Research Article

Identification of Influencing Factors for Optimal Adoptability of High Efficiency Irrigation System (HEIS) in Punjab, Pakistan

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Abstract | High efficiency irrigations systems (HEIS) are considered the most efficient technologies to apply water to the crops because these technologies use less irrigation water and produce more yield as compared to conventional irrigation methods. However, the most burning issue of these systems is their non-adoptability or low adoptability by the farming communities, despite their proven benefits. It was highly desirable to analyze and evaluate certain parameters which keep systems functional as well as ensure adoptability of these systems at farmer's fields. A total of 30 sites were selected randomly in Punjab province of Pakistan where HEIS were installed. Twelve parameters were selected based on the survey conducted that influenced the HEIS functionality as well as adoptability. The selected parameters were also ranked based on their influencing order such as net economic return, deployment of operator, literacy status, farming mode, pumping mechanism, backup support, system type, energy source, tenancy status, farm location, groundwater quality and farming experience because these parameters have significance coefficient values of 0.471, 0.342, 0.169, 0.163, 0.142, 0.110, 0.076,0.071,0.046, -0.037, -0.116, -0.212, respectively. The analysis indicated that parameters such as farm location near the head reach, groundwater quality and long farming experience showed negative impact on adoptability of HEIS in the study area. It was also observed that high economic returns, deployment of operator, farmer's training and presence of farmer at his farm are the gateway towards the success of these systems. The present study provides guidelines for the policy makers as well as farmers for sustainability of installed HEIS and up-scaling of these water saving techniques for the welfare of mankind.

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Introduction

Agriculture has major share in Pakistan's economy (19.8 % of GDP) and it accounts for 42.3 % of the country's labor force (PES, 2016). Agronomic sector mainly depends on country's crop productions however the crop productivity per unit of water is declining (Tariq, 2005; Ahmed, 2007; Jayakumar et al., 2015). Average negative growth of 6.25 % was reported for the fiscal year of 2015-16 due to various reasons including hostile climate and declining available water (Briscoe and Qamar, 2006; Khan, 2006; Wasti, 2016). The water availability during the Rabi season of 2015-16 was reported to be nearly 10 % less than its typical level. On the other hand, water demand has increased at an alarming rate of 1.5 MAF per year to accelerate the crop productivity. Consequently, the water shortage is expected to reach 31 % by 2025 (Ahsen, 2018). The irrigation water is also considered as one of the major contributor in crop productivity enhancement and poverty alleviation (Huang et al., 2006; Dinye, 2013; Mongat et al., 2015). However, there is a strong need to adopt high efficiency irrigation systems (HEIS) as water saving techniques. HEIS such as drip and sprinkler can be tried and tested for enhancing water and fertilizer application efficiency. It has been reported in the preceding literature that HEIS can increase the crop yield up to 27 % and water saving can be achieved upto 68% as compared to conventional irrigation methods (Latif et al., 2016). Water saving techniques of kind can also help to alleviate poverty in developing countries like Pakistan (Namara et al., 2007; Shakoor et al., 2012; Venot et al., 2014; Asif et al., 2016; Yao et al., 2017).

Recently, Pakistan has realized the necessity of HEIS, as it is evident from the fact that a large-scale project namely PIPIP (Punjab Irrigated-agriculture Productivity Improvement Project) has been commenced for implementation of drip and sprinkler irrigation systems over an area of about 0.05 million hectares (120,000 acres) throughout the Punjab province (DGA, 2011). Unfortunately, rate of adoption for HEIS in Pakistan is insignificant as compared to other countries. In USA and Australia, almost 50 % of the irrigated land receives water through HEIS, and even in a developing country like India 2 million hectares' arable land is being irrigated by either drip or sprinkler irrigation as compared to a trivial figure of 0.008 million hectares in Pakistan (NMMI, 2010; NPSI, 2013; Perlman, 2014). However, high capital cost, rising prices, energy crisis, lack of technical knowledge and awareness about HEIS have been identified as major challenges in adoption and sustenance of HEIS. Furthermore, the limited capacity of sale and service companies (SSCs) for provision of after-installation services may aggravate the operational costs of HEIS (DGA, 2014; PMU, 2016).

Another major factor negatively effecting the adoption is the abandoning or non-functioning of drip and sprinkler irrigation systems after their installation. The non-functioning of drip and sprinkler systems creates negative perception among the farming' community about this modern technology. It was also a prominent threat towards the progress and sustenance of any effort made to diffuse the modern technologies into Pakistan's agriculture. With that being mentioned, a diagnostic study to identify the ground realities related to adoption and operation of HEIS through pointing out the major factors influencing the sustained functioning of a highly efficient irrigation system is the need of the time. A study of the aforementioned type will potentially not only increase the pace of adoption of HEIS, but it will also help farmers run their system for longer periods of time (Kulecho and Weatherhead, 2005). The present study is believed to achieve above mentioned objectives and benefits because availability of more and better knowledge about a modern technology eases its path to adoption (Hall and Khan, 2003).

A preliminary assay of the status of HEIS installed at various locations in Punjab, can lead to a conclusion that the envisaged objectives of setting up of these systems have not been fully realized. Many of the installed HEIS have been either abandoned or non-functional. Reasons for this failure are ambiguous yet as all the stakeholders including farmers, implementation agencies and managerial organizations are found blaming one another. Furthermore, farmers seem to adopt modern irrigation systems at a snail's pace. This study aims to investigate the full picture behind the unsatisfactory success of already installed HEIS in a comprehensive and methodological way by defining the major factors concerning the fate of HEIS to aid planning, implementation and most importantly adoption of HEIS. Keeping in mind the deterministic and reductionist nature of this study, formulated methodology mainly comprises of three parts i.e. selection of sites, development of a comprehensive questionnaire for data collection and in turn defining the major factors concerning the adoption of HEIS.

Materials and Methods

Study area

Site selection plays a vital role to achieve the envisaged objectives of the research study. A well-defined sampling approach was adopted for selection of the sample sites which in turn will be a true representative of the entire study area. A total thirty (30) sites were selected from the installed/commissioned HEIS in Province of Punjab, Pakistan (Figure 1). These sites were selected on basis of established criteria i.e. areal distribution, crops, water source, pumping mechanism, power source and type of HEIS to ensure a real representative sample data and to achieve the objectives of the study.

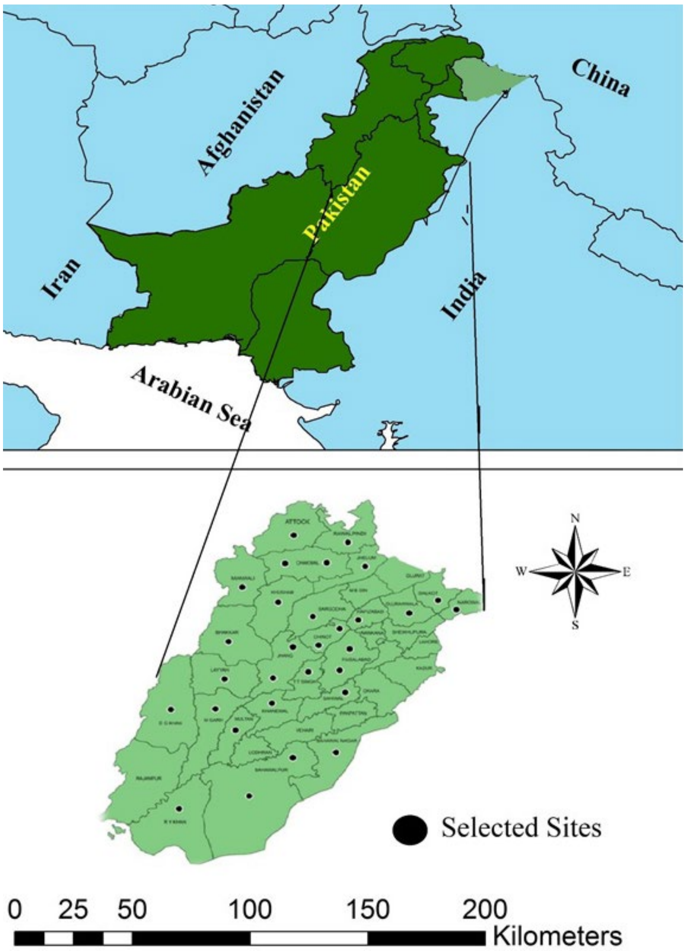

Figure 1: *Location of selected HEIS sites dispersed across all Punjab.*

Data Collection

The data was collected for the present research study mainly through randomly selected famers' interview and discussion from March to October, 2016. For this purpose, a comprehensive questionnaire was developed covering major aspects of farming techniques, crop production aspects, and economic returns. The questionnaire was designed and prepared in a very comprehensive manner to investigate the ground realities with facts and figures pertaining to HEIS and farmer's perceptions regarding modern HEIS. The salient features and sections of questionnaire are described below.

Farmer demographics: Farmer's personal features were collected through discussion with the selected respondent. This section of questionnaire comprises of general information about the farmer. It includes farmer name, location, farmers experience, farmers' qualification, farmers land holding, location of farm, farming practice, tenancy status. It was presumed that farmer demographics would keep the installed HEIS in operational condition for longer periods.

Farm characteristics: This section includes the information about the farmer's field regarding cultivable area, topography of the farm, cropping patterns, major crops sown during Rabi and Kharif seasons and land leveling status of farm, soil type, groundwater (GW) quality, available water resources (canal water or groundwater), HEIS type (Drip and Sprinkler), crop type under HEIS, Age of HEIS, mode of power (electricity or diesel engine), pumping mechanism (single pumping, double pumping, direct pumping). Important information pertaining to these parameters were collected through interactive discussion with the selected respondents. This section of the questionnaire is very important as it would provide answers to many presumptions related to sustainability of installed HEIS.

Data Analysis: Economic analysis was done to evaluate the performance of conventional and modern high efficiency irrigation in terms of cost and benefit of growing crops, as it directly influences the profitability of a farmer and in turn sustainability of a system. HEIS with positive net benefit were presumed to be sustainable for longer periods of time. Net economic benefit for HEIS was determined using following Equation 1 (Bakhsh et al., 2015) and further correlated with functioning status of the site i.e., functional or non-functional.

$$\boldsymbol{NB = (EV_{HEIS} - PC_{HEIS}) - (EV_{CI} - PC_{CI}) \quad \ldots.(1)}$$

Where;

NB = Net benefit of using HEIS over conventional irrigation (CI) methods; EV_{HEIS} = Economic value of crop yield under HEIS; PC_{HEIS} = Production cost under HEIS; EV_{CI} = Economic value of crop yield under CI; PC_{CI} = Production cost under CI; Identification of Influencing Parameters for HEIS functionality.

Statistical Package of Social Sciences (SPSS), a computer-based software capable of handling large amount of complex data entry and analysis through graphs and tables was used for defining the major

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factors concerning the fate of HEIS. SPSS is basically used to determine the relative contribution of various factors in the sustenance of HEIS sites (in terms of functioning status of sites). The SPSS software was used to find influencing factor using the collected data such as farmers' literacy, farming experience, tenancy status/farmer presence, water quality, type of HEIS, water and power source, operation mechanism, provision of service after installation, and deployment of operator are considered as major factors to keep a HEIS in a working condition. Based on collected facts and figures from selected sites, influence of various important factors pertaining to farm characteristics, HEIS installed and economic analysis, on functioning status of HEIS was analyzed. Accordingly, working status of a HEIS site was expressed as a function of farmer's literacy, farming experience, farm location, tenancy status, farming mode, power source, pumping mechanism, net benefit of HEIS over conventional methods of irrigation etc. Following Equation 2 is a mathematical representation of site functioning status (Machibya et al., 2004).

$$SF = f\,(LS, FE, TS, FL, FM, GW, ST, PM, PS, OD, BS, NB) \quad \ldots..(2)$$

Where;
SF = Site functioning status i.e., working or non-working condition; LS = Literacy status of farmer; FE = Farming experience of farmer; TS = Tenancy status of farm i.e., rented/owned; FL = Farm location with respect to the watercourse reach; FM = Farming mode i.e., self-managed or by manager; GW = Groundwater quality; ST = System type of HEIS i.e., drip or sprinkler irrigation system; PM = Pumping mechanism i.e., single, double or direct; PS = Power source i.e., electric or diesel; OD = Operator deployment for operation of HEIS; BS = Backup service provision post-installation of HEIS; NB = Net benefit of HEIS over conventional irrigation systems.

Through SPSS software, all the parameters were converted to either 1 or 0 to realistically evaluate their contribution to the functioning status of HEIS. Table 1 depicts the conversion of important parameters to binary digits.

Results and Discussion

Data collected through questionnaire was processed and analyzed to synthesize a clear concept about the influence of various kinds of factors on functioning status of HEIS on selected sites. The results indicated that threshold value for the status of experienced farmer was set at 10 years, according to which 77 % of the farmers in the study area were found to be experienced as demonstrated by the Figure 2a. Turning now to literacy status, 63 % of the farmers had education of 14 or more years as detailed in Figure 2b. Facts about the literacy status and farming experience in the study area seem to envisage a positive relation between education and success of HEIS. However, the reliable conclusions can only be drawn after detailed analysis. Moving on from literacy status, results further showed that sites where HEIS have been installed mainly fall in the category of farmers' land holdings of more than 10 hectares (Figure 2c). It was found that 13 out of 30 sites were installed on farms located in the non-canal command areas while remaining sites were situated in the command area of canals which were located on head, and tail reaches of watercourses in almost equal proportion (Figure 2d). Data about the tenancy status and farming mode was also collected through the questionnaire. The analysis showed that 67 % of the famers were taking care of farming operations themselves and others 33 % were relying on their manager as illustrated in Figure 2e. Similarly, all the farms with installed HEIS -were owned by the farmers except one (Figure 2f).

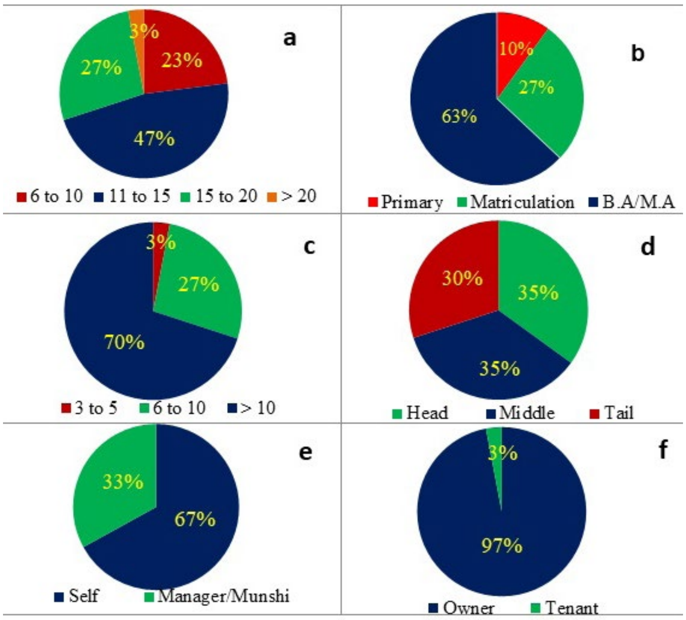

Figure 2: *Distribution of farmer demographics by HEIS adoption (a = Farmers experience; b = Farmers qualification; c = Farmers land holding; d = Location of farm; e = Farming practice; f = Tenancy status).*

Analysis of another major factor governing the selection of type of HEIS and agronomic practices i.e., soil type of farms where HEIS was installed revealed that 63 % sites had loamy soils while other sites had clayey and sandy soils (Figure 3a). Along with soil type, groundwater quality is also an important parameter especially when canal water is not available; groundwater of 22 sites (73 %) was identified as fit to use for irrigation while other sites had unfit or marginally fit groundwater in terms of salinity as groundwater was used on 40 % sites for irrigation (Figure 3b and 3c). As mentioned before, 80 % of the sites had drip irrigation installed while remaining sites were facilitated with sprinkler irrigation (Figure 3d). Further, data for types of crop grown in the study area under HEIS was collected, analyzed and categorized into four classes as summarized in the Figure 3e.

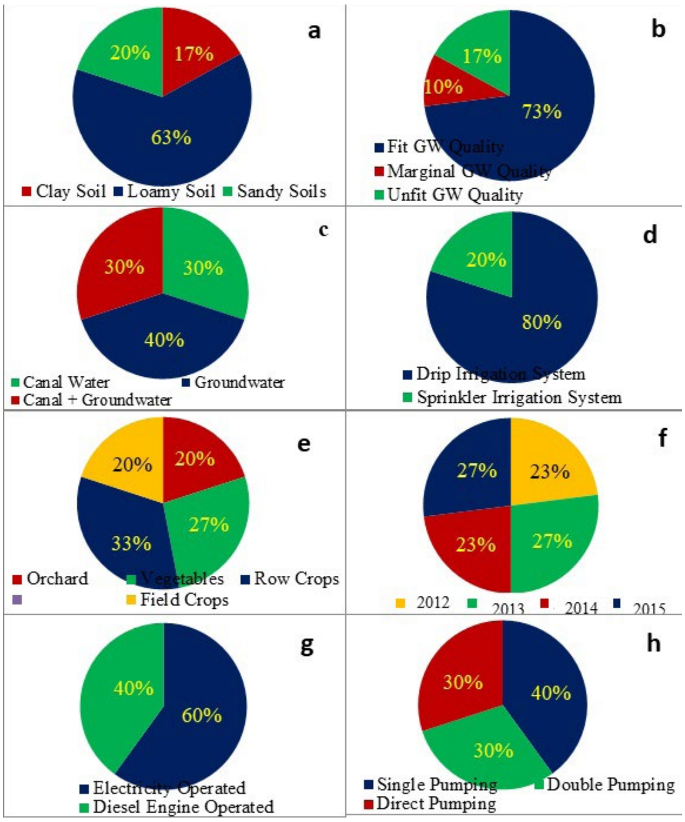

Figure 3: *Distribution of Farm Characteristics by HEIS adoption (a = Soil Type; b =; GW quality; c = Available Water Sources; d = HEIS type; e = Crop type under HEIS; f = Age of HEIS; g = Mode of power; h = Pumping mechanism).*

However, consideration about the age of installed HEIS was analyzed under this study. Determination of effect of oldness of HEIS on its functioning status is crucial, thus following data listed in Figure 3f was collected and analyzed. Having mentioned the type and age of HEIS, it is important to analyze the type of power source and pumping mechanism employed on various sites in the study area. Majority (60 %) of the sites met their power requirements through electricity while diesel engine was used as power source on 40 % of the sites in the study area (Figure 3g). Further, based on the available water sources and crop water requirements, single, double and direct pumping mechanism was used on 12, 10 and 8 sites respectively as shown in the Figure 3h.

Functioning status of HEIS installed throughout the Punjab is the most important indicator of its success regarding reliability that directly influences its adoption. Proper functioning of HEIS at a specific site not only shows a farmer's satisfaction but also helps in adoption of this modern technology through conveying a positive message to the fellow farmers, who have not adopted HEIS yet. Similarly, failure or abandoning of a single HEIS site can result in negative perception about HEIS in a community which consequently stops or slows down the adoption of HEIS (Parasuraman and Colby, 2001; Godoe and Johansen, 2012). The location of functional and non-functional sites out of selected sites in various districts of the entire Punjab is depicted in Tables 2 and 3. Analyses of the collected data showed that majority of the sites (73 %) were functioning properly while a significant number of sites (27 %) were non-functional. Important to note though was the fact that the sites installed even as early as in 2012 were still working efficiently which approves the aptness of the current implementation model being used for the installation of HEIS.

Another fact worth mentioning is that most of the non-functioning sites were managed by farm managers employed by the farmers. Above mentioned fact shows the reluctance of farm managers to adopt new technologies and their lack of motivation to manage extra workload for the betterment of farm. Abandoning of the HEIS is also due to the reason that farmers consider their manager's advice as the final word instead of evaluating the real grounds behind the ineffective results of water application through HEIS. Further assay of the sample data revealed that 100 % of the sites (4 in total) where HEIS was installed to irrigate cotton, ended up as non-functional. Failure of HEIS for irrigating cotton is important to point out as cotton has been successfully cultivated under drip irrigation in neighboring countries such as India and China (Aujla et al., 2005; Rajak et al., 2006; Choudhary et al., 2016; Narayanamoorthy, 2016; Du et al., 2008; Luo et al., 2016).

Table 1: *Parameters used in the development of model.*

Parameters		Description of Parameters
Site Functioning Status	(D_{SF})	D_{SF} =1, if site is fully functional, if non-functional D_{SF} =0
Literacy Status	(D_{LS})	D_{LS} =1, if educational qualification level of farmer>BA, otherwise, D_{LS}=0
Farming Experience	(D_{FE})	D_{FE} =1, if farming experience>15 years, otherwise, D_{FE}=0
Tenancy Status	(D_{TS})	D_{TS} =1, if tenancy status = owner, otherwise, D_{TS}=0
Farm Location	(D_{FL})	D_{FL} =1, if farm is located at head reach of watercourse, otherwise, D_{FL}=0
Farming Mode	(D_{FM})	D_{FM} =1, if farmer is doing farming activities by himself, otherwise, D_{FM}=0
Groundwater Quality	(D_{GW})	D_{GW} =1, if groundwater quality is fit, otherwise, D_{GW}=0
System Type	(D_{ST})	D_{ST} =1, if HEIS type is Drip, otherwise, D_{ST}=0
Pumping Mechanism	(D_{PM})	D_{PM} =1, if water is pumped through WST, otherwise, D_{PM}=0
Power Source	(D_{PS})	D_{PS} =1, if energy source is electricity, otherwise, D_{PS}=0
Operator Deployment	(D_{OD})	D_{OD} =1, if operator is deployed for HEIS at site, otherwise, D_{OD}=0
Net Benefits	(D_{NB})	D_{NB} =1, if net benefits (HEIS) is positive, otherwise, D_{NB}=0
Backup Support	(D_{BS})	D_{BS} =1, if SSCs provided backup support to farmers, otherwise, D_{BS}=0

Table 2: *Salient Features Associated with Functional Sites.*

Sr. No.	Site No.	District	Area (Ha)	Crop	Type of HEIS	Water Source	Power Source
1	S-1	Layyah	6.1	Citrus	Drip	Canal +Tube Well	Electricity
2	S-4	Mianwali	6.0	Vegetables	Drip	Canal +Tube Well	Diesel
3	S-5	Gujranwala	6.1	Wheat	Sprinkler	Tube Well	Electricity
4	S-7	Bahawal Pur	6.1	Vegetables	Drip	Canal +Tube Well	Electricity
5	S-9	Narowal	6.1	Wheat	Sprinkler	Tube Well	Electricity
6	S-10	Jhelum	6.1	Citrus	Drip	Tube Well	Electricity
7	S-11	Chakwal	3.2	Vegetables	Drip	Tube Well	Electricity
8	S-12	Rawalpindi	6.1	Wheat	Sprinkler	Tube Well	Electricity
9	S-13	Sargodha	6.1	Citrus	Drip	Canal	Electricity
10	S-15	Khushab	5.5	Wheat	Sprinkler	Canal	Electricity
11	S-19	R.Y.Khan	6.1	Citrus	Drip	Tube Well	Diesel
12	S-20	Bahawal Nagar	6.1	Citrus	Drip	Canal	Diesel
13	S-21	Multan	10.1	Maize	Drip	Canal +Tube Well	Electricity
14	S-22	Khanewal	4.9	Maize	Drip	Canal +Tube Well	Electricity
15	S-23	T.T.Singh	6.1	Maize	Drip	Canal	Diesel
16	S-24	Jhang	6.1	Vegetables	Drip	Canal +Tube Well	Diesel
17	S-25	Jhang	6.0	Vegetables	Drip	Tube Well	Diesel
18	S-26	Chiniot	2.7	Maize	Drip	Tube Well	Diesel
19	S-27	Chiniot	2.0	Maize	Drip	Tube Well	Electricity
20	S-28	Faisalabad	4.9	Vegetables	Drip	Canal +Tube Well	Diesel
21	S-29	Faisalabad	6.1	Vegetables	Drip	Canal	Diesel
22	S-30	Chakwal	3.6	Wheat	Sprinkler	Tube Well	Electricity

Correlation of parameters

Correlation analysis was performed to determine the correlation amongst various variables which were analyzed. It has been observed from the correlation analysis that strongest positive correlation existed among the literacy status and farming experience of using HEIS. Similarly, experienced and literate farmer can get maximum net economic benefits. The results indicated that the sites have operational expenses less than the conventional irrigation methods are functional and probably will sustain in the field. The farmers are also earning more money from their

Table 3: *Salient Features Associated with Non-Functional Sites.*

Sr. No.	Site No.	District	Area (Ha)	Crop	Type of HEIS	Water Source	Power Source
1	S-2	Muzaffar Garh	5.5	Cotton	Drip	Canal +Tube Well	Electricity
2	S-3	Attock	6.1	Wheat	Sprinkler	Tube Well	Diesel
3	S-6	Hafizabad	6.1	Maize	Drip	Tube Well	Electricity
4	S-8	Bahawal Pur	3.2	Cotton	Drip	Canal	Diesel
5	S-14	Bhakkar	4.9	Citrus	Drip	Tube Well	Diesel
6	S-16	Sahiwal	3.1	Cotton	Drip	Canal +Tube Well	Electricity
7	S-17	Sialkot	6.1	Vegetables	Drip	Tube Well	Electricity
8	S-18	D.G.Khan	2.0	Cotton	Drip	Tube Well	Electricity

Table 4: *Correlation Matrix for selected parameters.*

Parameters	Farming Experience	Literacy Status	Operator Deployment	Net Benefits	Backup Support	Farm Location	Tenancy Status	Farming Mode	Groundwater Quality	Energy Source	Pumping Mechanism
Literacy Status	0.791**										
Operator Deployment	0.585**	0.636**									
Net Benefits	0.585**	0.793**	0.489**								
Backup Support	0.522**	0.591**	0.537**	0.690**							
Farm Location	0.068	-0.138*	-0.075	-0.075	-0.067						
Tenancy Status	-0.152*	-0.141*	-0.112*	-0.112*	-0.162*	0.093					
Farming Mode	0.577**	0.783**	0.373**	0.693**	0.523**	-0.177*	-0.131*				
Groundwater Quality	-0.339*	-0.146*	-0.023	-0.193*	-0.223*	-0.264*	0.308*	-0.267*			
Energy Source	0.028	0.085	-0.185*	-0.031	-0.027	-0.272*	-0.152*	0.144*	0.123*		
Pumping Mechanism	-0.028	-0.085	0.031	-0.123*	-0.110*	0.442**	0.152*	-0.144*	0.031	-0.167*	
System Type	0.102*	-0.035	-0.113*	-0.113*	-0.101*	0.250*	-0.093	-0.177*	0.075	-0.238*	0.068

N: Number of Sites = 30.

HEIS sites. Education levels of the farmers have also shown a very strong correlation for the site function status. Well educated farmers are well receptive for the modern irrigation methods and they may keep their systems functional and sustainable and even make it more profitable business through their knowledge. Deployment of an operator for farming operations, provision of backup supports and performing farming activities by the owners of the farm themselves have also shown marginally strong positive correlation with the site function status. Other factors such as pumping mechanism, soil types, energy source, farm location and groundwater quality have not shown significant correlations with the site function status. The correlation amongst all the parameters used for analysis is shown in Table 4. It was observed that the sites with positive net benefit were found to be functional (Figure 4). Above mentioned results are barely distinguishable from Palanisami et al. (2011). It is however important to consider the type of crop grown under HEIS, as the value of the crop directly influences the net benefit.

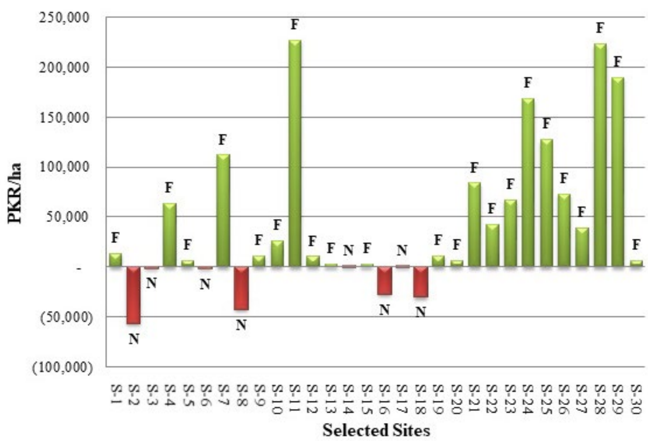

Figure 4: *Net economic benefits (PKR/ha) for all 30 sites (**F:** Functional **N:** Non Functional **S:** Site).*

Table 5: *Standings of selected parameters based on their influence.*

Significance Coefficients								
Parameters		Un-standardized Coefficients		Standardized Coefficients	T	Sig.	Rank
		B	Std. Error	Beta			
(Constant)		-0.176	0.362		-0.486	0.633	
Net Benefits	(D_NB)	0.471	0.198	0.471	2.380	0.029	1
Operator Deployment	(D_OD)	0.342	0.165	0.342	2.069	0.054	2
Literacy Status	(D_LS)	0.155	0.268	0.169	0.580	0.569	3
Farming Mode	(D_FM)	0.153	0.172	0.163	0.892	0.385	4
Pumping Mechanism	(D_PM)	0.128	0.104	0.142	1.229	0.236	5
Backup Support	(D_BS)	0.098	0.134	0.110	0.732	0.474	6
System Type	(D_ST)	0.084	0.136	0.076	0.615	0.547	7
Power Source	(D_PS)	0.064	0.112	0.071	0.567	0.578	8
Tenancy Status	(D_TS)	0.112	0.284	0.046	0.395	0.697	9
Farm Location	(D_FL)	-0.041	0.143	-0.037	-0.290	0.776	10
Groundwater Quality	(D_GWQ)	-0.116	0.137	-0.116	-0.847	0.409	11
Farming Experience	(D_FE)	-0.191	0.179	-0.212	-1.065	0.302	12

Parameters influential order

Further, statistical analysis was performed to evaluate the influence of above mentioned parameters on the working status of HEIS Table 5. Through the preliminary analysis, the nine factors positively affected the site function status while remaining 3 parameters had negative influence on the sustenance of HEIS in terms of functioning status. The selected parameters were also ranked based on their influencing order such as net economic return, deployment of operator, literacy status, farming mode, pumping mechanism, backup support, system type, energy source, tenancy status, farm location, groundwater quality and farming experience because these parameters have significance coefficient values of 0.471, 0.342, 0.169, 0.163, 0.142, 0.110, 0.076, 0.071, 0.046, -0.037, -0.116, -0.212, respectively (Figure 5). Results showed that abandoning of HEIS is also partly due to lack of easily accessible maintenance which is in conformity with earlier studies (Kulecho and Weatherhead, 2005; Belder et al., 2007). The deployment of operator has become necessary by the farmers because consulting companies do not provide proper sales sale and service facilities. Reliance of proper functioning of HEIS sites on an operator was realized by the fact that sites where there was no assigned person for operation of HIES, ended up as unserviceable.

However, sites with deployed operator functioned for longer periods of time with an acceptable level of satisfaction. Reluctance of experienced farmers to leave their old and traditional culturing practices contributed towards either abandoning or non-functioning of HEIS. Facts regarding farmer's experience and education proved a point that for adoption and sustenance of a new technology like HEIS, farmer's awareness about that technology counts more than the farming experience. Significance of personality dimensions including educational status and experience of users in adoption of a new technology is in conformity with previous findings (Alcon et al., 2011; Godoe and Johansen, 2012). Interestingly, parameters like location of farm on the watercourse reach (at head) and good quality ground water had negative though minor impacts on the site function status which implies that farm located at the tail reaches of watercourses and having saline or brackish (unfit for irrigation) water have more potential for adoption and sustenance of HEIS. The poor-quality water of the area put more pressure on the fresh water resources of area resulting in shortage of fresh water resources (Shakoor et al., 2018). Thompson et al. (2009) reported that water shortages are demanding in the adoption of water-saving agricultural practices within the area. Similarly, it has been reported that the trickle irrigation system provides the best possible conditions of total soil water potential for low quality of irrigation water. The yield difference of 59% for bell pepper between trickle and sprinkler irrigation systems was reported when the salinity of irrigation water was 4.4 dSm^{-1} but no difference was reported when good water was used (Bernstein and Francois 1973; Asif et al., 2015). Similarly factors like HEIS type, power source, pumping mechanism etc., showed minor impact on the site function status. However, misconception about the negative impact of pumping water from a storage tank on the sustenance of HEIS was cleared and results showed a positive yet minor impact of indirect pumping on the site function status. Further, electricity was proved to be the better power source for sustenance of HEIS.

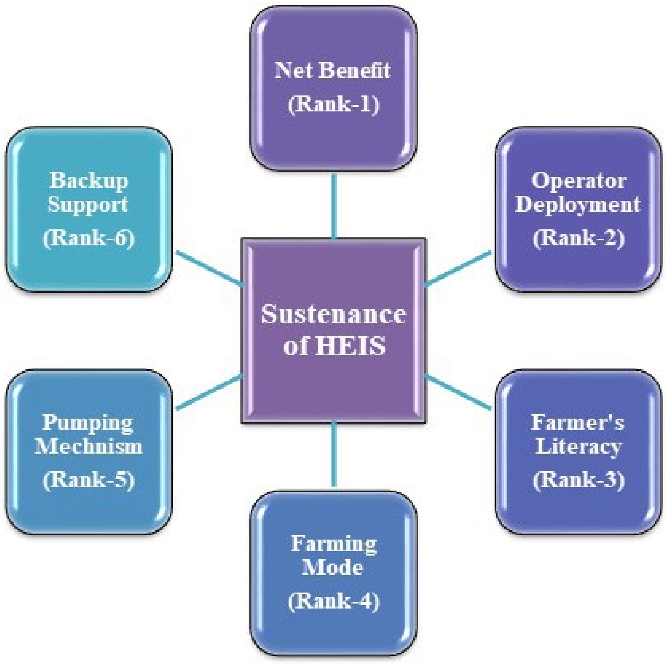

Figure 5: *Significant factors influencing the sustenance of HEIS.*

Conclusions and Recommendations

The results of the present study indicated that the most influencing parameters such as net economic return, deployment of operator, literacy status, farming mode, pumping mechanism, backup support have influencing order of 1 to 6, respectively as their significant coefficient values were found to be 0.471, 0.342, 0.169, 0.163, 0.142, 0.110, respectively. Net benefit is the prime factor governing the sustenance of HEIS and it relates directly to crop type, power source, pumping mechanism and marketing facilities accessible to farmers. Furthermore, deployment of a trained operator for operation and maintenance of HEIS contributes heavily in the proper functioning of these systems. Diffusion of HEIS into the farming community is also accelerated and smoothened by deploying on-site operators. Sustenance of systems are positively influenced by farmer's education and self-farming. However, extensive farming experience slows down the acclimatization process of HEIS that result in abandoning of these systems. Having mentioned that, direct pumping and provision of backup support prolong the proper functioning period of HEIS. But, availability of fresh ground water and farm's location at head reach of watercourse negatively affect the sustenance of HEIS. Abandoning and non-functioning of HEIS sites damages the perceived usefulness of these modern systems among the farming community that decelerates the adoption process. Supervision of HEIS sites should be done by farmer himself instead of any kind of farm manager to guarantee a valid assessment of drip and sprinkler systems. On the other hand, policy makers and the concerning departments in conjunction with all other stakeholders should synthesize a comprehensive and efficient implementation plan to ensure potential based installation and proper backup support.

Author's Contribution

Hafiz Umar Farid: Research study execution, design of questioner, data collection, analysis and wrote the manuscript.
Muhammad Zubair: Data Collection, data analysis and interpretation, helped in writing up the manuscript.
Zahid Mahmood Khan: Overall research supervision, provision of research facilities and data interpretation.
Aamir Shakoor: Helped in writing and editing the paper, reviewed the literature and data analysis.
Behzad Mustafa: Helped in data collection and analysis, reviewed the literature.
Aftab Ahmad Khan: Helped in design of questioner, writing and editing the paper.
Muhamad Naveed Anjum: Helped in statistical analysis and data presentation.
Ijaz Ahmad: Helped in data collection, analysis and results interpretation.
Muhammad Mubeen: Helped in data collection, analysis and crop water requirement determination.

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