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Who Will Think Outside the Sink? Farmers' Willingness to Invest in Technologies for Groundwater Sustainability in Pakistan

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ABSTRACT

Concerns over depleting aquifers tend to recommend water-saving irrigation technologies as a potential solution. This study examines farmers' enthusiasm towards one of such technologies in four southwestern districts of Pakistan. The required information was obtained through a survey questionnaire administered to a sample of 283 groundwater users, and it was analysed descriptively and via an ordinary least squares regression technique. Results indicate that adopting water-saving technologies is less likely in the absence of incentives such as subsidised system installation, a reliable supplier who can provide warranties on the system's service and spare parts, and training the participating farmers. Besides, promoting such technologies would be relatively easier in the southern region due to those farmers' relatively greater enthusiasm there compared with their northern counterparts. We conclude that promoting technologies such as drip irrigation may continue, but only as the mandatory initial step of a broad-based strategy aimed at nurturing water conservation values at the societal level. Among various possible interventions, enhancing water literacy is extremely important so that farmers discover and correct wasteful aspects inherent in their current irrigation practices, work through options to minimise those wastages, and develop a sense of water conservation as a collective social responsibility.

Keywords: Arid Agriculture, Aquifer Depletion, Drip Irrigation, Tubewell, Water Literacy, Water-saving Technologies

1. BACKGROUND

Amid rapid population growth and resource depletion across the globe, the groundwater is perhaps a substantially less exploited resource accounting for a withdrawal amounting to just 6 percent of the 11,500 km^3 estimated annual recharge [Giordano (2009)]. However, groundwater use has increased exponentially in various regions during the last few decades, mostly due to the widespread adoption of pumping technology. Since the 1970s, the groundwater pumping has become readily affordable due to government and donor subsidies on the installation and operations of tubewells (TW) meant to expand irrigated agriculture [Molle, *et al.* (2003); Giordano (2009)]. In regions like South Asia, these policy interventions' results had been sizable such that just five countries (Nepal, India, Bangladesh, Pakistan and China) now extract about half of the world's annual total groundwater withdrawals [Shah, *et al.* (2003)]. The groundwater rush in these countries has depleted aquifers and caused high levels of water-logging, salinity, and soil and water contamination [Shah, *et al.* (2003)]. This situation continues to be exacerbated due to climate change and its possible impacts on the regional hydrology [Burke and Moench (2000); Green, *et al.* (2011)].

In Pakistan, the policy support for tubewells has primarily sought to control waterlogging and salinity in the Indus Basin and, additionally, to expand irrigated agriculture [van Steenbergen and Oliemans (2002); Briscoe and Qamar (2009); Mulk (2009); Qureshi, *et al.* (2010)]. Inspired by its convenience, the possibility of conjunctive irrigation, and subsidies on installation and operation, millions of farmers have opted for tubewells [Briscoe and Qamar (2009);

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Qureshi, *et al.* (2010); Khair, *et al.* (2012)]. Currently, about 90 percent of the tubewells in Pakistan are used for irrigation [Qureshi, *et al.* (2008)]. Decades of 'open-access' groundwater use has depleted aquifers and is a serious threat to agricultural livelihoods in the Punjab and Balochistan provinces [Chaudhry (2010); Qureshi, *et al.* (2010)].

Unlike Punjab, however, the dependence on groundwater is almost inevitable in most parts of Balochistan due to its meagre rainfalls and negligible surface water resources. These biophysical conditions have motivated policymakers to subsidise equipment, installation, and operation of tubewells to expand irrigated agriculture [Molle, *et al.* (2003)]. Irrigated agriculture grew as envisioned, but it created an unjustifiably huge burden: recurrent subsidies, rapidly depleting aquifers, and the death of pro-poor *karezes* [Molle, *et al.* (2003); Mustafa and Qazi (2007); Abudu, *et al.* (2011); Mushtaq, *et al.* (2013); van Steenbergen, *et al.* (2015); Memon, *et al.* (2017)]. Today, virtually every study on water management in Balochistan suggests controlling the groundwater exploitation, sometimes through overly strict means. Any policymaker would certainly face a dilemma in responding to such calls, particularly when groundwater is the only source of irrigation and domestic water supply. Although supportive regulations exist, so far no strict measure has been applied with any degree of success due to various political and social reasons nicely discussed by van Steenbergen (1995); van Steenbergen and Oliemans (2002); van Steenbergen *et al.* (2015).

Some researchers, such as Hussain, *et al.* (2008) and Shah (n.d.) suggest soft measures, such as using policies to promote water-saving irrigation methods to ensure long-term water security without compromising yields or areas under cultivation. One of the highly-recommended water-saving technologies for Balochistan is drip irrigation. In general, a drip irrigation system comprises a transport system (like a hose or pipeline), emitters (for precise application), filters (to avoid clogging), and some types of pressure regulators (for smooth water application, usually between 20-50 psi) [eFresh (2017)]. These systems help apply water directly to plant roots (instead of entire land areas), reduce evaporation, wind effects, and other problems associated with flood irrigation [eFresh (2017); Brouwer, *et al.* (n.d.)] (See supplementary materials). However, despite its introduction decades ago, drip irrigation has hardly gone beyond pilot projects and field demonstrations. Apparently, farmers lack enthusiasm for it due to empirically unknown reasons.

Experiences elsewhere suggest that the lack of adequate information and high initial capital investment could hamper farmers from adopting agricultural and irrigation technologies [Adeel, *et al.* (2008); Wessels (2008)]. Studies conducted so far in Balochistan have focused on various important issues related to groundwater management, including farmers' willingness to adopt tubewells [e.g., Meinzen-Dick (1996); Khair, *et al.*

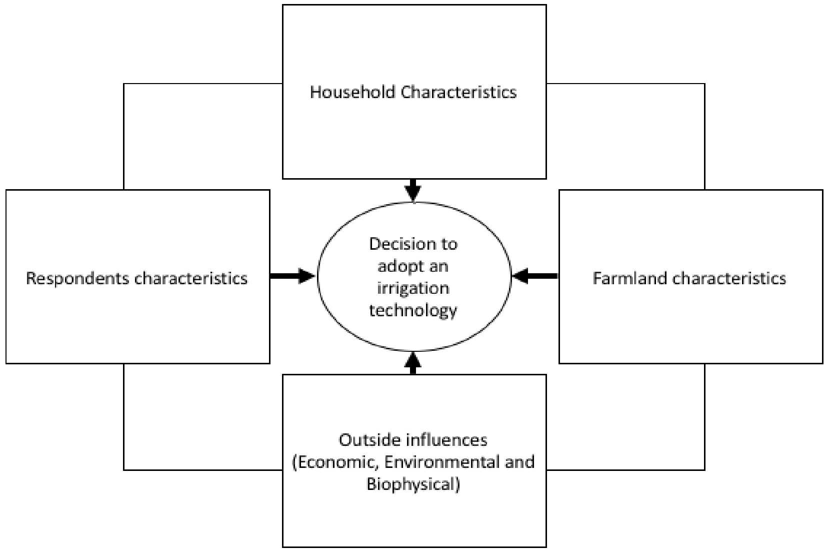
(2015)], the role that subsidies [e.g., Ahmad (2006a, b, c, d); Khair, *et al.* (2012)] and different institutions have played in it [e.g., van Steenbergen and Oliemans (2002); van Steenbergen, *et al.* (2015)], and reviving traditional irrigation systems [e.g., Mustafa and Qazi (2007); Sarfraz, *et al.* (2013); Memon, *et al.* (2017)]. Nonetheless, virtually none of these studies have assessed the demand for water-saving technologies, despite some studies recognising their importance [e.g., Altaf, *et al.* (1999); Ahmad (2006c); Ahmad (2016)]. This paper attempts to bridge this gap and presents the findings of a recent innovative research that empirically assessed farmers' demand for drip irrigation in Balochistan and the underlying factors.

To achieve this objective, the rest of the paper is organised as follows. Section 2 elaborates the conceptual basis for understanding the factors associated with adopting water-saving technologies and selecting relevant variables for the analysis. Section 3 provides the details regarding materials and methods, including a profile of the study area; Section 4 presents the study's major findings. Finally, Section 5 discusses study results in a broader theoretical and applied context, then draws policy implications for Balochistan and other arid areas experiencing similar water management problems.

2. CONCEPTUAL FRAMEWORK: ADOPTION OF AGRICULTURAL TECHNOLOGIES

Adoption of agricultural technologies has been a key area of scientific inquiry at least since the 'green revolution' was introduced in Asia and Africa. It is common to find technologies that perform excellently in laboratories but fail to impress farmers in the field; additionally, numerous other technologies might be highly successful in one context but completely discarded in the other [Staudt (1991)]. The context-specific nature of technology adoption makes associated policymaking extremely difficult. A very comprehensive literature review by Yila (2009) reveals that any decision to adopt an agricultural technology would consider certain biophysical, personal, socioeconomic, and institutional influences. Although these parameters' generic nature facilitates their relevance across diverse contexts [e.g., Wang, *et al.* (2015b, a)], the constituting variables under each parameter might be different or any particular variable may behave very differently in varying contexts. Thus, a variable explaining farmers' behaviour in one context may fail to do so in another context [Paudel and Thapa (2004); Rasul, *et al.* (2004)]. Besides, as Yila (2009) also pointed out, these factors are not an isolated set of variables but are often interlinked and, therefore, very difficult to model. Fig. **1.** provides the schematic diagram of farmers' attitudes towards irrigation technologies and the subsequent paragraphs discuss its key elements.

Fig. 1. Conceptual Framework



The personal characteristics of a farmer, who represents his or her household in a study of farmers' behaviour, are perhaps the first important group of variables to consider [Giampietro (1997); Johnson, *et al.* (1999)]. In fact, the survey respondents act as the window through which a researcher understands a farming family's tendency to adopt a technology. An 'educated' person, who is deeply involved in household decision-making and an experienced family member, may better represent his/her family than a young and naive member. Besides these, the respondents' gender is also a common variable in the models of technology adoption.

The characteristics of a farming household usually play an important role in technology adoption decisions [Rauniyar (1998)]. Among various others, frequently used variables in this set are: family size, level of the household's dependence on agriculture, the household's previous exposure to technologies, and social status. Although income is inherently difficult to measure accurately, whenever possible, it serves as a good proxy for variables such as social status, a technology's financial affordability, resourcefulness, and the household's quality of life; and these can be found in various studies, including Khair, *et al.* (2015) and Yila and Thapa (2008).

Farm characteristics are the most direct set of variables in any equation assessing adoption decisions related to agricultural technologies. The landholding size, tenure security, access and type of irrigation, types of crops cultivated, and methods of cultivation are some of the important variables explaining variation in farmers' tendency to adopt agricultural technologies [Cramb, *et al.* (1999); Yila and Thapa (2008); Yila (2009)].

The variables identified in the preceding paragraphs are very important but mostly pertain to farmers, their families, and farmlands. In fact, faming activities never take place in a vacuum and farming decisions are rarely isolated from their surroundings. Various external forces, such as the market, farmers' previous exposure to a technology, institutional support—such as government subsidies and extension services—and topographic and climatic variables are also important determinants of farmers' willingness to adopt a technology [Napier and Sommers (1993); Bekele and Drake (2003); Yila and Thapa (2008); Yila (2009)].

In Balochistan, Khair, *et al.* (2015) and Meinzen-Dick (1996) also used somewhat similar conceptual models to study the growth of tubewells. Hence, it is reasonable to rely on the above-discussed conceptual framework to understand the farmers' attitudes towards water-saving irrigation technologies in Balochistan. The below section provides the methodological underpinnings to obtain and analyse the information on various variables important in this study.

3. MATERIALS AND METHODS

3.1. Selection of Study Area and Respondents

To represent both Pakhtoon and Baloch ethnic majority districts, initially we selected five districts: Qila Abdullah, Chagai, Loralai, Panjgur, and Pishin. Despite surveying in all these districts, Qila Abdullah was dropped, as the field activity of local enumerators there could not be adequately monitored and the responses lacked internal consistency. Thus, the remaining four districts served as the study area (Fig. **2.**).

Fig. 2. Location of the Study Area

We targeted tubewell-using farmers and used tubewell statistics as the basis for sampling. As there were about 8,600 tubewells in the selected districts [Balochistan (2011)], a sample size of 283 was determined at 95 percent confidence level and ± 6 percent precession. This sample size was proportionately distributed among the selected district such that Pishin received a sample size of 137, Loralai 46, Panjgur 49, and Chagai 51. All our respondents were males as due to cultural reasons and post 9/11 security issues we could not employ female research assistants. During the field visit, the survey teams from all, but particularly the Loralai district, reported that some farmers had discontinued their own tubewells temporarily and were irrigating their farmlands with water either bought from neighbours or through *karez*. Considering that such farmers could give deeper insights into the situation, we did not exclude them.

3.2. Data Collection

We used a carefully designed, pre-tested, and Urdu-translated questionnaire, containing a disclaimer and about thirty mixed-type questions (66 percent simple and 33 percent grid questions—most of which were closed-ended) organised into four sections: respondents' profile, household characteristics, farm characteristics, and hypothetical market and policy scenarios. The questionnaire also reproduced the pictorial demonstrations showing the investigated technologies. The enumerators demonstrated a technology with the help of relevant picture(s) before presenting the associated hypothetical scenario and starting the inquiry (see supplementary materials).

3.3. Data Analysis

3.3.1. *Descriptive Analysis*

To build the context within which farmers work and make their farming decisions, the researchers carried out a descriptive analysis of the data, such as averages and percentages, and presented them graphically. Variables analysed in this manner included income, occupation, land holdings, and cultivation and irrigation management.

3.3.2. *Multivariate Analysis*

Based on the conceptual underpinnings in Section 2, Table 1 lists some of the important explanatory variables used in this study. It contains not only the codes and full descriptions of the variables, but it also marks them with ± signs showing the hypothetical relationship that the different independent variables have with the dependent variable, i.e. farmers' enthusiasm towards accepting the drip irrigation system.

Table 1

Key Variables and Their Relationships with Farmers' Enthusiasm Toward Drip Irrigation

Variable	Hypothesised Association
Dependent: Index (0-6) of farmer's enthusiasm towards drip irrigation	
RC_1: Dummy = 1 If respondent is the head of household	+
RC_2: Education of respondent farmer (in years)	+
RC_3: Age of respondent farmer (in years)	–
HH_1: Family size (No. of persons)	–
HH_2: Dummy = 1 if agriculture is intergenerational occupation within household	+
HH_3: Dummy = 1 if household has previous experience with drip/sprinkler or bubbler	+
HH_4: Farm size (in acres)	+
FC_1: Irrigated area as percentage of total land (No.)	+
FC_2: Dummy = 1 if all of the household's agricultural land is leased	–
FC_3: Number of tubewells owned by a farmer (No.)	+
FC_4: Dummy = 1 if the tubewell is electricity powered	+
FC_5: Dummy = 1 if the tubewell is diesel powered	+
DC_1: Dummy = 1 If household is in contact with extension agent regarding irrigation	+
DC_2: Dummy = 1 if farmers would respond to further GW decline by reducing its use	–
DC_3: Dummy = 1 If farmer would respond to an energy price increase by reducing GW use	–
DC_4: Dummy = 1 if the farmer belongs to the southern districts	+

The Equation 1 below is the econometric specification of variables hypothesised as influencing farmers' enthusiasm towards any offered irrigation technology:

$$Y = \alpha_i + \beta_i RC_i + \lambda_i HH_i + \varphi_i FC_i + \psi_i DC_i + \varepsilon_i \qquad \ldots \qquad \ldots \qquad (1)$$

Where:

Y is the index of the farmers' enthusiasm towards any offered irrigation technology. The index is the farmers' response to a hypothetical situation whereby a new supplier in Quetta was selling a drip irrigation system worth 32,000 PKR (≈320 USD) per acre at 25 percent discount (PKR 24,000 or ≈240 USD). If the farmer was willing to buy the system at the given offer, no further question was asked. In the case of unwilling farmers, however, the package was made more attractive each time by adding an incentive, namely, a guarantee of free service, a free spare parts replacement warranty, and free training in operating and maintaining the system, until the farmer expressed his or her willingness to buy the system. A persistently unwilling farmer was asked to quote a maximum price at which they could consider buying the system with all associated benefits. Those who did not quote any price and were still unwilling were asked to confirm their decision and give the reasons for their persistent unwillingness (see supplementary materials).

Based on the offer that made them willing to buy the system, each farmer received a score on the index that ranged between zero and six (representing an unenthusiastic to a highly enthusiastic farmer, respectively). Those who showed willingness to consider the first offer qualified with the highest score (6), and those who persisted on not accepting it, no matter whether it was accompanied by any additional offers, qualified with the lowest score (0). This index has an obvious advantage over the binary choice variable (having only adopters or non-adopters) because farmers might exhibit different levels of motivation rather than having a clear-cut binary choice.

However, modelling Y through an ordinary least squares (OLS) regression technique needs to fulfil some basic parametric assumptions. First, the descriptive analysis of the dependent variable (Y) showed a normal distribution curve (skewness 0.024, kurtosis –1.314 and none of the cells empty or with a few observations). Second, the dependent variable (Y) is the construct of many items, which all measure the same attitude and have seven values out of which an individual farmer could take any value; therefore, these data sets were suitable for analysis via parametric techniques [Lubke and Muthén (2004); Norman (2010)]. Ordinal logistic regression (OLR) could estimate Y, but one must accept proportional odds that assume similar coefficients describing a relationship across different pairs of outcomes. This assumption is stronger than assuming an equal interval between any two consecutive points along the continuum of Y. Besides, applying OLS instead of OLR did not change the coefficient estimates to the extent that it could affect any conclusions the model may draw.

On the right side of the equation, the term RC_i is the vector of respondent characteristics; the term HH_i is the vector of household characteristics; the term FC_i is the vector of farm characteristics; and, the term DC_i is the vector of outside influences. Expression α_i is the intercept or constant, expression β_i, λ_i, φ_i, and ψ_i are parameter coefficients of the explanatory variables' vectors, respectively (to be estimated by the model), and expression ε_i is error term or the unexplained part of the equation.

3.4. Profile of the Study Area and Participants

3.4.1. *Agro-ecological Context*

The study area lies in the southwest of Pakistan (Fig. **2.**) and accounts for about 23 percent of the Balochistan province. The terrain is mostly highlands and mountainous, but the Chagai district has plains and deserts as well. The Pishin and Loralai districts are Pakhtoon-dominated districts, whereas Panjgur and Chagai are Baloch-dominated districts. In the rest of the discussion, the Pakhtoon-dominated areas are called the northern region, whereas the Baloch-dominated areas are referred as the southern region (roughly, these ethnic groups are geographically distributed in this pattern). The northern region is more densely populated than the southern region, but population density in the districts never exceeds 75 persons per km^2 (the lowest, in Chagai, is 7 persons per km^2 and the highest, in Pishin, is 71 persons per km^2).

Table 2 gives a comparative view of the selected districts' agro-climatic settings.

Table 2

Agro-climatic Profile of the Selected Districts in Balochistan

	Northern region		Southern Region	
Indicator	Pishin	Loralai	Panjgur	Chagai
Location	66°46'–67°49' E lon 30°44'–31°14' N lat	67°41'–69°44' E lon 29°54'–30°41' N lat	63°04'–65°20' E lon 26°08'–27°17' N lat	60°49'–65°28' E lon 29°49'–27°51' N lat
Elevation	1,500–3,300 m above MSL	924–3,100 m above MSL	465–1,776 m above MSL	486–2,800 m above MSL
Area	7,819 km2	8,155 km2	16,891 km2	45,444 km2
Terrain	Mountains	Mountains and valleys	Mountains	Highlands, plains, and deserts
Climate	Delightful summer, dry and bitterly chilly winter	Mild summer, chilly and windy winter	Warm summer, chilly winter	Extremely hot in summer, extremely chilly in winter
Rainfall	308 mm	279 mm	76 mm	104 mm
Population	559,359	351,579	304,966	292,191
Agriculture potential (% of area)	23.5% (sown 4%, fallow 15.3%, culturable waste 4.2%)	24% (sown 4.5%, fallow 11.2%, culturable waste 8.3%)	4.6% (sown 1.4%, fallow 0.4%, culturable waste 2.7%)	9% (sown 0.8%, fallow 0.4%, culturable waste 7.6%)
Irrigation source	Groundwater (TWs 95.7%, wells 1.8%, karez 2.5%).	Groundwater (TWs 94.1%, wells 3.4%, karez 2.5%)	Groundwater (TWs 81.3%, wells 7.8%, karez 10.9%)	Groundwater (TWs 71%, wells 26%, karez 3%)
TWs (No.)	4,366	1,316	1,461	1,427
Karez (No.)	123	50	188	56
Major Crops and fruits	Wheat, potatoes, pumpkins, grapes, apples, pomegranates, plums, and peaches	Wheat, cherries, pomegranates, plums, peaches, grapes, apricot, and apples	Wheat, broad beans, luffa, ladyfingers, and date palms	Wheat, barley, onions, carrots, radish, date palms, pomegranates, grapes, and apricots

Sources: Compiled from GoB and UNICEF (2011) except the number of tubewells (TWs) and karezes, which are taken from GoB (2011) and IUCN (2013), respectively.

The local climate is hot in summer and chilly in winter. Although all districts receive low and erratic rainfall (between 76 to 308 mm), in relative terms the northern districts receive slightly better rainfall. In all districts, the ground is the only reliable source of water for domestic use and irrigation. Groundwater is extracted using tubewells and *karezes*, but now tubewells dominate, as most of the *karezes* have dried up. Of the area suitable for cultivation, only a small percentage is cultivated due to the limited availability of irrigation (Table 2). The land and climate are highly suitable for high-value deciduous fruits and vegetables such as almonds, pistachios, grapes, apples, plums, pomegranates, date palms (mostly in Panjgur), olives, tomatoes, chilies, cucumbers, pumpkins, and many others. In general, the northern farmers grow more crops and get better yields compared to their southern counterparts (Table 2).

3.4.2. *Respondents' Characteristics*

The majority of the respondents were household heads – a percentage highest in Chagai, followed by Panjgur and Pishin, respectively. In Loralai, however, roughly half were just family members (Table 3). Except those from Chagai, the respondents were, on average, older than 35 years and had more than 10 years of farming experience; but those belonging to Chagai were younger and less experienced (Table 3). About three-fourths of the respondents reported formal schooling. The respondents from Pishin, on average, received a few more years of schooling compared to those from the other districts (Table 3).

Table 3

Respondents' Characteristics

Particular	Northern region		Southern Region		Entire Study Area
	Loralai (n = 46)	Pishin (n = 137)	Panjgur (n = 49)	Chagai (n = 51)	(N=283)
Head of household – %	52	66	78	80	68
Just a member – %	48	34	22	20	32
Age in years – $\bar{X}$ [SD]	40 [14]	43 [10]	42 [11]	37 [12]	41 [12]
Farming experience in years – $\bar{X}$ [SD]	19 [13]	19 [8]	20 [11]	13 [10]	18[10]
Schooling in years[1] – $\bar{X}$ [SD]	8 [3]	10 [3]	9 [3]	7 [3]	9 [3]
Family size – $\bar{X}$ [SD]	15 [6]	18 [12]	6 [2]	10 [5]	14[10]

Notes: School attainment was 96 percent in Loralai, 85 percent in Pishin, 57 percent in Panjgur, and 37 percent in Chagai. One-way ANOVA Post Hoc Tukey comparisons show a statistically significant difference in respondents' average years of schooling in Pishin compared with Chagai *($p = .000$)* and Loralai *($p = .000$)* but not with Panjgur.

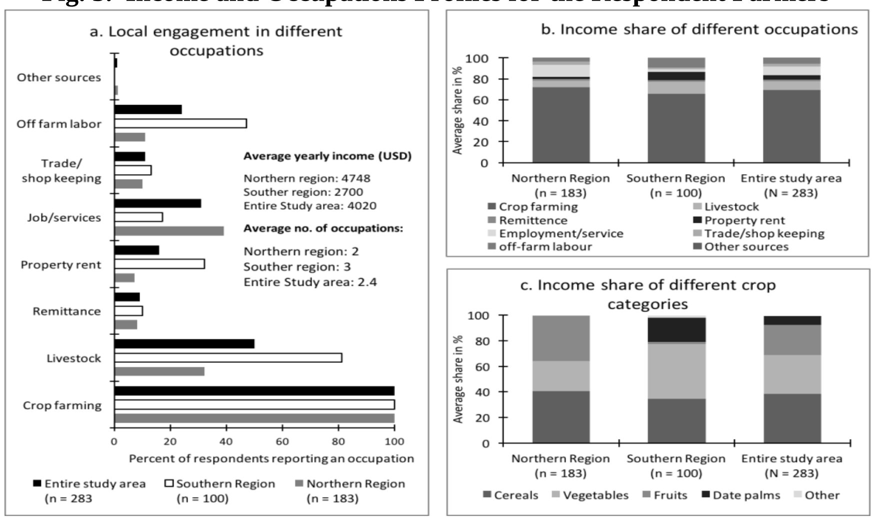
Nonetheless, in all districts, the average schooling was less than 10.5 years. Only 23 percent of all farmers reported more than 10 years of schooling, 72 percent of whom were from Pishin, 11 percent from Loralai, 15 percent from Panjgur, and 2 percent from Chagai. Of the one-fourth who did not report any schooling, the majority belonged to Chagai (42 percent), followed by Pishin (28 percent), Panjgur (27 percent), and Loralai (3 percent).

3.4.3. *Households' Dependence on Agriculture*

Despite the suitability of agro-climatic conditions for high-value agriculture and orchards, the farmers' self-reported yearly incomes in both regions suggest that they were not rich (Figure 3a). An average farmer earns less than 5,000 USD per year, but those from the northern region earn substantially higher incomes compared to their southern counterparts. Interestingly, the southern region appears occupationally more diverse than the northern region (Fig. **3.** a) but occupation diversity does not provide them with higher incomes.

In both regions, crop farming was the major income source, but the northern farmers earned more from crop farming compared to the southern farmers. Keeping livestock was highly common in the southern region and, on average, contributed slightly more than 11 percent to the yearly incomes there, but livestock contributed just 6 percent to the northern farmers' incomes (Figure 3a and b).

Fig. 3. Income and Occupations Profiles for the Respondent Farmers



Besides agriculture, other occupations were also important for the locals. Two fifths of the northern and under one-fifth of the southern respondents reported engagement with a job or service. This source, on average, contributed 11 percent and 3 percent to the yearly incomes of the northern and southern farming families, respectively (Fig. **3.** a and b). In the southern region, one-third of the farmers reported property rents, which on average contributed 8 percent to their incomes. Besides, almost half of the southern farmers also reported being engaged in off-farm labour and earned, on average, 9 percent of their incomes from it (Figure 3a and b).

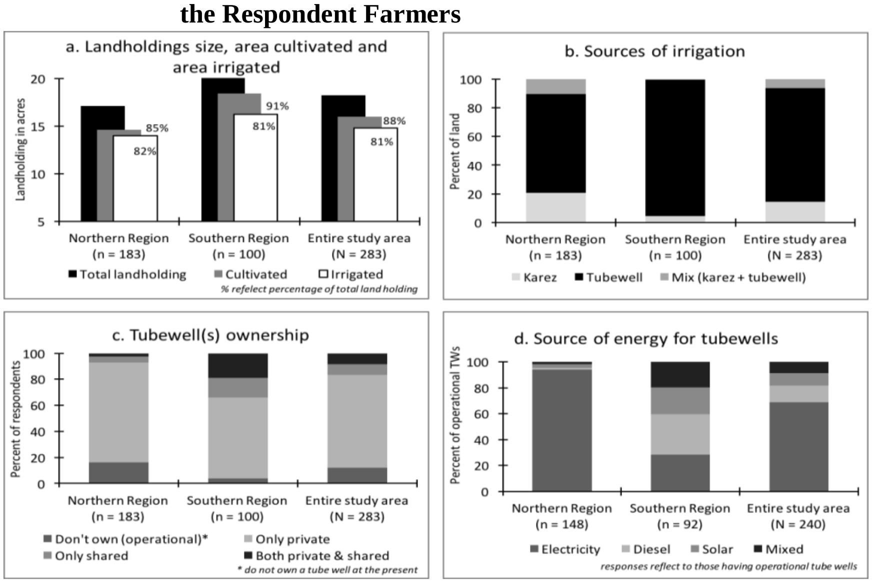
Nowhere (except one-fifth from Pishin) did farmers earn 100 percent of their farming income from a single crop category. All farmers in the southern region and more than two-thirds in the northern region cultivated cereals and earned, on average, 35 percent and 40 percent of their crop farming income from it, respectively (Figure 3c). The majority of the farmers grew vegetables in both regions, but more so in the southern region. It provided the southern farmers 43 percent and the northern farmers 24 percent of their crop farming income (Figure 3c). In the northern region, fruit cultivation was common and, on average, contributed 35 percent to farmers' crop incomes (Figure 3c). Although, in general, the contribution of fruit cultivation seems meagre in the southern region, date palm was an important fruit crop for more than 90 percent of farmers in the Panjgur district, who, on average, earned 42 percent of their income from it.

4. RESULTS

4.1. Irrigation Management

It is hard to notice any significant regional difference in the irrigated land as percentage of total land holdings (Figure 4a). Background disaggregated analysis, however, suggests that the districts differ significantly from each other in terms of their landholdings' size. Chagai had the highest average irrigated landholding (more than 30 acres) while Panjgur had the smallest irrigated land holdings (less than 2 acres)—and both districts belong to the southern region. However, most farmers in both regions were irrigating most of their land with tubewell water (Figure 4b). Some of the farmers had abandoned their tubewells and were currently irrigating their land either with *Karez* water or with the water purchased from the neighbouring tubewell owners. Still, more than 80 percent of farmers in both regions reported owing private or shared tubewell(s) (Figure 4c). In both regions, it was also common for a farmer to have more than one tubewell. Sharing a tubewell was rare in Chagai and Loralai but very common in Panjgur, understandably, due to the small landholdings encouraging shared tubewells.

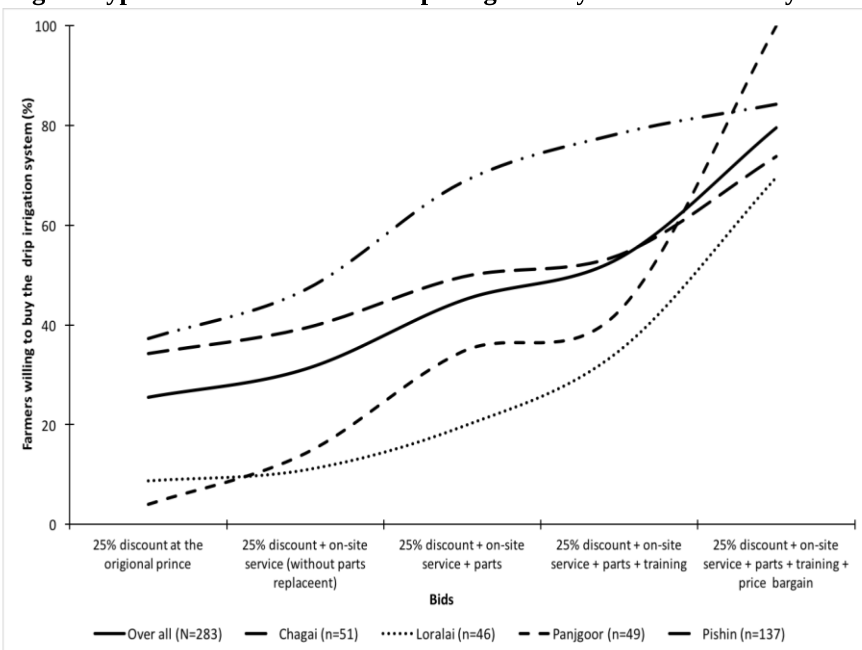
Fig. 4. Landholdings, Sources of Irrigation, and Energy for the Respondent Farmers



4.2. Demand for Drip Irrigation

The demand for drip irrigation was determined based on assessing farmers' responses to the hypothetical scenario explained in section 3.3.2. Enumerators informed the farmers that the purpose of the hypothetical scenario and subsequent questions was to assess the demand for drip irrigation and was by no means any indication of an upcoming policy or incentive package. Farmers were asked to imagine what would they do if found themselves in a scenario like the one sketched to them. The result of the exercise, formulated as a change in the demand for drip irrigation, is summarised in Figure 5.

Fig. 5. Hypothetical Demand for Drip Irrigation Systems in the Study Area



Considering that drip irrigation systems have been tried in the study area for many years but the majority of the farmers still do not adopt them, the initial bid offered a 25 percent general discount on the original system price (PKR 32,000 or USD 320 per acre) and received a positive response from about one-fourth of the respondents. Those still unwilling got the offer that the system supplier would also handle the periodic maintenance on their systems at no cost, but they would have to pay for spare parts. This offer attracted only 6 percent more farmers. Still unwilling farmers were offered free spare part replacement in their package, and this expanded the willing farmer list by 13 percent, but more than half were still unwilling.

Adding training on how to operate the system attracted 8 percent more farmers to the list of the willing farmers. Still-unwilling farmers received the final offer to quote a maximum price at which they could consider buying the system with all its associated discounts and offers. This added another 26 percent of the farmers, of which 42 percent were from the southern region (who, on average, were willing to buy the system at 27 percent (SD 12 percent) of its market price); about 52 percent were from the northern region (who, on average, were willing to buy the system at 17 percent (SD = 9 percent) of its market price). These differences in their willingness to pay were statistically significant at 1 percent. Of the remaining 21 percent, farmers who were firmly unwilling, about 90 percent were from the northern region. Of these, about 23 percent thought that the system was still expensive, 42 percent were doubtful that it would function as promised, 14 percent did not trust the promises suppliers made about the system warranties, and 20 percent thought that the system installation would not bring sufficient benefit to cover its cost.

4.3. Determinants of Farmers' Enthusiasm for Drip Irrigation

Sixteen explanatory variables (Table 1**Error! Reference source not found.**) were organised into four groups: respondent characteristics (three variables), the farming household's characteristics (four variables), farm characteristics (five variables), and outside influences (four variables). Each group of variables was entered into the model step-by-step (Table 4). ANOVA and model summary statistics suggested that at each step, and from an overall point of view, the model was statistically significant (p=.000). Besides, the model's explanatory power (r^2) increased with the addition of each group of variables. Overall, the model explains about 31.5 percent of the variation in the farmers' enthusiasm towards buying drip irrigation systems. Individually, the responding farmer group's characteristics explained 10 percent of the variation; the farming household and farm characteristics groups each explained 4 percent of the variation; and outside influences explained 17 percent of the variation in the dependent variable (*Y*). Besides, a few individual explanatory variables had a statistically significant impact on the variation in *Y*. The subsequent text elaborates on the final model's results (given as Model 4 in Table 4).

When modelled together, none of the three variables accounting for the responding farmers' personal characteristics was statistically significant (Table 4). However, the RC1 (suggesting that keeping everything else constant, a household heads would be a half unit more enthused than just members) showed a clear trend towards statistical significance. Both the responding farmer's education and age were positively associated with *Y* but were statistically insignificant and had very small coefficients.

Among the farming household characteristics (Table 4), HH1 (family size) was statistically significant, at a 1 percent level, but had a very small coefficient with a negative sign. Thus, keeping all other factors constant, an increase of one member in family size would decrease *Y* by less than one-tenth of a unit. HH2 was another statistically significant variable at a 5 percent level, and this suggests that keeping all other factors constant, a farming family having an intergenerational association with crop farming would show a one unit increase in *Y*. Both HH3 (previous experience with drip irrigation) and HH4 (farm size) were, however, statistically insignificant but positively associated with *Y*.

Dozens of farm characteristics may influence any technology decision, but those included in this model also explain *Y* in a reasonable fashion (Table 4). Despite the failure of HH4 (farm size) to predict anything meaningful, FC1 (irrigated land as percentage of total land) was statistically significant, at a 5 percent level, and this suggests that keeping other factors constant, bringing an additional one percent of landholding under irrigated crops would raise *Y* by one-tenth of a unit. At the margins of statistical significance, an additional tubewell (FC3) would also increase *Y* by one-fifth of a unit. Interestingly, the energy sources (FC4 & FC5) to run (a) tubewell(s) were important and statistically significant predictors. Keeping all other factors constant, a farmer running a tubewell with electricity (FC4) or with diesel (FC5) would show a position 1.1 units higher on *Y* compared to a farmer having solar powered pumps.

In the external influences group, all variables except DC2 were highly important predictors of farmers' enthusiasm towards drip irrigation system installation (*Y*) (Table 4). DC1, the contact with a public extension agent regarding irrigation affairs, was statistically significant at a 5 percent level. Keeping all other factors constant, farmer's contact with a public extension service would raise *Y* by two-thirds of a unit compared to those who do not avail themselves of public extension services. DC2 and DC3 measured farmers' sensitivity towards further decline in the groundwater table and increases in the cost of energy for tubewells, respectively, as witnessed in their tendency to reduce the groundwater use. DC2 is neither statistically significant nor does it have any sizable coefficient. However, it did not behave negatively towards *Y* as hypothesised (Table 1). On the contrary, keeping all other factors constant, DC3 (farmers whose groundwater use may decrease due to energy price increases) would decrease *Y* by about two units (the largest predictor in the model) (Table 4). Finally, DC4, despite being at the margins of statistical significance, suggests that keeping other factors constant, farmers living in the southern region would be about three-fourths of a unit more enthused to adopt drip irrigation compared to their northern counterparts.

Table 4

Regression Results of Farmers' Enthusiasm for Drip Irrigation (Y)

Variables (Full Titles of Variables in Table 1)	Model 1		Model 2		Model 3		Model 4		Hypothesis (See Table 1)
	β	Sig.	β	Sig.	β	Sig.	β	Sig.	
(Constant)	2.668	0.000	1.981	0.008	0.352	0.694	0.086	0.929	
RC_1 (Status in family)	1.443	0.000	1.145	0.000	1.06	0.001	0.498	0.097	Supported
RC_2 (Education)	0.054	0.026	0.059	0.014	0.064	0.019	0.032	0.258	Supported
RC_3 (Age)	-0.022	0.056	-0.011	0.364	-0.005	0.714	0.009	0.434	Not supported
HH_1 (Family size)			-0.042	0.004	-0.055	0.001	-0.045	0.004	Supported
HH_2 (Association with agriculture)			0.74	0.168	0.878	0.100	0.984	0.050	Supported
HH_3 (Experience with drip irrigation)			0.402	0.284	0.501	0.192	0.529	0.151	Supported
HH_4 (Farm size)			0.013	0.123	0.013	0.150	0.006	0.467	Supported
FC_1 (Irrigated land as % of total land)					0.012	0.033	0.011	0.028	Supported
FC_2 (if all land leased)					0.463	0.314	-0.252	0.568	Supported
FC_3 (No. of tubewells)					0.273	0.086	0.295	0.055	Supported
FC_4 (if TW electricity-powered)					-0.03	0.924	1.111	0.002	Supported
FC_5 (if TW diesel-powered)					0.291	0.511	1.161	0.009	Supported
DC_1 (Contact with public extension)							0.693	0.034	Supported
DC_2 (GW use if aquifer further declines)							0.013	0.967	Not supported
DC_3 (GW use if energy price increases)							-1.999	0.000	Supported
DC_4 (if farmer is located in southern region)							0.777	0.064	Supported
Dependent variable:									
Model summary									
R	0.315		0.368		0.416		0.561		
R^2	0.099		0.135		0.173		0.314		
Std. Error of estimate	2.0468		2.02026		1.99437		1.83024		
ANOVA:									
DF	3		7		12		16		
F	9.942		5.969		4.571		7.389		
Sig	0.000		0.000		0.000		0.000		

5. DISCUSSION AND CONCLUSIONS

Widespread aquifer depletion requires governments to promote water-saving practices and technologies in the agriculture sector. Generally, the energy and water shortages and potential for agricultural expansion stimulate farmers to adapt water-saving technologies. However, this has not been the case in Balochistan. Despite it having plenty of cultivable land, the potential for high-value deciduous fruits and vegetables, its water shortages, and state-sponsored promotion, the water-saving technologies have failed to capture farmers' attention. To investigate this, we designed a hypothetical drip irrigation package and made it gradually more attractive to observe the behaviour of 283 farmers towards it. The included incentives were: a 25 percent discount on the system's purchase, an after-sales service and spare parts warranty, and farmer training to operate the system.

Consistent with Bekele and Drake (2003), we found that the household heads of relatively small-size families and those with most of their land under irrigated agriculture responded more positively. Like Cramb, *et al.* (1999) and Mbaga-Semgalawe and Folmer (2000), but unlike Khair, *et al.* (2015), we did not find that the farmers' age and education influenced their technological decisions in any significant manner. Nevertheless, our findings support the importance of agricultural extension in farmers' positive attitudes towards new irrigation methods, as found by Paudel and Thapa (2004); Deressa, *et al.* (2008); Yila and Thapa (2008). We also found farmers in the southern region of Balochistan more receptive to these technologies than their northern counterparts. Although Karami (2006) has already rejected the presumption that farmers are a homogenous group and one irrigation technology fits every farmer's needs, we further add that even for the same irrigation technology, farmers may encounter different sets of barriers. Any entity interested in technological promotion would ensure wider acceptability if such differences are acknowledged, understood, and incorporated in policies and programmes.

It is important to understand that the acceptance rate of 80 percent for the said technology, which this study could achieve in the hypothetical situation, was due to the incentive sets offered to farmers. In the absence of incentives, farmers would be less likely to welcome new technologies, as Rogers Everett's influential work on 'diffusion of innovations' suggests [Rogers (1995)]. While subsidised drip system installation is certainly important, it is necessary to focus on the local supply of system and spare parts through a competitive market. "Why would a farmer install an irrigation system for which they would purchase even an emitter from Karachi [800 km far from Quetta]?" (Personal communication with Dr Ashraf, ICARDA Pakistan). Nevertheless, before offering any technological package, it is important to assess its economic impact in the form of reducing the existing subsidies, assessing its technical viability in a particular region, addressing farmers' training needs, and evaluating its possible impacts on the local environment.

Even if farmers adopt efficient irrigation technologies, the adoption is not an end unto itself and does not automatically translate into water-saving behaviour among farmers. As Benouniche, *et al.* (2014) and Levidow, *et al.* (2014) have shown, farmers who adopt new irrigation technologies may not share the water-saving vision that the policy promoters of such technologies have. Water-saving behaviour constantly evolves through time, and relatively quickly, if it becomes a part of the farmers' ultimate objective to improve yields and if farmers work in a society that exerts social pressure to irrigate prudently [Benouniche, *et al.* (2014)]. Many farmers in our study who were reluctant to buy the new system also reasoned that they would not invest in water-saving technologies when no one else concerns about the depletion of aquifer commons.

Thus, the groundwater depletion is difficult to curb without bringing about fundamental changes in the structures governing current groundwater management. Policymakers may continue to promote technologies such as drip irrigation, but only as a mandatory first step within a broad-based strategy aimed at nurturing water conservation values at the societal level. Besides promoting drip irrigation technology, farmers may be introduced to a larger set of viable technological options that include but are not limited to alternative cropping patterns, dry land farming, laser levelling, moisture monitoring, and irrigation scheduling, as identified by Negri and Brooks (1990). Each of these options may have its own set of barriers, including availability and affordability, which must be removed to make these accessible to farmers. Another—and the most important—ingredient would be to enhance water literacy among farmers so that they be able to detect wastages inherent in the current irrigation practices and work through options that can minimise those wastages. Besides, continuous support through public extension services, media slogans, and awareness programmes may help farmers conserve water as a collective social responsibility. Until the entire process is managed as a transition towards sustainable groundwater conservation and management, any effort in this direction is doomed to fail.

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