements are suggested.

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Appendix: Empirical Models for Determinants of Groundwater Selling and Buying

Groundwater Selling: The empirical model for determinants of groundwater selling, discrete choice logit regression is given as under:

$(Sellwater)_k = \beta_0 + \beta_1(SAGE)_{jt} + \beta_2(SEDU)_{jt} + \beta_3(DEPTHBORE)_{jt} + \beta_4(CROPINTEN)_{jt} + \beta_5(FRUITHIGHWAT)_{jt} + \beta_6(VEGKHARIF)_{jt} + \beta 7(DECWTABLE)_{jt} + \beta_7(DIAPIPE)_{jt} + \beta_8(TWELLNUMB)_{jt} + D_1(WSELLKINSHIPS)_{jt} + D2(SELLCASH)_{jt} + D_3(SITE1LOW)_{jt} + D_4(SITE3HIGH)_{jt} + \varepsilon_{jt}$

Where,

(Sellwater) = Dichotomous dependent variable for the decision to sell water, its value = 1 if the decision is yes and zero otherwise.

βs	= Vectors of parameters to be estimated,
Di	= Vectors of parameters to be estimated for dummy variables,
εk	= Error term,
(SAGE)	= Age for the water seller (years),
(SEDU)	= Education as number of schooling years (years),
(DEPTHBORE)	= Depth of tubewell (feet)
(CROPINTEN)	= Crop intensity (percent)
(FRUITSHIWAT)	= Area under high delta fruits (acres)
(VEGKHARIF)	= Area under *kharif* vegetables (acres)
(DECWTABLE)	= Decline water table (feet)
(DIAPIPE)	= Tubewell pipe (diameter of delivery pipe)
(TWELLNUMB)	= Dummy Variables for tubewells own
(WSELLKINSHIP)	= Kiships in water selling
(WSELLKINSHIP)	= 1, if the farmer considers kinship and 0 otherwise.
(SELLCASH)	= Prefer water sale in cash (SELLCASH) =1, if farmer's response is yes and 0 otherwise
(SITE1LOW)	= Dummy for site 1, if the location is low altitude and zero otherwise
(SITED3High)	= Dummy for site 3, if the location is high altitude and zero otherwise

Groundwater Buying: The empirical model for determinants of groundwater buying, discrete choice logit regression is given as under:

$(Buywater) = \beta 0 + \beta 1(BAGE)_{jt} + \beta 2(BEDU)_{jt} + \beta 4(FARMSIZE)_{jt} + \beta 5(CROPINTEN)_{jt} + \beta 6(FRUITHIGHWAT)_{jt} + \beta 7(VEGKHARIF)_{jt} + \beta 7(PLOTSNO)_{jt} + D1(TWOWN)_{jt} + D2(RELIABILITY)_{jt} + D3(WATBUYKIN)_{jt} + D4(DRIEDTWOWN)_{jt} + D5(SOILQUALITY)_{jt} + D6(POWERCONNEC)_{jt} + D7(LACKALTERNATE)_{jt} + D1(SITE1LOW)_{jt} + (SITE2HIGH)_{jt} + \varepsilon_{jt}$

where,

βi	= Vectors of parameters to be estimated,
Di	= Vectors of parameters to be estimated for dummy variables,
εk	= Error term,
(BAGE)	= Age of water buyer (years),
(BEDU)	= Education of water buyer as number of schooling years for the kth farm (years),
(FARMSIZE)	= Land owned by the water buyer (acres)
(CROPINTEN)	= Crop intensity (percent)
(FRUITSHIWAT)	= Area under high water demanding crops (acres)
(VEGKHARIF)	= Area under kharif vegetables (acres)
(PLOTSNO)	= Plots numbers/land parcels (number)

Dummy Variables,

(TWOWN) = Dummy for tubewell ownership and defined in terms of dichotomous dependent variable (TWOWN) 1, if the farmer own TW and 0 otherwise.
(RELIABILITY) = dummy for tubewell reliability as a source of irrigation. (RELIABILITY) =1, if farmer's response is yes if tubewell is reliable and 0 otherwise;
(WATBUYKIN) = dummy for kinships in water buying. (WATBUYKIN) =1, if water buyers consider kinships and 0 other wise.
(DRIEDTWOWN) = dummy for dried tubewell owners. (DRIEDTWOWN) =1, if water buyers have got dried their tubewells and 0 otherwise
(SOILQUALITY) = dummy for soil quality. (SOILQUALITY) =1, if soil quality is good and 0 otherwise.
(PWRCONEC) = dummy for power connection (PWRCONEC = 1, if the farmers response is yes for electric connection availability and 0 otherwise;
(LACKALTR) = dummy for availability of alternative source of irrigation, (LACKALTR)k = 1 if yes and 0 otherwise.

The description and definition of the variables are as under:

AGE: Age of the water buyer/seller. This factor is considered as a proxy for the experience of the water buyer/seller in the society-the older the person the more he has got experience and social status. Age affects the selling decision of the water buyer/seller in terms of utilization of surplus water or buy, and help fellow farmers. This was measured in terms of years.

CROPINTEN: Cropping intensity (%) of buyer/seller. It is assumed that those farmers having higher cropping intensity use more water at own farm and less is available for sale to someone else.

DEBTHBORE: Depth of tubewell. Depth of bore indicates the water scarcity in a particular aquifer. It is assumed that deeper bore well mean water is being pumped from great depth, hence more is available for sale.

DECWTABLE: Decline in watertable in feet during the last ten years. It is assumed that more rapid decline in watertable shows rapid drawdown and less water available for sale.

DIAPIPE: Discharge flow of tubewells delivery pipe. It is assumed the more the outlet of tubewell's delivery pipe the more will be the water discharge and hence more will be the water available for sale.

DRIEDTWOWN: Ownership of dried tubewells. It is assumed that those who have got dried their tubewells, are short of own irrigation source, will be buy water through water markets to save their orchards.

EDU: Education level of the water buyer/seller. Education could increase the farmers' ability to obtain, process, and use information relevant to the adoption of tubewell/ or sell water. Thus education is supposed to increase the probability of a rational decision by household with regard to water selling/buying. This was measured in terms of years of schooling.

FARMSIZE: Total cultivated area of the water buyer/seller. Land ownership is important factor determining water selling/buying. This was measured in acres. It is expected that large farmers usually own tubewell while small and medium farm size farmers buy water.

FRUITSHIWAT: Area (acres) under high water demanding fruits. It is assumed the more the area under high water demanding fruits (high in terms of number of irrigation required) the higher will be the demand for water at own farm and less will be available for sale.

LACKALTR: Lacking an alternate source of irrigation (Kareze, spring) except tubewell. This influences the decision to buy water from water markets or adopt a tubewell for those who do not have an alternate irrigation source. Farmers were asked to answer in yes =1, if they didn't have an alternate source of irrigation or no = 0, otherwise.

PLOTSNO: Number of land plots into which the total farm area is divided (fragmentation). The more the number of plots, the more likely is the demand for water.

POWRCONEC: Availability of power connection. Having an electricity connection is a very vital prerequisite to own a tubewell. Because the electricity is highly subsidized, getting the approval of new electric connection is banned by the government. Therefore, it is assumed that having a power connection means tubewell installation more easy. Farmers were asked to answer in yes =1 or no = 0, otherwise.

RELIABILITY: Reliability of the tubewell as a source of irrigation. It is generally believed that a more reliable supply through tubewells will increase the demand for tubewell water. Farmers were asked to answer yes = 1, if tubewell was a reliable source of irrigation or no = 0, otherwise.

SELLCASH: Sale of water for cash. Mostly, cash strapped tubewell owners prefer to sell water in cash rather than delayed payments. It is expected that sell in cash is preferred. This may influence the decision to sell water. Farmers were asked to answer in yes =1, and 0 otherwise.

SITE1LOW AND SITE2HIGH: Site dummies for low altitude areas and high altitude areas to compare it with the medium altitude (control).

SOILWHCP: Quality of soil. It is expected that farmers are rational in their decision making and buy water when the soil is of good quality to get maximum return.

TWELLNUMB: Number of tubewells own by the farmer. It is expected that the higher the number of tubewells the more will be water pumping and more water available for sale.

TWOWN: Adoption/ownership of tubewell. Farmers were asked to answer in yes =1, if they own a tubewell or no = 0 otherwise. Water sellers are also buyers in some instances, their tubewell does not fulfil their demand. It is expected that those farmers who do not own tubewells are more likely to buy water from water markets.

VEGKHARIF: Area (acres) under *kharif* vegetables. Most of water selling for crop share occurs for *kharif* vegetables. They are high in water demand (in terms of number of irrigation required). More *kharif* vegetables mean more capacity.

WATERSALEKINSHIP: Kinships in water selling. It is expected that water buyers are more likely get water easily when they buy it from some relatives. On the other hand, it is expected that water seller prefer their friends/relatives/neighbours than the other while selling water.