Measuring Farmers' Willingness to Adoption of Solar Operated Drip Irrigation System: A Case Study of Ganj, Chakri

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CERTIFICATE

This is to certify that this thesis entitled: ***"Measuring Farmers' Willingness to Adoption of Solar Operated Drip Irrigation System: A Case Study of Ganj, Chakri"*** submitted by Mr. Naveed Ahmed accepted in its present form by the PIDE School of Public Policy, Pakistan Institute of Development Economics (PIDE), Islamabad as satisfied the requirements for partial fulfillment of the degree in Master of Philosophy in Environmental Economics.

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ABSTRACT

In rain-fed areas of Pakistan, agriculture is mainly dependent on rain water. In view of changing climatic conditions rains have become uncertain and underground aquifers are shrinking. This research purported to assess farmers' willingness to adopt the said technology in rain-fed area of Union Council Ganj in District Rawalpindi. The research based on randomly selected 141 farmers from the said union council. A well-structured questionnaire was employed to collect data from the field. Age, knowledge about existence of PARC solar site at Chakri (main town in the study area), land fragmentation, Level of underground water table, dependence on agriculture as main source of livelihood and knowledge about use of solar pump were found statistically significant in adopting solar powered pump drip irrigation technology. Findings of the study substantiate to make suggestion for Pakistan Agriculture Research Council (PARC) to expand its project for awareness of the masses about on-farm water saving technologies by conducting more trainings for farmers. Government may advance subsidy worth Rs 50,000 to promote solar panel along-with drip irrigation paraphernalia and reverse electricity meter.

Chapter 1

Background:

Climate change implies valid concerns for the earth eco system. An important implication of the climate change is rise in the Earth temperature which may lead to water shortage for human and agriculture. It is also likely to increase demand for water for agriculture in Pakistan.

Pakistan is predominantly an agricultural economy. About 18.5% of its GDP and 38.5% of labor employment rely on agriculture (Government of Pakistan 2019). As such agriculture requires considerable quantity of water for irrigation. But in view of climatic changes water availability is declining day by day. According to FAO Pakistan is placed in severely water stressed countries because it has depleted many of its water reserves by pumping through tube wells (Molle, Shah, and Barker 2003). It is really important to manage water resources in country.

In Pakistan agriculture is mainly managed through surface and underground waters. Main sources of surface water for irrigation are Tarbela and Mangla Dams. But overtime no appreciable measures have been taken for increasing storage capacity of these reservoirs. To complement for irrigation water requirement considerable quantity of underground water is pumped through diesel and electricity tube wells. In 2017-18 there were 1.4 Million tube wells in Pakistan (Government of Pakistan 2019). Both diesel and electricity use for pumping underground water incurs considerable expenditure to farmers. Farmers in Pakistan generally are resource poor and can hardly afford tube well operation and maintenance costs.

Moreover, energy is considered as basic necessity of life. Almost, every sector of economy uses energy for running their operations ranging from industrial production to agriculture outputs. Access to energy is key development goal and challenge universally accepted under sustainable development goals. Developing countries like Pakistan face serious energy shortages which hinders their economic development and affect quality and standard of life. Consequently, people are now moving towards clean energy production like solar and wind energy.

Government and its support agencies try to reduce gap between supply and demand of electricity (Ansari and Unar 2012). Pakistan can produce 60,000 MW with hydro-Power electricity, however, currently producing much less than the capacity (Kamran 2018). By switching to solar technology farmers can have continuous supply of water at cheaper rates. Moreover, consumption of petrol and diesel negatively affect environment. Studies in Bangladesh showed that solar powered pumps have low operating and maintenance costs. The long life of solar technology made it popular among farmers in rural Bangladesh.

In this background it may be ascertained that Pakistan will face considerable hardships in future to manage for irrigation water requirements. Thus, futuristic view on one hand calls for evolving on-farm measures capable of minimizing irrigation water requirements (Hussain et al. (2015). And on the other reduce energy cost for pumping underground water through tube wells. This would improve water efficiency in agriculture. New 'state of the art' technologies suggest to operate tube wells with solar energy by installing solar panels. It is widely acknowledged that solar panels may considerably reduce energy cost.

For minimizing energy costs and crop water requirements, a number of High Efficiency Irrigation Systems (HEIs) have emerged overtime. Solar operated Drip irrigation is one of these. Unlike conventional method of 'flood irrigation', in drip irrigation water is directly provided to the roots of the plant which saves a lot of water.

1.1 Problem statement

Installation cost of High Efficiency Irrigation System (HEIs) is relatively higher than the conventional irrigation system (Adeel, Zafar; Schuster, Brigitte; Bigas 2008). This may result in farmers' lack of enthusiasm to adopt HIES technology even in a water scarce region (Memon et al. 2019). In farmers' cost and benefit breakdown, many important barriers to adaptation of HEIs can be hypothesized to have an impact on their technology adaption decision (Giampietro 1997). One of such determinants may be water scarcity and energy requirement for irrigation. So, it is grossly unknown what would be the farmers' adoption behaviours when offered a subsidized solar powered drip irrigation system having zero energy cost. Furthermore, what role their socioeconomic profile plays in their adoption decisions.

Furthermore, farmers' exposure to practical demonstration to such technologies may also be an important factor in their adoption decision (Khair et al. 2012) and (Yila and Thapa 2008). And either pilot projects aimed at demonstrating such technologies have any impact on changing their perceptions and thereby tendencies towards such technologies may also be an important insight from policy perspective of technology launching. Some of these factors were explored in some studies in Pakistan which may provide insight into farmers' behavior towards different agricultural and irrigation technologies such as adoption of tube wells (Khair et. al 2010), drip irrigation systems (Memon, Alizai, and Hussain 2019).

No study has been found directly embarking on factors determining farmers' willingness to adopt advance irrigation technology like solar panels for drip irrigation in rain-fed areas of Potohar region of Punjab in Pakistan. And what should be the government policy to promote drip irrigation system in the country? Furthermore, no study investigates what role exposure to practical demonstration of HEI systems plays in farmers' adoptation decisions.

1.2 Research objectives

The broader objective of the study is to investigate key determinants of farmer's willingness to adopt HEIs in Potohar region. Specific objectives are:

- To investigate among other variables, the role of water scarcity in farmers' decisions to adopt HEI systems.
- To explore if technology demonstration plays any role in changing farmers' willingness to adopt these technologies.

1.3 Significance of Study

This study determines the farmers' willingness to pay for the envisaged drip irrigation system and how this varies across farmers. Results from this study may assist government to determine policies regarding efficient use of ground water especially in river basins of Potohar region. National Agriculture Research Institute (NARC) and other organizations might use this study to determine impact of their projects in other rain-fed areas resembling the area selected for this research. How much these projects are useful in motivating farmer to adopt water efficient technologies in agriculture sector. Farmer's behaviours can be predicted regarding awareness and use of technologies. It also helps to identify the factors which are resisting technological adoption. Secondly, this study can contribute to the body of knowledge and deepening empirical literature on willingness to pay for drip irrigation systems in Potohar region.

1.4 Organization

First Chapter will cover introduction of the topic which includes background, significance of the study and objectives of the study. Chapter 2 will comprise literature review on three different themes and Chapter 3 will discuss about the data collection sampling technique, conceptual frame work, and methodology. Chapter 4 will elaborate descriptive statistics including regression results of econometric modelling for assessing farmers' willingness to pay for drip irrigation system. It also gives conclusion and suggestions proposed through this study

CHAPTER 2 THEMATIC LITERATURE REVIEW

This chapter provides us insight into factors affecting technological adoption. What are possible strategies to combat the water problems arising from climate change. Moreover, features and use of specific agriculture technologies are also discussed.

2.1 Adoption strategies to combat climate change in agriculture sector

It is a common observation that adverse climate has more impact on the environment and human systems as compared to the positive impact (IPCC, 2014). Specifically, in developing regions livelihood and agricultural production are more vulnerable to calamities and plant pests and diseases due to variations in climate (Adger, Neil, Huq Saleemul, Brown Katrina, Conway Declan, Hulme Mike 2003). Another report depicts that net cereal production in South Asia is said to deplete around 4-10% by the end of this century because of such variations in climate (Lal, 2011). An alarming situation rises for Pakistan in near future in which it has been supposed that productivity of most important staple crops like rice and wheat is going to face a declining trend by 6–8% and 16–19% against B2 and A2 scenarios mentioned in the special report on emission scenarios (SRES) respectively (IPCC 2014). Even worse scenario is that agricultural production will hold its position as a key source for livelihood for more than half population of South Asia. In such scenario better adaptation to new technologies is need of the hour to combat any worst event in climate variation.

To adopt new technologies in the agriculture sector, extensive efforts are to be made at diverse scales. For instance, taking into account regional and national levels, governments should put investment in the development of growing heat-resistant and drought-resistant varieties, conservative plans for water and soil and should introduce new crop insurance schemes. At the local level, farmers must be provided training ensuring provision of knowledge and information regarding climate variations and calamities and development of policies are needed to combat such events (Ignaciuk, D'Croz, and Islam 2015).

As far as policies related to adaptation are concerned, these require in-depth perceptions and keen observation for a better understanding of climate changes coupling with current adaptation pattern and its noteworthy key drivers. There had been no appreciable investigations over climate variations and its adaptations in Pakistan. Most of the studies over climate just deal with the impact assessments (Hanif et al. 2018) and a very minor overview on adaptations in the agriculture sector.

Extensive investigations are needed on the dynamics of human-environment in the agriculture sector essential for development of efficient adaptation policies related to agriculture in Pakistan (Abid et al. 2017).

2.2 Drip irrigation system

There has been a great debate and research on international level regarding diverse agricultural irrigation technologies depending on the investment capacity of this sub-sector of the economy. Many interesting facts have been gathered through such investigations, for example as (Kadyampakeni et al. 2015) recorded the water usage and yield obtained by the customary method of surface water irrigation that is a traditional mode of the agricultural sector. Going side by side (Benouniche et al. 2014) investigated drip irrigation impacts on the highlands of Eritrea. The conclusion of both investigations suggested that introducing new techniques maximizes the yield capacity and very less use of water has been recorded. Referring to the results of later studies, it was clearly shown that crop yield doubles more than half with the help of drip irrigation method. Though new technologies are expensive and are not welcomed by farmers at ease but it cannot only solve the problem of dissipate of water but can also prove to be an excellent support to the agriculture sector.

It has also been investigated that drip irrigation secures nutrients and minerals in the soil that are customarily taken away by flood irrigation method that has an adverse effect on yield of crops and more work and investments have to be put on lands to replenish the nutrients. Both (Benouniche et al. 2014) and (Kadyampakeni et al. 2015) also threw light over the difference of water usage by each technique. Drip irrigation method only targets the roots of the plants that helps in saving water. The investigator also highlighted the fact that drip irrigation is an efficient and more relevant method, as water is only supplied to the targets when and where it is needed in the desired quantity. An important point was discussed during studies about behavior of farmers in adopting such technologies. Previous studies depict that those farmers who are well informed about better management practices like climate variation resistance and timing of water demands for specific crops are more successful in getting high yield as compared to traditional farmers. Proper management includes use of drip irrigation system that minimizes extensive use of water, so it proves to be powerful water securing technology (Kavianand et al. 2016).

Comparing the surface and drip irrigation technology, a major difference relates to the usage of water by keeping good management practice constant. Explaining this point, excessive water loss is a common trend in surface irrigation system even though good practices are employed. Surface irrigation counts flooding of fields that take away nutrients and barren the soil. For such reasons, adopting drip irrigation method is beneficial, specifically when the system is well established and well managed and further when it is implemented in the greenhouses. For example in US (Enciso et al. 2015) linked the water use efficiency to flood irrigation. He found that 45% of all crops in the US are being irrigated by surface and sub-surface (seepage) system. He concluded that such methods require extensive water usage and a huge amount of water is being lost. Moreover, a huge amount of water is needed to maintain the water table, so low efficiency of water use is the outcome.

As mentioned earlier, continuous malpractice of flooding the fields for irrigation purposes, salinity has become a problem that results in retarded plant growth and overall yield. These traditional methods have water usage efficiency by around 33% or even lower (Ignaciuk et al. 2015). In the horticultural sector, overhead and sprinkler methods are used extensively including center pivot system, solid set system, portable and traveling gun methods, etc.

To get excellent results through implantation of drip irrigation technique, water and nutrient factors should be carefully observed. While these researchers tested the numerous irrigation strategies on the subject of yields, other investigations depict the water use efficiency of irrigation structures. The literature indicates that drip irrigation is much better and advanced than other irrigation strategies in terms of both productivity and water saving.

2.3 Factors Affecting Technology Adoption

Recognizing primary components which can impact the farmers' choice to embrace the innovation in agriculture is one of the key motivations behind the literature review. These advances can be useful in water management in agriculture and furthermore decrease the burden on nature. Results from an investigation in Baluchistan demonstrates that to adopt innovations which are productive in water use for agribusiness intention is just conceivable with the assistance of government backing and subsidy in the regions of Baluchistan that are facing excessive water shortage. The investigation also throws light for the development of new organizations which can persuade farmers to adopt new technologies in the agriculture sector.

If the farmer has a good production of crops, adaptation of technology becomes easy. Different factors are related to the production of crops that include the education level, temperature variation awareness and rainfall. In addition, technologies are helpful for farmers of any category to continue the farming activities even in crises.

To adopt new technology in farming also relates to the practice and behavior of the farmers. Farmers who are risk bearer and can manage the risk in future are more inclined to welcome innovations. Cost and price of production is another important pointer that affects the decision of farmer to couple a new technology in his production system (Vijayasarathy & Ashok 2015).

Climate factor as mentioned above also plays an important role in the agriculture sector. A study conducted in the northern area of Ghana suggests that farmer' pieces of training, awareness, and economic resources control the adaptive capacities to counter climate variations. Taking into account for capital and social institutions in such regards, these things seem to be less important (Dinar & Yaron 1992).

It has also been suggested by the literature that decent policies at large scale give helping hand to small farmers to counter variations in climate. Best policy strategy emphasizes analysis of every factor which affects vulnerability of farmers as well as considering incorporation of technology to meet local demands. Furthermore, it has also been noted that vulnerable governance, low schooling and pass over facts in marketplace reasons high opportunity cost in technological adaptation (Wright et al. 2014).

Farmers adopt those practices which they think are imperative and gainful for them. The study demonstrates that 90 percent of ranchers feel variation in climate and try to counter by few measures - the most common and prevalent trend is multi-cropping in place of mono-cropping, employing livestock to meet up the expenses, water, and soil conservation through multi - technologies (Belay et al. 2017).

Choice to adopt innovation in farming relies upon how much the farmer is confronting the risk for crop failure and variations in production in rain-fed regions. If the chance of risk in the above discussed region seems to be more there is aconteelikelihood, they will welcome the technology. Going forward - what sort of innovation they need to embrace and incorporate also values in the adaptation process (Ogada et al. 2010).

Investigations carried out in the sugarcane industry suggest that socio-economic factors play a valid role in the adaptation of technology. It is likewise concluded in the study that regions, where extension services are furnished the conversion rate, is higher (Peiris et al. 2012).

Laser leveling is taken into consideration as a way which may be helpful in the efficient use of water, however, farmers in India are pessimist and blank in use of this innovation because of much less cognizance regarding the benefits of laser leveling and information gap against farmers who use these technologies (Larson & Sekhri 2012)

Gender also performs a vital function in China concerning adopting of new technology. Results of the observation display that male farmers have greater adaptation rate than females who have an off-farm occupation, in addition to, serve as managers in the farms (Zhou et al. 2008).

Decision whether to depend on rainwater for agriculture relies upon various factors, forinstance, the level of family head, awareness, education and schooling, extent of labor, number of family members and outside help available from any authority (Siraj 2017).

Research Gap:

The literature review gives us insight into the facts that are helpful in adopting the new agriculture technologies and the factors that may affect in adopting new innovations. However, implications of preceding studies might not the same in our examine area. To find out the principal factors which help the adoption of solar operated drip irrigation system in our study area and advantages which farmer can drive via the use of this innovations is one of the most important motives of this study.

CHAPTER 3 RESEARCH METHODOLOGY

This chapter explains methodology used for achieving the research objectives. Moreover, rationale for choosing research method is also justified. Different aspects of data including, information of the respondents, sample size, sampling method and potential variables will be discussed in this Chapter.

3.1 Selection of the study area

To promote judicious use of irrigation water in agriculture National Agriculture Research Centre (NARC) – subsidiary organization of Pakistan Agriculture Research Council (PARC), has established a demonstration site near Chakri in district Rawalpindi. The site is developed under the Hi-AWARE (Himalayan Adaptation, Water and Resilience) Project.

The reason for selecting Ganj Union Council as study area is that it is located near Soan river. In this area people have limited amount of underground water as to compare to other areas of potohar region, where famers have no underground water for irrigation. Due to this reason Solar operated drip irrigation system is very suitable for efficient use of underground water for irrigation in this area.

The potohar region of Punjab cover about 7 Million Hectare of total cultivated land and are home to over 19 million people. This is equivalent to about 40% of the total area of the Pakistan Punjab. These areas, however, contribute less than 10% to total agricultural production and depend solely on the rainfall. However, Potohar plateau is capable to significantly contribute in the economy of Pakistan because more than 1200 kg/acre wheat is grown in the area which shows its potential to lower import load. M. A., & Majid, A. (2019). To disseminate water saving irrigation techniques technological interventions are introduced in three experimental plots at the above referred site.

These technological interventions include Mobile Solar System, Fixed Solar System and Replacement of Animal Driven Persian Wheel with small Solar Pumping System, Solar Heating System. Currently, we focus only on solar operated drip irrigation technology to study prospects for its dissemination among the farming community.

Reason for choosing this technology for this study is that most of the farmers have small land holdings. They cannot afford high cost technologies like 'Moving Solar System' and 'Weather Station' whose costs are Rs 16 and Rs 35 Lac respectively. According to experts from Zaraee Traqiati Bank (Mr. Farhat Karim Shamsi, EVP, ZTBL) farmers have low earnings from their crops as compared to their cost of production. Main factor increasing cost of production for farmers are fuel and energy expenses incurred in producing crops. So, it seems feasible for farmers to select among technological options which can minimize their energy expenditure to increase crops profitability. They may choose to adopt drip irrigation system whose cost is approximately Rs 1,50,000 according to Government of Punjab under the Program OFWM (On Farm Water Management Program) also provides 60% subsidy for purchasing these technologies.

3.2 Research question

In view of water scarcity in the selected area of research and high energy cost it seems pertinent to explore whether farmers are willing to adopt this technology? The present research purports to reply this question.

3.3 Important elements of research

Table shows the variables which were used in research to identify the attitude of farmers towards adoption of solar operated drip irrigation system.

3.3.1 Willingness to adopt for solar powered pump

Traditionally, farmers were using animal driven Persian wheels, electricity powered and diesel-powered pumps for irrigation purpose. However, cost of fuel and shortage of electricity hinders the supply of irrigation water for crops. Solar powered pumps with no operational cost may be an alternative for electricity and diesel-powered pumps to fulfil the water requirements of crops.

Cost of solar powered pump and panel is 150000 thousand rupees for total of 8 kanals Response of farmer was recoded as “1” if he was willing to adopt and “0” if he was not willing to adopt.

3.3.2 Willingness to adopt solar powered pumps with drip irrigation

The above-mentioned price of Rs 150000 for solar powered pump may be higher for farmers in rain fed areas. To assess motivation of farmers for solar powered pumps and drip irrigation system, we decrease the price to Rs 95000 in lieu of some subsidy from that government. Responses of farmers were recorded as “1” if they are willing to adopt and “0” if they are is not willing to adopt.

3.3.3 Willingness to adopt for solar powered pump, drip irrigation and reverse meter

In this package a free reverse meter has been offered to famers along with solar pump and drip irrigation system. This device adds conveyance of additional energy saved from solar panel to national electricity grid station. In reward WPADA will give 10000 Rupees to each farmer per annum.If farmer was willing to adopt this package, we coded his response as “1” and “0” otherwise.

3.4 Data collection procedures and sample size

For the present research a well-structured questionnaire was used to collect field data from randomly selected farmers. Data was gathered from the farmers by interview method. Before starting every interview, field enumerators ask for farmer’s approval to fill the form. They also explained ultimate purpose and use of the collected data. The data was collected through convenient sampling technique. convenient sampling is a type of non-probability sampling method where the sample is taken from a group of people easy to contact or to reach

Data were collected from four villages in a radius of 5 kilometres around the experimental sites of NARC (National Agriculture Research Centre). These villages are located near river Soan namely and are named; Saroba, Gung, Gahi and Sihal.

There are approximately 2600 farms in these villages. Specific reason to collect information from these villages is that all experimental sites are located in this area and the project staff had conducted farmer trainings and launched awareness campaigns in the area.

As mentioned above population size is about 2600 farms. If we take margin of error equal to10% and confidence level equal to 90% by using Z-score, our sample size approximates to 141. So, a sample of 141 farmers was selected.

3.5 Conceptual Framework

3.6 Econometric model

In case of binary dependent variable, ordinary least square and other classical linear models may lead regression results toward inconsistent estimators (Greene 2007). To avoid this issue maximum likelihood estimation is used. Although, using maximum likelihood method may also raise the problem of heteroscedasticity. However, using Logit or Probit with flexible function helps to overcome the heteroscedasticity problem (Wooldridge 2002).

Logit and Probit models can be used alternately, there is no strong justification to select one over the other. (Gujarati 2004) Although, logit model has ease of mathematical expressions. Logit model show its results in odds ratios which is easy to interpret as compare to Probit. Decision of adopting solar operated drip irrigation system largely depends on farmers' perception about new technology. If adopting a new technology increases his financial benefits as compare to old technology preference will be given to new technology assuming linear relationship between benefits and utility (Debertin 2012).

Energy is considered as one of the main component of farmers' irrigation costs. Solar operated drip irrigation system can be used as a cheap alternative with no operational cost. Secondly, research objective about role of energy in farmers' willingness to adopt can be fulfilled by estimating farmers' willingness to adopt for solar operated drip irrigation system and reverse meter. Furthermore, product three includes Reverse meter which provides farmers an opportunity to earn by selling extra electricity to WAPDA.

Finding key factors affecting the adoption of solar operated drip irrigation system is the main objective of research. Adoption is a categorical variable in this study. Farmer may adopt the technology or not? To accomplish above stated objective, we need farmers' feedback. Questionnaires were used to accumulate the response of farmers from study area. Due to nature of response for dependent variable (willingness to adopt solar operated drip irrigation system with and without reverse meter) from farmer, we can categorize dependent variable as binary or dichotomous.

3.6.1 Model specification

Following models were used in the study. These models have three products as independent variable along with set of independent variables.

Model 1

Probability to adopt for product 1 (Solar Powered pump) = $\beta 0 + \beta 1 (X_1) + \beta 2 (X_2) + \beta 3 (X3) + \beta 4 (X4) + \beta 5 (X5) + \beta 6 (X6) + \beta 7 (X7) + \beta 8 (X8) + \beta 9 (X9) + \beta 10 (X10) + \beta 11 (X11) + \beta 12 (X12) + \mu i$

X_1 = Education in number of years

X_2 = Age in number of years

X_3 = Status within family, whether the farmer is head of household or member.

X_4 = whether farmer knows purpose of Solar site or not

X_5 = Number of land parcels owned by farmers

X_6 = Total size of land owned farmer in (kanals)

X_7 = Tenure status, whether farmer is owner of land or Tenant

X_8 = Level of underground water

X_9 = Agriculture as primary economic activity of farmer

X_{10} = Family size of farmer

X_{11} = Farmer knows about existence of solar site in study area

X_{12} = Farmers Knowledge about how solar Pump works

Model 2

Willingness to adopt for product 2 (Solar powered pump with drip irrigation system) =. $\beta 0 + \beta 1 (X_1) + \beta 2 (X_2) + \beta 3 (X3) + \beta 4 (X4) + \beta 5 (X5) + \beta 6 (X6) + \beta 7 (X7) + \beta 8 (X8) + \beta 9 (X9) + \beta 10 (X10) + \beta 11 (X11) + \beta 12 (X12) + \mu i$

X_1 = Education in number of years

X_2 = Age in number of years

X_3 = Status within family, whether the farmer is head of household or member.

X_4 = whether farmer knows purpose of Solar site or not

X_5 = Number of land parcels owned by farmers

X_6 = Total size of land owned farmer in (kanal)

X_7 = Tenure status, whether farmer is owner of land or Tenant

X_8 = Level of underground water

X_9 = Agriculture as primary economic activity of farmer

X_{10} = Family size of farmer

X_{11} = Farmer knows about existence of solar site in study area

X_{12} = Farmers Knowledge about how solar Pump works

Model 3

Willingness to adopt for product 3 (Solar powered pumped with drip irrigation system and reverse meter) = $\beta 0 + \beta 1\ (X_1) + \beta 2\ (X_2) + \beta 3\ (X_3) + \beta 4\ (X_4) + \beta 5\ (X_5) + \beta 6\ (X_6) + \beta 7\ (X7) + \beta 8\ (X8) + \beta 9\ (X9) + \beta 10\ (X10) + \beta 11\ (X11) + \beta 12\ (X12) + \mu i$

X_1 = Education in number of years

X_2 = Age in number of years

X_3 = Status within family, whether the farmer is head of household or member.

X_4 = whether farmer knows Purpose of Solar site

X_5 = Number of land parcels owned by farmers

X_6 = Total size of land owned farmer in kanals

X_7 = Tenure status, whether farmer is owner of land or Tenant

X_8 = Level of underground water

X_9 = Agriculture as primary economic activity of farmer

X_{10} = Family size of farmer

X_{11} = Farmer knows about existence of solar site in study area

X_{12} = Farmers Knowledge about how solar Pump works

3.6.2 Independent variables used

Above independent variables were used to regress the dependent variable ‘Willingness to adopt solar panel for high efficiency irrigation systems.

Socio-economic characteristics:

Socio-economic characteristics contains the respondents’ personal information. It contains information about name of farmer, age, agriculture as primary economics activity, education, status within family and family size. Household personal circumstance play huge role in adoption of technology and these characteristics vary from farmer to farmer. It also provides us a guess about the social status of the family in local context.

Age:

Farmers were asked to report their age in number of years. Age may be positively linked to adoption because old farmers’ mostly have more agriculture experience. Moreover, they understand the needs of farm lands. They can oversight that how technology can be beneficial for them. (Shields, Rauniyar, and Goode 1993)

Education:

Education of farmers was recorded as number of years in school. Education increases the analytical capability and foresight of farmers regarding decision making. Moreover, the adoption rate is higher in educated farmers because they can understand the technological complexities and modify the technology according to their local needs, as a result we consider education have positive impact on adoption process. (Spencer et al. 1976)

Status within family:

This variable depicts the decision-making trends in study area. Installing a technology on farmland is solely decided by family head or family members. Both may have their role in decision making. This might be positively or negatively related to adoption of new technology. (Doss et al. 2011)

Farm Size:

It is well established hypothesis in literature that large farm size is positively related to adoption of new technologies because of their ability of bear risks. However, farm size may also be negatively related to adoption of technology, if technology available is not suitable to facilitate the large portions of farm land then the relationship between technology adoption and farm size may be negative. (Kumar, Engle, and Tucker 2018)

Tenure Status:

Ownership of land increases the capability of farmers to adopt new technologies. Farmers can acquire the long-term benefits by using technologies. There are no contractual bindings on farmer to use new technologies as in case of tenant. If farmer is tenant, he cannot get long term benefits of technology due to time bound contract with owner. Decision to adopt technologies involve complexities like permission and contractual bindings with owner (Dey et al. 2006). Land ownership is positively related to adoption of technologies.

Purpose of Solar Site:

Farmers' knowledge about why this solar site was established in study area can positively influence the decision to adopt the technology. If farmer knows the purpose of solar site his response was coded as 1 and 0 otherwise.

Agriculture as main source of Economic activity:

If agriculture is main source of income then it is obvious that farmer will be more concentrated towards improvement of agricultural outputs. Reliance on agriculture as main source of income is positively linked to adoption of new technologies that can help farmer to fulfil its water and energy needs.

Family size:

Family size may be positively or negatively related to adoption of technologies because it forces the farmer to adopt efficient technologies to increase its agricultural output and to fulfil his family needs. Similarly, big household size provide ease to farmer in performing day to day tasks. On the other hand, high family expenditures may restrict the farmer to adopt new technologies.

Existence of solar site:

Farmers were asked they have knowledge about the existence of government solar site in their constituency. Knowledge about existence of solar site can positively affect the adoption of new technology as compare to those who even don't know the existence of solar site in their area Demonstration effect is a critical factor in adoption of new technology.

Knowledge about working of solar pumps and drip irrigation:

Practical knowledge about how solar operated drip irrigation works positively impact the adoption decision. It gives farmer a closer look at technology and its use.

Level of underground water:

Level of underground water is an important factor for adoption of solar operated drip irrigation system. If the water level increases, people have sufficient water for irrigation purpose, as a result they may not be willing to adopt solar operated drip irrigation system. However, if they have less water for irrigation, they may adopt water efficient and energy saving technologies forirrigation.

No of land parcels:

Number of land parcels may have negative impact on the adoption of solar operated drip irrigation system. This is mainly due to land fragmentation; farmers cannot apply technological innovations on all land parcels this may cause technological inefficiency.

Table-1 List of variables

S.No	Variable	Variable type	Response/ code	Expected sign
1.	Education	Categorical	No. of year	(+)
2	Age	Continuous	No. of year	(+/-)
3	Status within family	Continuous	Head=1 member=2	(+/-)
4	Knowledge about purpose of solar panel site	Categorical	Yes=1 No=0	(+)
5	No. of land parcels	Continuous	No. of parcels	(+)
6	Farm size	Continuous	Farm size in kanal	(+)
7	Tenure status	Categorical	Yes=1 No=0	(+)
8	Level of underground water	Categorical	Yes=1 No=0	(-)
9	Information about existence of solar panel site in the area	Categorical	Yes=1 No=0	(+)
10	Family size	Continuous	Yes=1 No=0	(+/-)
11	Agriculture as being main source of income	Categorical	Yes=1 No=0	(+)
12	Knowledge of working of the solar panel	Categorical	Yes=1 No=0	(+)
13	Willingness to opt Product-1	Categorical	Yes=1 No=0	
14	Willingness to opt Product-2	Categorical	Yes=1 No=0	
1	Willingness to opt Product-3	Categorical	Yes=1 No=0	

Chapter 4 Results and discussion

This chapter purports to analyse the data collected from the field for this study. Findings of the data are consolidated for deriving important findings.

Basic objective of the said analysis is to identify factors which determine farmers' willingness to adopt solar pump operated drip irrigation system. The analytical findings are produced in the following paragraphs.

4.1 Characteristics of respondents and their farms

4.1.1 Characteristics of respondents

Majority of the respondents 39% were of age 49 & above. Second major age group (27%) were of 29-38 years. Of all respondents, 45% had only 9 years schooling while 38% had completed graduation. Farmer's status within family determines his discretion in household or agricultural decisions. It is known through the survey that 12% of the respondents were family members while 88% were heads of their families. Most of the respondents (52%) reported that they had more than eight members. Only 24% of respondents had 1-4 members. As most of the respondents depend on agriculture, large family size reflects pressure on agriculture. It is ascertained through the survey that main source of livelihood/ income is agriculture in the area. Among the sample respondents 60% derive their income from agriculture and livestock (agriculture and livestock should not be taken separate enterprises rather all of the land owners have some livestock as well, so this actually refers to agriculture). Second major source of income is combination of agriculture, livestock and government service. As the survey area lies closer to Rawalpindi some of the family members of the survey farmers got an opportunity to find jobs in Rawalpindi. Thus, they had versatile sources of income. This category constituted 25.5% of the total sample. Third most important source of income comprised income from agriculture, livestock and manual labour jobs.

About 7% of the farmers reported their incomes accruing from this combination. Those who were receiving foreign remittances in addition to their agricultural and livestock income were only 5%. Remaining 2.8% of the respondents fell into 'other' category which were just negligible.

4.1.2 Farm characteristics

Being focused on objectives of the study it seems pertinent to assess farmers' interest and motivation of its development. In this regard an important indicator is respondents' tenure status to their land. It is known from the survey that 95% of the respondents were owner cultivators and about 6% were tenants. The survey revealed that 62% of the owned land is cultivated, 28% is uncultivated. Remaining 7% could not be cultivated due to mountainous terrains. Majority of the farmers (68%) had farm size between 20 and 79 Kanals. However, a considerable proportion of farmers in the sample (15.56%) possessed above 80 Kanal which may be considered economic land holding.

4.2 Management of irrigation water

Land ownership is mostly in parcels. Most of the farmers have land in three parcels. About 74% of the respondents referred high cost of harvesting irrigation water from natural streams and extraction of underground water as the biggest water constraint. Most of the farmers (84%) access irrigation water from multiple sources. Multiple sources mean combination of rain water, Persian well, natural nullah and tube well water. Those who depended only on rain water were 11%. Describing satisfaction with the existing irrigation water arrangements 62% of respondents informed that underground water was shrinking, 32% viewed it constant and only 7% of said that water table was rising. Significant proportion of the respondents (75%) are not satisfied with availability of irrigation water while 25% looked satisfied.

4.3 Awareness about solar pump/ panel technology

All of the survey farmers knew about solar panel/ pump technology. About 70% of them knew purpose of this technology in agriculture. Out of them (76%) knew about establishment of solar demonstration site established by Pakistan Agriculture Research Council (PARC) at Chakri.

As electricity connection is necessary for installing solar pump and reverse meter at the farm, data was obtained about availability of electricity connection at the farm. Of the survey farmers 61% have electricity connection at their farms. About 28% of the interviewed farmers knew how to operate solar pump. Farmers are generally deficient of savings for investing in agriculture which they complement through borrowing. It is assumed that they may need to borrow for purchasing solar pump so their borrowing behavior was assessed in the survey. It is found that 89% of them have already borrowed for agriculture.

4.4 Implications of respondents' characteristics for drip irrigation

We are interested in whether there is any relationship between the farmers' decision for willing to pay for product 2(solar powered pump) and product 3(Reverse meter). There may be an association between decisions for adopting the product 2 and product 3 because farmer can get more benefit if he adopts both of these products in combination. To check this association, we conduct Pearson chi square test

consider product	3	
product 1 0	1	Total
0 22	30	52
1 0	89	89
Total 22	119	141
Pearson chi2(1) =	44.6151	Pr = 0.000

As the value of Pearson correlation is statistically significant. This shows that there is association between the decision of adopting two products. This means the decision of adopting these two products are interlinked.

Education has positive impact on adoption process (Spencer et al. 1976). As education level is relatively higher in the study area farmers may be likely to purchase solar pump technology for drip irrigation. Majority of respondents were between 39 and 48 years. This is dynamic age and people are more inclined to innovations.

By and large it is agreed in the literature that main contribution in agricultural decisions is made by family heads (Garner and de la O Campos 2014). Vast majority of the respondents are family heads. This recommends for farmers' willingness to adopt drip irrigation at their farms.

Major segment of the sample had larger family size who are dependent on agriculture. Farmers in the survey area primarily derive their livelihood from agriculture and livestock so legitimately they would be interested in promoting their agriculture.

As irrigation expenditure is high, they search for some cheaper irrigation arrangement like drip irrigation.

Lower intensity of land use may be an important indicator of need for drip irrigation. Under rain-fed conditions cropping intensity is low which motivates farmers for adoption of irrigation techniques like drip irrigation operated with solar energy.

Survey reveals 28% of agriculture land un-cultivated. Farmers mainly derive their livelihoods from agriculture so they are motivated to enhance their incomes from agriculture. A reasonable proportion of farmers have economic size of land holdings and due to scarcity of irrigation water this area cannot be used effectively. Any judicious means of irrigation is likely to attract farmers.

It was known during the survey that farmers generally use tractors for lifting water from the natural stream. As tractors are run with diesel and price of diesel is high so their irrigation expenditure increases. It requires to minimize the irrigation expenditure for which solar panel for drip irrigation may be a potential option.

According to sample findings almost every farmer has his land at least at three places which increases his irrigation expenditure. In view of high irrigation expenditure farmers seek cost minimizing techniques.

It may be argued that farmers in the survey area face shortage of irrigation water because primarily they all depend on rain or rein-fed means of irrigation. In case of less rains, water table falls, consequently water from all of the rain-fed sources decrease. The situation demands for some alternate arrangement of water for irrigation. Furthermore, water table is falling in the area which jeopardizes agriculture in future and the situation is suggestive of making judicious use of water for irrigation.

Respondents' dissatisfaction about availability of irrigation water at their farms lends to recommend for on-farm economic use of water.

Farmers in the survey area know about the existence of PARC drip irrigation demonstration site. They also know about purpose of the site that it is made to educate farmers how they can save water with drip irrigation system. This shows their interest in solar operated drip irrigation.

It is important here to state that this study primarily concerns with drip irrigation technique run with solar pump. While at the same time solar pump with reverse meter also conserves energy. The solar panel produces electricity which in case of surplus, may be sold to Water and Power Development Authority (WAPDA). This is done with the help of 'reverse meter' fixed with the solar pump. This can be an additional source of income for the farmers.

An important requirement of adoption of solar pump technology with reverse meter is availability of electricity connection on the farm. Surplus electricity produced by the solar pump

will be transmitted back to the national grid station. As reasonable no. of respondents have electricity connections at their farms it seems practical to suggest for promotion of solar pumps for drip irrigation.

PARC has conducted trainings for farmers on how to operate solar pumps, consequently some of the farmers have learnt to operate the technology.

It is widely accepted that farmers in general are short of finances for investing in agriculture. Government of Pakistan bridges this investment gap through lending from the Zarrai Tarraqiati Bank (ZTBL) and farmers in the study area are found frequently making use of these loans.
Thus survey results offer promising prospects for adoption of drip irrigation technology operated with the solar pump.

4.5 Regression results

Product-1 Solar power pump without drip irrigation equipment

Following Table- provide regression results for scenario-1 where only solar operated pump is offered to farmers for replacing the existing diesel/ electric pumps used for extracting underground or natural stream water for irrigation.

Of the survey respondents 63% agreed to adopt this technology. Average willingness to pay for this technology was Rs. 61000. We ask every farmer directly what amount then want to pay on average for product 1. By doing so we have data on amount every farmer want to pay for product 1. Then we calculate average amount for willingness to pay for product 1. While actual cost of the referred technology is Rs 1,50,000.

Farmers' willingness to adopt solar powered pump for extracting irrigation water regressed through the above logit model. As initial installation cost of the said technology is high it is necessary to study various determinants of farmers' willingness to adopt it.

Regression results show that education has positive effect on technological adoption but the variable is not found statistically significant. Moreover, as age of the farmer increases then he is more likely to adopt the solar powered pump. Age has positive and statistically significant effect on dependent variable.

This may be ascribed to length of experience in agriculture in adopting solar power pump technology.

Table-2 **Probability to adopt solar power pump without drip irrigation equipment**

Variable	Coefficient	Marginal effect	Z Value	P>[Z]
Education	.0184697	.0040134	.36	.722
Age	.0392101	.0085	2.26	.024
Status within family	-1.028508	-.2234933	-1.89	.059
Knowledge about purpose of solar site	.4527979	.1011147	.97	.330
No. of land parcels	.2877249	.0625222	2.30	.022
Farm size	-.0021587	-.0004691	-1.22	0.233
Tenure status	1.490194	.3554872	1.86	.063
Level of underground water table	-1.242261	-.2699414	-2.92	.003
Agriculture being main source of income	.4319274	.0979196	.70	.485
Family size	.0259708	.0056434	.39	.694
Information about existence of solar site	.3337825	.0701009	.63	.530
Knowledge of use of solar technology	2.044325	.2303318	2.29	.022

Theory suggests that more fragmentation of land, less will be farmer motivation for adopting technology like solar pump. But regression results indicate in the above table that more the no. of land parcels owned by a farmer, more is his willingness to go for solar power pump for drip irrigation. Reason is that land fragmentation provides the farmers an opportunity to fix the said technology on the piece of land where irrigation water is difficult to reach. This fact increases the motivation of farmer to adopt technology to irrigate those pieces of lands where they have issue of water scarcity.

Farmers have been asked to responded as, if level of underground water increase then coded as =1 and if level of underground water decreases then coded as =0. Coefficient for level of underground water is (-1.2422). Negative sign shows that as level of underground water increase (coded as =1) farmers are less likely to adopt solar powered pump and vice versa.

We do not interpret for what happen if level of underground water decreases because it is other side of same coin.

This is highly significant relationship. It is obvious that if level of underground water decreases there will be more expenditure to extract water as a result people will more likely to adopt the solar powered pump to reduce the extraction cost.

Knowledge of the respondent about use of solar technology for irrigation is significantly related with willingness to adopt solar pump technology. Coefficient value of independent variable shows (2.0443) that farmers are more likely to adopt the solar powered pump as their knowledge about how to use the solar pump increases.

Product-2 Solar pump along-with drip irrigation equipment

In product 2 we offered same solar powered pump at subsidized rate along-with drip irrigation equipment capable of irrigating farm of more than 8 kanal. Both technologies were offered for Rs 95000. Response of farmers for adoption of this combination of technology increased from 63% to 75%. Meaning that 75% of the respondents agreed to purchase and adopt this technology. Its main reason seems possibility to economize on water requirements and reduce irrigation water expenses.

Regression results indicate 7 variables significantly related with the dependent variable i.e. willingness to adopt for solar powered pump with drip irrigation system. Coefficient of independent variable age is positive and statistically significant. This means that as age increases then farmers are more likely to adopt the technology. Theoretically and practically it may be possible because with increase in age farming experience may also be increased.

Usually, increase in number of land parcels reduces the adoption of technology but in our case, technology is helpful to provide water to land parcels, which have less or no water for irrigation. Furthermore, drip irrigation system can irrigate more area of land with less quantity of water. Due to these reasons adoption for product increases for increase in number of land parcel.

Tenurial status play an important role in adoption of technology. As vast majority of respondents were land owners so relationship between land ownership and adoption of product 2 is found positive and statistically significant.

The reason is that owner cultivators plan for both short-term and long-term benefits. Coefficient value (2.275766) with positive sign shows that if one unit increase in independent variable i.e. (in other words, going from tenant to owner). We expect (2.275766) increase in log odds of dependent variable adoption of product 2.

Farmers have been asked to responded as, if level of underground water increase then coded as =1 and if level of underground water decreases then coded as =0. Coefficient for level of underground water is (-1.15334). Negative sign shows that as level of underground water increase (coded as =1) farmers are less likely to adopt solar powered pump and vice versa. It is obvious that if level of underground water increases there will be less expenditure to extract water as a result people will less likely to adopt the solar powered pump and vice versa.

Agriculture as being main source of income is statistically significant and positively related with dependent variable adoption of technology. It explains because agriculture is bread and butter for farmers in study area. If farmer's main source of income is agriculture then he is more likely to adopt the technology as compare to those whose main source of income is other than farming.

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Respondent's knowledge about purpose of solar site established by PARC is found positively related with willingness to adopt for solar pump with drip irrigation system and it is also significant relationship. Farmers who are more aware about use of technology are more likely to adopt technology as compare to those who are less aware.

Table-3 **Probability to adopt solar power pump with drip irrigation equipment**

Variable	**Coefficient**	**Marginal effect**	**Z Value**	**P>[Z]**
Education	.03366349	.0039809	.48	.631
Age	.0454022	.0053736	2.22	.026
Status within family	-.7371889	-08725	-1.09	0.277
Knowledge about purpose of solar site	1.097363	.1520679	2.09	.037
No. of land parcels	.3283733	.0388646	2.40	.013
Farm size	-.009557	-.0001131	-.53	.596
Tenure status	2.575766	.5227377	3.54	0.000
Level of underground water table	-1.1533473	.1365194	-2.39	.017
Agriculture being main source of income	1.432923	.2296465	2.22	.026
Family size	.0804537	.0095221	1.08	.279
Information about existence of solar site	.3929043	.0432363	.67	.501
Knowledge of use of solar technology	3.553201	.7032227	3.04	.002

Product-3 Solar pump along-with drip irrigation equipment and reverse electricity meter

In product-3 we offered farmers solar powered pump, drip irrigation system and reverse electricity meter. The number of farmers willing to adopt solar powered increased from 75% to 84%. Though education, age, knowledge about purpose of the solar panel, no of land parcels, size of farm, tenure status of respondent and others are positively related to willingness to adopt but these are not significantly related. Only farm size and change in water table are found significantly related with the dependent variable. Coefficient of farm size is (-.009557) shows that as farm size increases farmers are less likely to adopt the technology because the above-mentioned technology is suitable for approximately 8 kanal of land. High cost hinders the process of adoption.

Table-4 Probability to adopt solar power pump along-with drip irrigation equipment and reverse electricity meter

Variable	Coefficient	Marginal effect	Z Value	P>[Z]
Education	.0934094	.0073742	.85	.396
Age	.0309048	.0014967	1.52	.129
Status within family	-.7101916	-.1294642	-1.14	.255
Knowledge about purpose of solar site	.7676015	.1093317	1.37	.169
No. of land parcels	.2085912	.0230808	1.57	.116
Farm size	.0033628	.0007417	2.88	.004
Tenure status	2.089883	.447308	1.36	.175
Level of underground water table	-1.085366	-.0829155	-2.32	.020
Agriculture being main source of income	.8190949	.1390361	1.32	.187
Family size	.0343964	.0021512	.53	.599
Information about existence of solar site	1.026937	.0755779	1.52	.129
Knowledge of use of solar technology	.4725128	.071617	1.13	.260

4.6 Conclusion and recommendation

Agriculture in the area selected for this research directly or indirectly depends on rains. At most of the land crop are grown with rain water. However, underground water is also extracted with Persian wheels, diesel and electricity pumps and small size tube-well bores. But in view of uncertainty of rains sometime underground water is not recharged which due to which underground water shrinks and crops are jeopardized. In view of receding underground reservoirs experts frequently suggest to promote on-farm water saving technologies. Drip irrigation operated with solar pump is one of such technologies. The present research is an endeavor to study farmers' willingness to adopt this technology. As agricultural revenues are generally smaller in rain-fed areas farmers' enthusiasm to adopt such technologies is dubious.

To assess farmers' willingness to adopt drip irrigation technique operated with solar pump a sample of 141 farmers was drawn from Barani (rain-fed) area 60 Km away from Rawalpindi. Three packages of the solar pump and drip irrigation equipment were offered to farmers and their willingness was assessed with gradually declining price of the technology Education and age are found having positive affect on farmers' decision for adopting solar pump technology for drip irrigation. This is in conformity with the generally held belief that longer experience motivates for progressiveness. Instead of family heads, family members are found more inclined towards drip irrigation. Solar site established by PARC has played positive role in inducing farmers towards solar technologies. Land fragmentation strongly compels farmers to go for solar pump technology because farmers make investment in more productive parcels of land.

Land holding size directly associates with capacity of the solar powered drip irrigation system. Level of water table also plays significant role in selecting water saving drip irrigation technology.

Being specific to three different combinations of solar technology offers made to respondents, they preferred to purchase solar pump along-with drip irrigation paraphernalia at a subsidized cost of Rs 95,000 – because actual cost of the equipment is Rs 1,50,000. However, the largest majority of farmers are found more interested for purchasing solar powered pump

Along with drip irrigation and reverse electricity meter facility. It is ascertained through the survey that instead of solar powered pump technology for drip irrigation farmers are more inclined to use solar pumps for lifting water from the natural stream for irrigation. So solar pump may be tested for lifting water from the stream and make modification if necessary. Farmers also demand for subsidy for laying pipe lines to carry water from the stream. They also emphasized for more training from PARC for operating solar pump and other irrigation techniques. In view of the foregoing conclusion and feedback from the field it is suggested that PARC may expand its project for awareness of the masses about on-farm water saving technologies by conducting more trainings. Government may advance subsidy worth Rs 50,000 to promote solar panel along-with drip irrigation paraphernalia and reverse electricity meter.

References:

Abid, Muhammad, Grace Ngaruiya, Jürgen Scheffran, and Farhad Zulfiqar. 2017. "The Role of Social Networks in Agricultural Adaptation to Climate Change: Implications for Sustainable Agriculture in Pakistan." *Climate*.

Adeel, Zafar; Schuster, Brigitte; Bigas, Harriet. 2008. *What Makes Traditional Technologies Tick? A Review of Traditional Approaches for Water Management in Drylands*.

Adger, Neil, Huq Saleemul, Brown Katrina, Conway Declan, Hulme Mike. 2003. "Adaptation to Climate Change in the Developing World -- Adger et Al. 3 (3): 179 -- Progress in Development Studies." *Journals.Sagepub.Com*.

Amir, S., Saqib, Z., Khan, A., Khan, M. I., Khan, M. A., & Majid, A. (2019). Land cover mapping and crop phenology of Potohar region, Punjab, Pakistan. *Pakistan Journal of Agricultural Sciences*, *56*(1).

Ansari, Abdul Khalique and Imran Nazir Unar. 2012. "Sustainable Development Indicators for Energy in Pakistan." in *Energy, Environment and Sustainable Development*.

Dey, M. M., P. Kambewa, M. Prein, D. Jamu, F. J. Paraguas, D. E. Pemsl, and R. M. Briones. 2006. "Impact of Development and Dissemination of Integrated Aquaculture-Agriculture (IAA) Technologies in Malawi." *NAGA, WorldFish Center Quarterly*.

Doss, Cheryl, Terri Raney, Gustavo Anríquez, Andre Croppenstedt, Stefano Gerosa, Sarah Lowde, Jakob Skoet, and Ira Matuscke. 2011. "The Role of Women in Agriculture." *Food and Agriculture Organization of the United NAtions*.

Garner, Elizabeth and Ana Paula de la O Campos. 2014. *Identifying the "Family Farm": An Informal Dicussion of the Concepts and Definitions.*

Giampietro, Mario. 1997. "Socioeconomic Pressure, Demographic Pressure, Environmental Loading and Technological Changes in Agriculture." *Agriculture, Ecosystems and Environment.*

Government of Pakistan. 2019. "Pakistan Economic Survey 2018-19." *Pakistan Economic Survey, 2017-18*.

Greene, William H. 2007. *Econometric Analysis, Fifth Edition*.

Gujarati, Damodar N. 2004. *Basic Econometrics 4th Edition*.

Hanif, Zarka, Haider Ali, Ghulam Rasool, Asif Tanveer, and Bhagirath Singh Chauhan. 2018. "Genus Salsola: Its Benefits, Uses, Environmental Perspectives and Future Aspects - A Review." *Journal of Rangeland Science*.

Ignaciuk, Ada, Daniel D'Croz, and Shahnila Islam. 2015. "Better Drip than Flood: Reaping the Benefits of Efficient Irrigation." *EuroChoices*.

Kamran, Muhammad. 2018. "Current Status and Future Success of Renewable Energy in Pakistan." *Renewable and Sustainable Energy Reviews*.

Khair, Syed M., Shahbaz Mushtaq, Richard J. Culas, and Mohsin Hafeez. 2012. "Groundwater Markets under the Water Scarcity and Declining Watertable Conditions: The Upland Balochistan Region of Pakistan." *Agricultural Systems*.

Kumar, Ganesh, Carole Engle, and Craig Tucker. 2018. "Factors Driving Aquaculture Technology Adoption." *Journal of the World Aquaculture Society*.

Memon, Junaid Alam, Mehwish Qudoos Alizai, and Anwar Hussain. 2019. "Who Will Think Outside the Sink? Farmers' Willingness to Invest in Technologies for Groundwater Sustainability in Pakistan." Environment, *Development and Sustainability* (0123456789).

Molle, François, Tushaar Shah, and Randy Barker. 2003. "The Groundswell of Pumps: Multilevel Impacts of a Silent Revolution." *Water Management.*

Shields, M. L., G. P. Rauniyar, and F. M. Goode. 1993. "A Longitudinal Analysis of Factors Influencing Increased Technology Adoption in Swaziland, 1985-1991." *Journal of Developing Areas*.

Siraj, Nasir. 2017. "Determinants of Adoption of Rainwater Harvesting Technology: The Case of Gursum District, East Hararghe Zone, Ethiopia." *Social Sciences*.

Spencer, D. S. C., D. Byerlee, C. H. Gladwin, R. Perrin, and D. Winkelmann. 1976. "Small Farmers' Resources in Rural Development: Current Research and Application." *American Journal of Agricultural Economics*.

Uhunamure, S. E., N. S. Nethengwe, and D. Tinarwo. 2019. "Correlating the Factors Influencing Household Decisions on Adoption and Utilisation of Biogas Technology in South Africa." *Renewable and Sustainable Energy Reviews*.

Wooldridge, Jeffrey M. 2002. "Econometric Analysis of Cross Section and Panel Data." *Booksgooglecom*.

Yila, Othniel M. and Gopal B. Thapa. 2008. "Adoption of Agricultural Land Management Technologies by Smallholder Farmers in the Jos Plateau, Nigeria." *International Journal of Agricultural Sustainability*.

ANNEX-I Data Tables

Table-1 Respondents distribution by age

Age group	Frequency	%
19-28	16	11
29-38	39	27
39-48	32	23
49 & above	55	39
Total	**142**	**100%**

Table-2 Respondents distribution by level of education

Schooling (No. of year)	No. of respondents	%
0-4	22	15%
5-9	64	45%
10-14	54	38%
15-19	2	1%
Total	**142**	**100%**

Table-3 Respondents status within family

Status within family (1 for Family head 2 for family member)	No of respondents	%
1	124	88
2	17	12
Total	**141**	**100**

Table-4 Distribution of respondents according to their family size

Family size (No. of family members)	No. of respondents
1-4	24
5-8	65
9 or above	52
Total	**141**

Table-5 Different sources of income of respondents

Source of income	No. of respondents	Ranking in order of importance
i. Agriculture and livestock	81	59.6
ii. Agriculture, livestock and government service	36	25.5
iii. Agriculture, livestock and labour job	10	7.1
iv. Agriculture, livestock, govt. service and remittances	**7**	**5**
v. Other	**4**	**2.8**

Table-6 Respondents distribution according to their tenure status

Tenancy status	No. of respondents	%
Tenant	7	5.6
Owner	134	94.4
All	141	100

Table-7 Average use of farm land as reported by respondents

Type land	Average area (in kanal)	%
Cultivated	44.50	62
Un-cultivated	20.70	28
Cultivable waste	6.81	10
Total	71.72	100

Table-8 Farm size distribution of sample respondents

Farm size (in kanal)	No. of respondents	%
< 20	22	15.6
20-39	36	25.5
40-59	37	26.2
60-79	24	17.0
80-99	8	5.7
100 & above	14	9.9
All	141	100.0

Table-9 Reasons for not cultivating cultivable land as reported by Sample respondents

Reason	No. of response	%
Cost of harvesting irrigation water high	104	74.0
Water table decreased	5	3.5
No response	32	23.5
Total	141	100.0

Table-10 Statistics about land fragmentation

No. of observation	Mean	St. dev	Min	Max
141	2.94	2.109	1	9

Table-11 Different sources of irrigation water in order of their importance

Source of irrigation	No. of respondents	%
Rain water	16	11
Multiple source	119	84
Natural nullah	6	5
Total	141	100

Table-12 Overtime change in depth of underground water in the survey area

Water depth	No. of respondents	%
Increased	10	7
Decreased	92	61
Constant	49	32
Total	141	100

Table-13 Respondents' distribution regarding their satisfaction about availability of irrigation water

Response	No. of responses	%
Satisfied	36	25
Not satisfied	105	75
Total	**141**	**100**

Table-14 Respondents knowledge about solar panels

Response	No. of responses	%
Yes	141	100
No	0	0
Total	**141**	**100**

Table-15 Respondents information about existence of solar Panel site at Chakri

Response	No. of responses	%
Yes	107	76
No	34	24
Total	**141**	**100**

Table-16 Respondents' knowledge about purpose of Solar Panel for irrigation water

Response	No. of responses	%
Yes	99	70
No	42	30
Total	**141**	**100**

Table-17 Availability of electricity at the farm

Response	No. of responses	%
Yes	86	61
No	55	39
Total	**141**	**100**

Table-18 Respondents training in operating solar panels for irrigation

Response	No. of responses	%
Yes	39	28
No	102	72
Total	**141**	**100**

Table-19 Respondents' borrowing tendency for promotion of agriculture

Borrowing response	No. of responses	%
Yes	125	89
No	16	11
Total	**100**	**100**

ANNEX-II REGRESSION OUTPUT

```
Logistic regression                          Number of obs     =        141
                                             Wald chi2 (16)    =      44.11
                                             Prob > chi2       =     0.0002
Log pseudolikelihood =  -71.21165            Pseudo R2         =     0.2328
--------------------------------------------------------------------------------------------
                               |              Robust
        considerproduct1       |    Coef.   Std. Err.      Z    P>|z|      [95% Conf. Interval]
-------------------------------+------------------------------------------------------------
             Education |   .0184697    .051937     0.36   0.722    -.0833249    .1202643
                   Age |   .0392101   .0173371     2.26   0.024     .0052301    .0731901
  Status within family | -1.028508   .5440642    -1.89    0.059   -2.094854     .037838
     Purposeofsolarsite |   .4527979   .4650938    0.97   0.330   -.4587692    1.364365
      Nooflandparcels   | .2877249     .1253517    2.30   0.022     .0420401    .5334097
      SizeoffarmKanals |  -.0021586   .0017718    -1.22   0.223    -.0056313    .0013142
      Ownership of land |    1.490194   .8004401     1.86  0.063    -.0786396   3.059028
Levelofundergroundwater|  -1.242261   .4249228    -2.92   0.003    -2.075094   -.4094275
   Agriasprimaryeconomic |   .4319274   .6192121    0.70   0.485     -.781706    1.645561
            Family size |   .0259708   .0659818    0.39   0.694    -.1033512    .1552929
    Exiatenceofsoalrsite |   .3337825   .5309235    0.63   0.530    -.7068084    1.374373
  Kowledgeaboutsolartech|   2.044325   .8911709    2.29   0.022     .2976619    3.790988
                  _cons |  -4.899067   2.264555    -2.16   0.031    -9.337514   -.4606204
--------------------------------------------------------------------------------------------
```

This output shows variables significance at different levels of confidence for instance 99, 95, and 90 Percent.

```
------------------------------------------
     Variable |    active
  -------------+----------------
howsolarpu~s | 1.0600064**
   Education | .01846971
         Age | .03921013*
Statuswith~y | -1.0285081
Satisfacti~m |  .13864843
Purposeofs~e |   .4527979
Nooflandpa~s  |    .28772488*
Sizeoffarm~s | -.00215858
tenurialst~t |     1.4901941
 depthofund~r | -1.2422609**
agricultur~g    |    .43192741
Family size | .02597083
Exiatenceo~e   |   .33378254
knowledgeably | 2.0443248*
        _cons | -4.8990673* Legend:
------------------------------------
* p<.05; ** p<.01; *** p<.001
```

Product two contains solar pump, solar panel and drip irrigation.

Logistic regression — Number of obs = 141; Wald chi2(16) = 41.17; Prob > chi2 = 0.0005; Log pseudolikelihood = -54.609598; Pseudo R2 = 0.2989

considerproduct2	Coef.	Robust Std. Err.	z	P>|z|	[95% Conf.	Interval]
Education	.0336349	.0699903	0.48	0.631	-.1035435	.1708134
Age	.0454022	.0204252	2.22	0.026	.0053697	.0854348
Statuswithinfamily	-.7371889	.6786099	-1.09	0.277	-2.06724	.592862
Satiswithirrigation	-.0211304	1.027551	-0.02	0.984	-2.035093	1.992832
Purposeofsolarsite	1.097363	.5258894	2.09	0.037	.0666388	2.128087
Nooflandparcels	.3283733	.1320987	2.49	0.013	.0694646	.5872821
SizeoffarmKanals	-.0009557	.0018018	-0.53	0.596	-.0044872	.0025758
tenurialstatus	2.575766	.7280698	3.54	0.000	1.148775	4.002757
depthundergroundwater	-1.153473	.4826434	-2.39	0.017	-2.099437	-.2075097
agricultureprimaryeconomic	**1.432923**	**.6457718**	**2.22**	**0.026**	**.1672332**	**2.698612**
Familysize	.0804537	.0743346	1.08	0.279	-.0652395	.2261469
Loanforagrisig	-4.002443	1.292562	-3.10	0.002	-6.535817	-1.469069
Exiatenceofsoalrsite	.3929043	.5832977	0.67	0.501	-.7503381	1.536147
Kowledgsolartechnology	3.553201	1.169801	3.04	0.002	1.260433	5.845969
Howsolarpumpworks	.5680618	.3930357	1.45	0.148	-.202274	1.338398
_cons	-4.029177	2.687209	-1.50	0.134	-9.296009	1.237655

Estimates table, star (.05 .01 .001)

Variable	active
Education	.03363492
Age	.04540223*
Statuswith~y	-.73718894
satisfacti~m	-.02113039
Purposeofs~e	1.0973631*
Nooflandpa~s	.32837331*
Sizeoffarm~s	-.00095569
Tenurialst~t	2.5757659***
levelofund~r	-1.1534734*
Agricultur~g	1.4329227*
Familysize	.08045367
electricit~n	1108414
loanforagr~g	-4.002443**
exiatenceo~e	.3929043
kowledgeab~y	3.5532006**
howsolarpu~s	.56806184
_cons	-4.0291768

legend: * p<.05; * p<.01; *** p<.001

Product three contains solar pump, solar panel, drip irrigation and reverse meter

Loan for agriculture has been omitted from model due to multicollinearity

Logistic regression	Number of obs = 141
	Wald chi2 (15) = 31.71
	Prob > chi2 = 0.0070
Log pseudolikelihood = -50.922917	Pseudo R2 = 0.1660

considerprodcut3	Coef.	Robust Std. Err.	Z	P>|z|	[95% Conf. Interval]	
Education	.0934094	.1099799	0.85	0.396	-.1221472	.308966
Age	.0309048	.0203804	1.52	0.129	-.00904	.0708495
Statuswithinfamily	-.7101916	.6236412	1.14	0.255	-1.932506	.5121226
satisfactionirrsystem	.4491226	1.054202	0.43	0.670	-1.617075	2.515321
purposeofsolarsite	.7676015	.5586959	1.37	0.169	-.3274223	1.862625
nooflandparcels	.2085912	.13286	1.57	0.116	-.0518097	.4689921
SizeoffarmKanals	.0033628	.0024802	1.36	0.175	-.0014982	.0082239
tenurialstatus	2.089883	.7251592	2.88	0.004	.668597	3.511169
depthundergroundwater	-1.085366	.4677093	-2.32	0.020	-2.002059	-.1686726
Agriculture	.8190949	.620874	1.32	0.187	-.3977958	2.035986
Familysize	.0343964	.0654855	0.53	0.599	-.0939528	.1627456
elect connection	-.4482444	.5902376	-0.76	0.448	-1.605089	.7085999
existenceofsoalsite	1.026937	.6770453	1.52	0.129	-.3000476	2.353921
kowledgeaboutsolar	.1575141	.9438976	0.17	0.867	-1.692491	2.007519
howsolarpumpworks	.4725128	.4194276	1.13	0.260	-.3495503	1.294576
_cons	-2.560495	2.74786	-0.93	0.351	-7.946202	2.825213

ANNEX-III QUESTIONNAIRE

Assessment of Farmer Willingness To Adopt Solar Operated Drip Irrigation System

Introduction for respondents:

I am collecting these data for an MPhil thesis which purports to measure farmers' willingness to adopt Solar Operated Drip Irrigation System

Name of interviewer		
Date		
Signature of enumerator	Signature of Supervisor	Signature of Field Manager

A. Respondent information

Name: ------------------------------ Gender: Male-------- Female-------

Age: --------- (Years) Education ----------- (Years of schooling) Name of village:----------

Status within family: Head ---------- Member --------

Q1. Do you know that government ***solar panel demonstration*** site exists in your area?

Yes...................... No ....

Q.2 **If 'Yes'** above, do you know what is the ***purpose of establishing Chakri*** *d*emonstration site?

Yes ------------- No -------------

Q. 3 **If 'Yes' above**, do you know ***how water saving technologies*** are used there?

Information about farm and family

Q. 4 What **is size of your farm**?-------------------------------------Acre

Q. 5 What is your **tenurial status**?

Owner cultivator ------------- Tenant -------------------Owner cum tenant

Q. 6 What is your **family size**?

No. of adults ------------- No. of children --------------

Q. 7 Which of the following ***occupations*** your adult family members have?

Occupation	Adults engaged (No)
Agriculture	
Labourer	
Livestock rearing	
Govt. service	
Any other	

Q. 8 What is ***educational status*** **of your family**?

Education level	No. of persons
Illiterate	
Matric	
Intermediate	
Bachelor	
Masters	

Q. 9 Which of the following make your ***annual family income***? Please ***rank in descending order*** of importance?

Source of income	**Rank from 1-6**	**Source of income**	**Rank from 1-6**
Agriculture		Govt. service	
Labour job		Remittances	
Livestock		Any other	

Q. 10 Use of ***farm land***

Type of land	Area (Kanal)	Reason for not cultivating land
- Cultivated		
- Uncultivated		
- Cultivable		- Water shortage - Lack of money
		- Lack of money - Low profit in agri.
		- Shortage of labour -All of above

Q. 11 Which of the following ***sources of irrigation*** are used at your farm? Please **rank in descending order of importance**:

<u>Source Rank</u>

1. With tube well - 2. With rain water - 3. With solar panel -
4. By lifting water from the nullah -
5. Persian well -
6. Any other (specify) -

Q. 12 What has overtime happened to ***Level of underground water*** at your farm?

Increased ----------------- Decreased --------------------

Q. 13 Are you satisfied with ***water availability*** at your farm?

Yes ……………………………   No ----------------------------

If 'No' above, give reason:

Reason
Rains reduced
Underground water decreasing
Modern water extraction technology not available
Cost of harvesting underground water high
All of the above

Q. 14 How *much area* was sown with following crops during last year?

Crop	Area sown (Kanal)	Yield obtained (40 Kg/ Kanal)
Wheat		
Maize		
Vegetables		
Others		

Q. 15 How many ploughings and planking you gave to following crops grown during last year

Crop	Ploughing	Planking	Hoeing
Wheat	……………………No./ Kanal………………….		
Maize			
Vegetables			
Any other crop			

Q. 16 How much fertilizer, pesticide and irrigation was applied to different crops grown during last year

Source	**Irrigation (No)**	**Fertilizer (Bag)**	**Sprays (No)**
	……………………………………….per Kanal……………………………………..		
Wheat			
Maize			
Vegetables			
Any other			

Q. 17 Irrigation time required and rate of water by source of irrigation during last crop year

Source	**Time/irrigation/Kanal (In Hour)**	**Rate/hour (in Rs)**
WHEAT		
Purchased tube well water		
Solar Panel		
Persian well		
MAIZE		
Rented tube well		
Solar Panel		
Persian well		

Q. 18 Irrigation time required and rate of water by source of irrigation during last crop year

Source	Time/irrigation/Kanal (Hour)	Rate/hour (Rs)
VEGETABLES		
Rented tube well water		
Solar Panel		
Persian well		
ANYOTHER (specify)		
Rented tube well water		
Solar Panel		
Persian well		

Q. 19 What is the position of electricity supply at you farm? (Tick mark)

Connection availability		**Regularity in supply**		
Yes	No	Continuous flow	Occasional shut down	Frequent shut down

Note: Data about overtime changes in temperature and annual precipitation may be obtained from the Met Office, Islamabad.

Q. 20 Do you know about the ***water pump*** which operates with solar energy?

Yes................................ No ....

Q. 21 If 'Yes', do you know how ***solar water pump*** works?

Don't know -------- Know somewhat --------- Knows very well--------
Already have installed my own solar pump --------

Q. 22 Would you like to borrow ***solar water pump*** for irrigating your farm?

Yes...................... No ....

The following scenarios are set out hypothetically and should not be interpreted as expectations of future conditions or upcoming government policies. The purpose of these scenarios is to understand the obstacles farmers face when taking different investment decisions about their farms.

1. In doing so, I shall demonstrate a product through poster and ask you certain questions related to it.
2. Please answer the questions based on what you anticipate doing if found yourself in the following situation in reality.

HYPOTHETICAL SCENARIOS

Following hypothetical scenarios are set out to know obstacles which influence farmers' investment decisions about their farms.

Hypothetical Scenario (Product-1)

Before asking Q. 23, the surveyor would explain ***Product-1*** to the respondent.

Q. 23 Would you consider buying the solar system that I just introduced to you in PKR 150,000?

Yes______________ No ____________

What maximum price you would be willing to pay to obtain the system? ___________

If 'No' above, Please give reasons.

a.

b.

c.

d.

Hypothetical Scenario (Product-2)
Before asking Q. 24, explain ***Product-2*** to the respondent with the help of a Poster.

Suppose government decides to provide solar system along with 'Drip' irrigation system on subsidy at Rs 95,000/ acre while actual price of the said systems in market is Rs 3,12,500.

Q. 24 Are you willing to purchase Product-2 at the said subsidized rate?

Yes ------------ No -------------

If 'No' above, Please give reasons.

a.

b.

c.

d.

Hypothetical Scenario (Product-3)
Before asking Q. 25, explain Scenario-3 to the respondent as below: Suppose government attach ***reverse metering facility*** with ***Product-2*** to enable farmers to sell their surplus solar energy back to the national grid station and earn additional income worth Rs. 10,000/ acre/ annum.

Q. 25 Would you like to purchase Product-2?

Yes__________ No __________

If 'Yes' above, at what price----------------Rs

If 'No' to Q. 25, give reasons why not willing to purchase?

a.

b.

c.

d.

Q. 26 Please state if something important has been missed.

a.

b.

c.

d.

Thank you for participating in the survey.