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ADOPTION OF HIGH EFFICIENCY IRRIGATION SYSTEM (HEIS) IN PUNJAB, PAKISTAN: CHALLENGES AND OPTIONS

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The present study was undertaken to conduct a detailed survey in all agronomic zones of Punjab, Pakistan to find out the factors responsible for impeding adoption of High Efficiency Irrigation Systems (HEIS) among the farmers. A sample of 242 respondents (farmers and other stakeholders i.e. manufacturers and service providers, NGO's and Government officials) were interviewed, using three comprehensive pretested questionnaires. The respondents comprised four categories i.e. HEIS adopters of drip and sprinkler, those who adopted HEIS but discontinued, those who did not adopt HEIS named as non-adopters, and professionals. The analysis prioritized the factors as financial issues, less backup support/repair and maintenance, intensive supervision, non-availability of skilled operator, small land holdings, absentee land owners and certain operational problems. The motives behind farmers' decision to adopt HEIS were also analyzed empirically, using Endogenous Switching Regression (ESR) technique. The ESR results complemented the inferences, derived from descriptive data analysis. The ESR analysis indicated that farmers having favorable resource base, young and having better access to education / awareness (formal and informal) along with other indicators such as availability of skilled operator, frequent contacts with professionals and non-occurrence of financial issues increased chances to adopt HEIS. Based on these results, it is suggested that level of awareness, education and training of farmers need to be enhanced. It is proposed to launch skill development programs at demonstration farms to train youth for growing high value crops, using HEIS through enabling environment and providing backup support to make farming a profitable business.
Keywords: Adoption, Drip Irrigation, Endogenous Switching Regression, Sprinkler Irrigation.

INTRODUCTION

Flooding is the most common irrigation method practiced by the farmers in Punjab, Pakistan, having water use efficiency less than 50 %. Such low irrigation efficiencies at farm level is a major constraint in attaining potential production from highly productive agricultural lands. In addition, more than 40 % of canal water is being lost between mogha/ outlet and farmers' fields due to poor condition of tertiary conveyance system (watercourses) (Rizwan *et al.,* 2019). Due to uneven fields and poor farm designing, a significant (25%) of irrigation water is lost during its application (Kaur *et al.,* 2012; Aslam *et al*., 2018; Anjum *et al*., 2019). This leads to excessive application to low-lying areas and under-irrigation at higher spots. Over-irrigation leaches soluble nutrients from the crop root zone, makes the soil less productive, and degrades groundwater quality. Under-irrigation of elevated parts of the fields results in accumulation of salts besides causing water stress and injurious effects of the applied fertilizer. Moreover, crop water requirements are not being met timely because of supply based irrigation water delivery system i.e. warabandi, which has negatively affected the overall agricultural production (Bakhsh *et al*., 1994).

In Punjab, various types of irrigation techniques can be used at the farm to increase water productivity. The modern irrigation techniques are efficient enough to supply irrigation water uniformly to the entire field, so that each plant has the amount of water according to its needs (Yaseen *et al*., 2028). Each technology, however, works at the best under its suitable land and water conditions. For example, sprinkler irrigation is mostly suitable under undulating terrain where otherwise it is difficult to apply irrigation water through gravity. Similarly, drip irrigation is highly suitable for point application of irrigation water especially for orchards. Both sprinkler and drip are considered as high efficiency irrigation systems. Drip irrigation system is most commonly used as HEIS for water saving in Pakistan. Drip irrigation is considered as the most efficient irrigation technology, which can enhance water application efficiency by 98% (Bakhsh *et al*, 2015), increase in crop yields by 100 % (Anjum *et al*., 2014), save in fertilizer use by 25 % (Vijayakumar *et al*., 2010). It is especially suitable to orchards and in tunnel farming for growing high value crops. Tunnel farming with drip irrigation can make earnings of Rs. 1.24 to 1.98 million per hectare annually (Bakhsh *et al*., 2015). Many studies (Chauhdary *et al*., 2015; 2017; 2019; 2020) have been conducted on drip irrigation to explore its advantages and suitability under local conditions of Pakistan.

Although these modern irrigation methods are efficient enough to curtail the water scarcity problem, but are not being adopted at the pace as desired. Their adoption is facing various constraints as economic, social, technical, marketing and lack of knowledge/awareness. But HEIS has adequate potential to improve livelihood of small farmers by adopting with tunnel farming and that can enhance their earnings manifolds compared with traditional methods. Growing high value crops such as vegetables and fruits on small land holdings can increase annual net returns of the farmers ranging from Rs 0.74 to 2.47 million per hectare only by adopting HEIS. In this context, the Government of Punjab under Punjab Irrigated-Agriculture Productivity Improvement Project (PIPIP) is already giving subsidy of 60 % for HEIS while remaining cost is contributed by the beneficiary farmers. The subsidy is being provided to farmers having land up to 15 acres. In addition, government also provides same percentage of subsidy for construction of water storage pond, if needed, based on site specific technical requirements. This PIPIP project has been sponsored by Government of Punjab and World Bank through On Farm Water Management (OFWM)Department and is being implemented from 2012 to 2021 all over Punjab (WMP, 2011).Now the government of Punjab has further subsidized the drip irrigation program by providing subsidy of 80 %for solar powered system and 50 %subsidy on tunnel farming for five acres.

Despite all benefits and subsidies provided by the government, farmers are still reluctant to adopt HEIS. There are examples where drip irrigation systems were installed and later abandoned due to assorted reasons, further badly affecting the adoption process of HEIS. Besides having some success stories, majority of the farmers are still surviving marginally and are reluctant to further promote HEIS. This compells the government and policy makers to investigate the reasons impeding the adoption process of HEIS and frame policy guidelines for its promotion so that small farmers can ehnace their crop productivity (GOP, 2011).

This study, however, attempted to identify the key constraints, which prevented the farmers from adopting / discontinuing the drip irrigation system, and constraints being faced by the farmers in shifting towards these modern irrigation systems in Punjab, Pakistan. The study also focused on investigating the causes responsible for non-adoption of HEIS by conducting a comprehensive survey of farmers. These farmers were categorized as (1) adopters of the drip and sprinkler, (2) adopters but have left it abandoned and (3) non-adopters in addition to interacting with professionals. It also included survey of other stakeholders who are considered as implementing bodies of the above mentioned project like service suppliers, consultants, government officials, NGOs and other relevant organizations. Moreover, water availability, farming and socio-economic conditions of farmers in Punjab vary from one cropping zone to other because of different climate, crop water requirements, growing season, cost of production and net income to the farmers. These varying conditions also influence the farmers about their decision to adopt HEIS and its further promotion. Therefore, the present study was designed to outreach farmers in different cropping zones and investigate the factors responsible for adoption / promotion of HEIS so that the government can formulate policies to address these issues for improving livelihood of small farmers in all these cropping zones. The specific objectives of the study are as:

- To conduct a comprehensive survey of all categories of farmers i.e. HEIS as drip and sprinkler adopters, those who adopted but discontinued, those who did not adopt as non-adopters, consultants, and other relevant public-private organizations for identifying the constraints/factors responsible for non-adoption of high efficiency irrigation technologies.
- To propose guidelines for providing enabling environment by the government for farmers in adopting high efficiency irrigation technologies to increase their net returns.

MATERIALS AND METHODS

The study is based on primary data. Five zones (mixed cropping, cotton-wheat, Thal, rice-wheat and Pothowar) from Punjab province were selected for survey. The detail of these zones is given in Table 1. These zones were selected because they were the major sites in Punjab having different characteristics such as cropping patterns, water availability and quality, soil and climatic conditions. The location of sampling zones in Punjab province is presented in Figure 1.

Table 1. Copping zones and surveyed districts.

Sr. No.	Category	Districts/tehsils in one Zone
Zone-I	Mixed cropping	Faisalabad, Toba Tek Singh, Jhang, Chiniot and Nankana Sahib
Zone-II	Cotton-wheat	Multan, Bahawalpur, Lodhran and Muzaffargarh
Zone-III	Thal	Layyah and Athara (18) Hazari (Tehsil of district Jhang)
Zone-IV	Rice-wheat	Gujranwala, NosheraVirkaan, Wazirabad and tehsil Kamonki in district Gujranwala and Daska of district Sialkot
Zone-V	Pothowar	Tehsil Chakwal, Talagang and Kalarkahar in district Chakwal. Tehsil Dina in district Jhelum

After selection of tehsils, villages were randomly selected from each tehsil of the selected district where adopters of HEIS were significant in number. A list of adopters of drip irrigation and sprinklers was obtained from agriculture departments, especially OFWM for each zone. However, the same number of non-adopters in the vicinity of adopters was also interviewed to compare the socio-economic characteristics of both classes. A total sample size of 242 respondents from all zones of Punjab was taken, comprising50, 50, 50, 42 and 50 in mixed cropping, cotton-wheat, Thal, rice-wheat and Pothowar zones, respectively (Table 1).

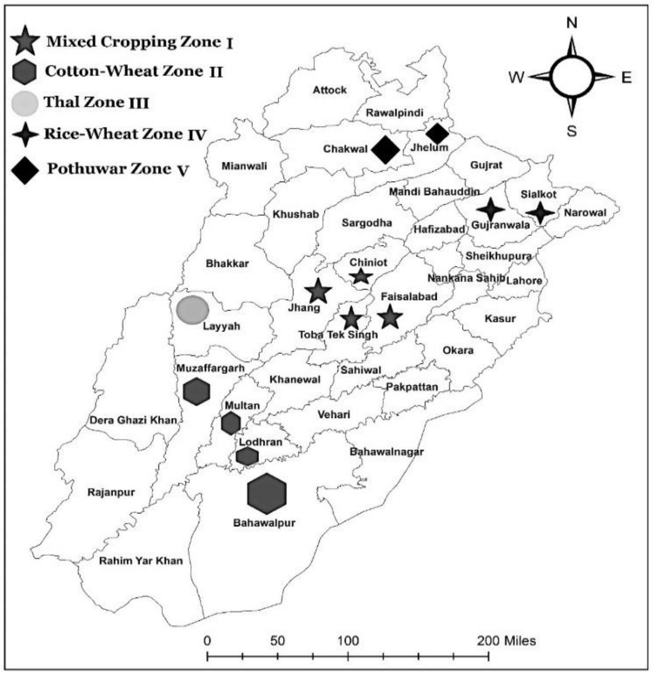

Figure 1: Locations of sampling zones in Punjab

***Descriptive Statistics*:** The constraints responsible for non-adoption of drip and sprinkler irrigation systems were identified under the current study. So, the farmers were mainly asked about the constraints, which they faced or perceived for better adoption process and prioritized these constraints on percentage basis. For considerations and making comparisons, percentages were calculated and presented graphically. The study also drawn the basic estimations such as mean values socio-economic and demographic factors of farmers who adopted the technology and their counterparts while explaining the descriptive methodology. Their sample means were also compared to check differences in various characteristics of adopters (drip and sprinkler), discontinued and non-adopters.

***Factors affecting Farmers' Decision to Adopt HEIS (Endogenous Switching Regression)*:** While estimating, factors contributing to adoption of HEIS, the analysis faced two issues. The first was heterogeneity between adopters and non-adopters of HEIS. All adopters and non-adopter's households were not homogenous with respect to their financial status (Feder *et al*. 1990). Under financial constraints, factors of production may have differential effects on agricultural productivity than with financial well off. The second issue was endogeneity, which motivated the analysts to use an Endogenous Switching Regression (ESR) model that accounts for both heterogeneity and sample selection bias (Dong, 2010).

Endogenous Switching Regression, however, was employed to explore the potential of traditional irrigation system in shifting towards HEIS. Adopting HEIS is based on the net benefits of this adoption. The farmers will adopt HEIS if net returns from adopting these systems ($U_P(\pi)$) are more than non-adopting ($U_N(\pi)$ and $U^*(\pi)$ represents error term. It is specified as:

$$U_P(\pi) - U_N(\pi) = U^*(\pi) \qquad (1)$$

Hence the participation linear equation;

$$\mathbf{B}_i = \alpha X_i + \mu_i \qquad (2)$$

To estimate the relationship between adopting HEIS and net returns, start with a linear function:

$$Y = \beta Z_i + \gamma B_i + \varepsilon_i \qquad (3)$$

Where Y is net returns, B_i is dummy variable representing adopting HEIS, Z_i is individual household, farm level and locational characteristics, ε_i is random error term.

RESULTS AND DISCUSSIONS

***Composition of respondents by different categories*:** The composition of respondents under different cropping zones was designed to determine response of stakeholders under various cropping conditions (Table 2). A total of 242 respondents were interviewed including78 adopters of drip irrigation system, 18 adopters of sprinkler irrigation system, 86 non-adopters, 15 non-operational/discontinued and 45 professionals.

Overall, the major constraints faced by drip adopters were less backup support from service supply companies as well as Government Departments, skilled labor requirement, intensive supervision, absentee land owners, financial issues as increased cost of production, operational problems and reluctance to change cropping patterns. Most of the adopters were facing constraint of less backup support and showed the highest scores i.e. 96 and 88 % in mixed cropping and cotton-wheat zones, respectively. Thal and Pothowar zones presented response of 18 and 24 percent of drip adopters about less backup support. Another major constraint of drip adopters was less technical knowledge about drip irrigation system, which was faced by 83, 82, 10 and 6 % adopters in the mixed crops, cotton-wheat, Thal and Pothowar zones, respectively. The farmers, however, were demanding not only to operate HEIS but also make it profitable. The third major

Table 2. Composition of respondents: zone and category wise

Zones	Category					Total
	Adopters (Drip)	Adopters (Sprinkler)	Non-adopters	Discontinued	Professionals	
Mixed Cropping	24	0	15	4	7	50
Cotton-Wheat	17	0	21	2	10	50
Thal	20	0	20	4	6	50
Rice-Wheat	0	12	13	5	12	42
Pothowar	17	6	17	0	10	50
Total	78	18	86	15	45	242

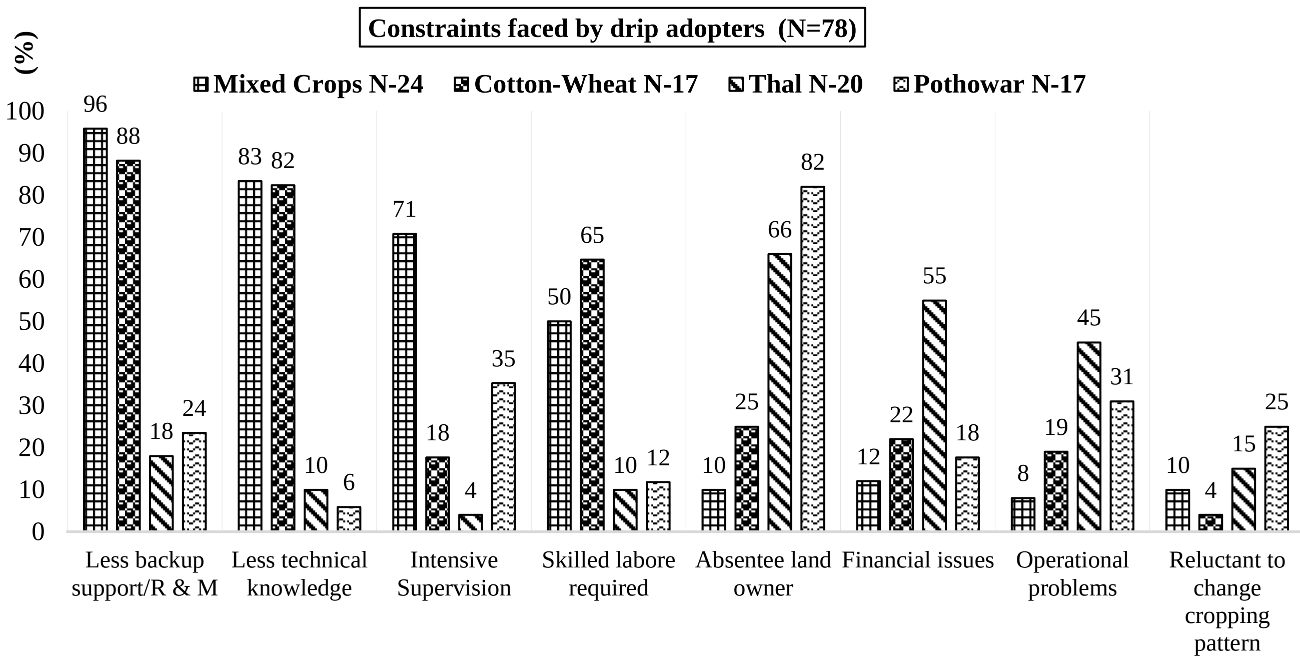

Figure 2. Constraints in the adoption of HEIS perceived by drip adopters.

issue reported by the farmers was requirement of intensive supervision which included safety of different parts of the system. This issue was shown as 71, 18, 4 and 35 % in mixed cropping, cotton-wheat, Thal and Pothowar zones, respectively. The fourth constraint was non-availability of skilled labor at their farms. Figure 2 showed that responses about skilled labor required on permanent basis were 50, 65, 10 and 12% in the mixed crops, cotton-wheat, Thal and Pothowar zones. Absence of actual decision maker or land owner was the fifth major issue in the way of wide adoption of HEIS. This was major issue / constraint especially in Thal and Pothowar zones as 66 and 82 %, respectively. Financial constraint was also appeared as an important concern of farmers and ranked at number six. The 12, 22, 55 and 18 % of farmers reported this issue in mixed cropping, cotton-wheat, Thal and Pothowar zones, respectively. High cost for replacement of drip irrigation components was also included in the financial concerns of the adopters that occurred following adoption of drip irrigation system. Drip adopters also had the seventh reservation to operate the system properly as they have not got proper trainings. The eighth important problem faced by some of the drip users was about the stagnation in trend of cropping system in their respective areas as most of the farmers were growing traditional crops. This constraint was faced by 10, 4, 15 and 25 % adopters in mixed cropping, cotton-wheat, Thal and Pothowar zones, respectively.

***Constraints in adoption of HEIS faced by drip Adopters (N=78)*:** Drip irrigation system was adopted in four zones among five selected zones of Punjab. The bar graph shows the different constraints in each zone faced by the adopters (Figure 2).

***Constraints faced by adopters of sprinkler irrigation system (N=18)*:** Figure 3 shows the major constraints in wide adoption of sprinkler irrigation system. The adopters of sprinkler irrigation system were mainly found in the Rice-Wheat zone where irrigation water mostly did not leach down due to heavy soils. Further, sprinkler irrigation is mostly suitable under undulating terrain areas. The farmers, however,

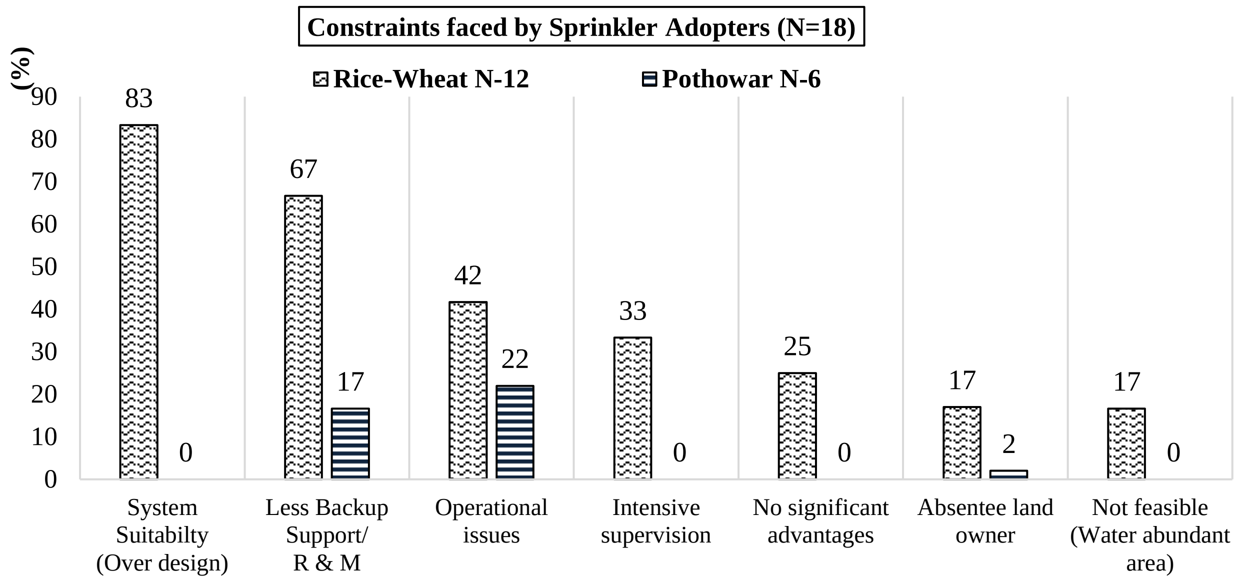

Figure 3. Constraints in adoption of HEIS perceived by sprinkler adopters

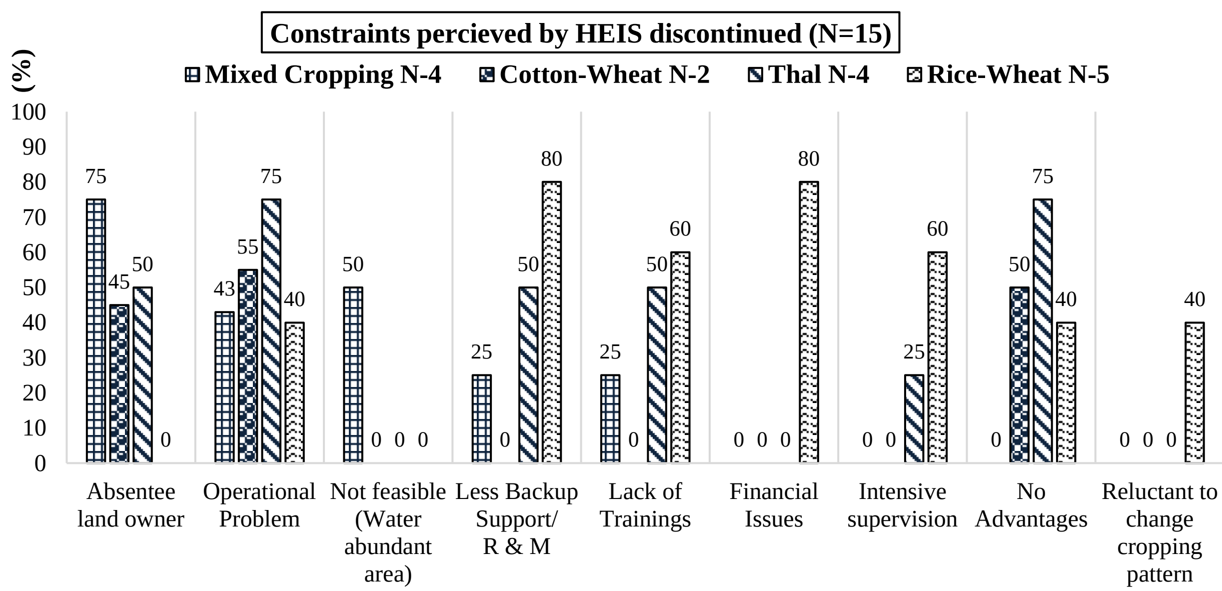

Figure 4. Constraints in the adoption of HEIS perceived by discontinued adopters.

also adopted this system in some areas of Pothowar zone as well.

The first major constraint reported by sprinkler adopters was overdesign of the system. In this constraint, design overlapping was the main problem in sprinkler irrigation system as it was more than 65 %. The 83 % of adopters in rice-wheat zone faced this problem and none of the adopters showed this concern in Pothowar zone. The second major constraint of sprinkler adopters was less backup support from professionals as well as repair and maintenance problem with percentage of 67 and 17 in rice-wheat and Pothowar zones, respectively. The third constraint reported by the farmers was operational issues that mostly encompassed over designing of the sprinkler irrigation system. These issues faced by adopters were of 42 and 22 % in Rice-Wheat and Pothowar, respectively. The analysis found that these constraints were mostly reported in the rice-wheat zone as compared to these in Pothowar zone.

***Constraints in adoption of HEIS faced by those who discontinued farmers (N=15)*:** Figure 4 shows the constraints in adoption of HEIS faced by those farmers, who discontinued drip and sprinkler irrigation systems. This included 10 and 5 adopters of drip and sprinkler irrigation system, respectively, and they left it abandoned. These farmers, who discontinued, belonged to all selected zones except Pothowar zone. The rice-wheat zone had 5 discontinued farmers of sprinkler irrigation system while 10 respondents from other three zones belonged to drip irrigation system.

The absentee landowner was the first constraint as apparent from three zones i.e. mixed cropping, Cotton-Wheat and Thal zones with percentage of 75, 45 and 50, respectively. Operational problem had these constraints faced with percentages of 43, 55, 75 and 40 in the four zones. The 50 % respondents in mixed cropping zone were having enough canal water at their farms and they discontinued HEIS, for whatever reason they early adopted the system. Less backup support whether from supply and service companies (SSCs) or government department, was the fourth constraint faced by farmers, who discontinued with percentages of 25, 50 and 80 in mixed cropping, that and rice-wheat zones, respectively.

***Constraints (%) perceived by HEIS Non-Adopters (N=86)*:** The current study also focused on non-adopters of HEIS and identified main constraints in the adoption of HEIS (Fig. 5). The major constraints regarding non-adoption were financial issues, lack of awareness, requirement of skilled labor to operate the system, reluctance to change cropping pattern due to less crop diversification and non-availability of marketing for produce in the area, small land holdings, water abundant

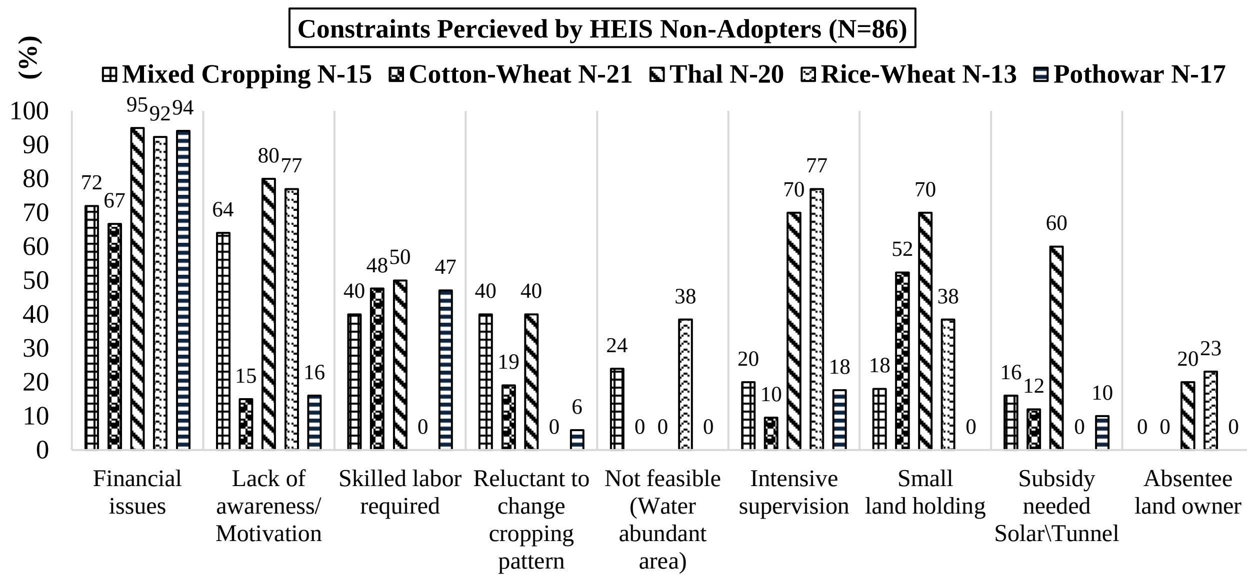

Figure 5. Constraints in the adoption of HEIS perceived by non-adopters

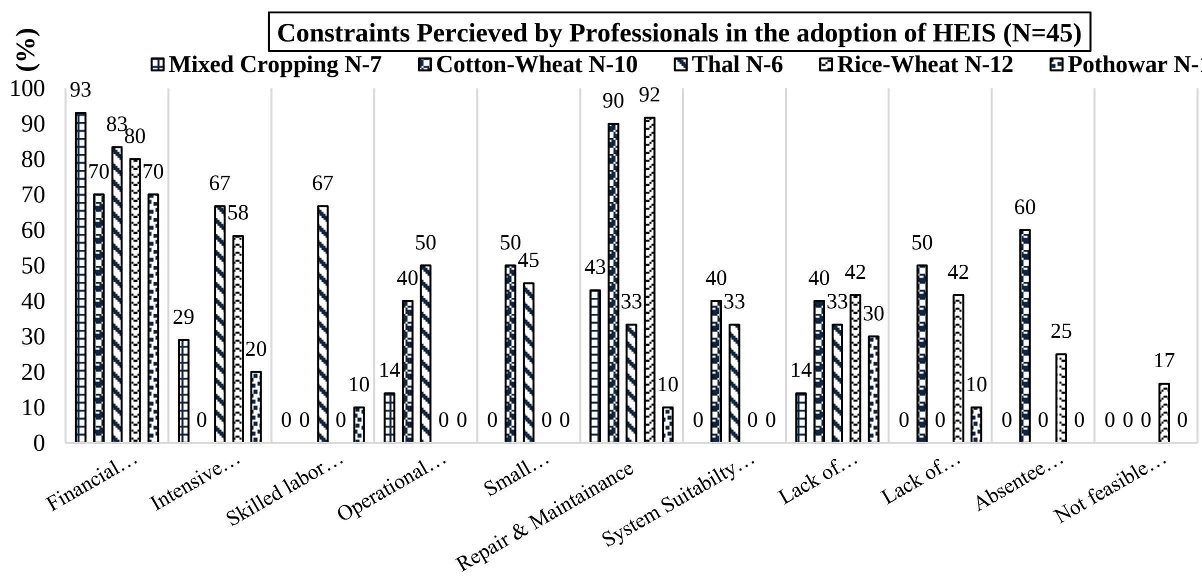

Figure 6. Constraints perceived by professionals in HEIS adoption

area (not feasible), requirement of intensive supervision, complementary solar and tunnel subsidy demanded by farmers and absentee farmers at the farms.

Among all constraints as non-adopters perceived, less financial asset was ranked at first level with percentages of72, 67, 95, 92 and 94% in mixed cropping, cotton-wheat, thal, rice-wheat and Pothowar zones, respectively. The second major constraint which non-adopters reported was lack of awareness regarding economic as well as technical know-how of these efficient irrigation systems and it was found in all zones with percentages of 64, 15, 80, 77 and 16 in mixed cropping, cotton-wheat, Thal, rice-wheat and Pothowar zones, respectively. A considerable number of farmers in all zones except rice-wheat had shown their concerns about non-availability of the skilled labor at their farms to operate the system.

***Constraints (%) perceived by professionals in HEIS adoption (N=45)*:** Figure 6 shows major constraints determined by professionals (stakeholders, consultants, Govt. officials and service suppliers). According to professionals, these constraints were faced by adopters, non-adopters and discontinued farmers of drip and sprinkler irrigation system.

The major constraints in the adoption process pointed by professionals were financial issues, intensive supervision, skilled labor required, operational problem, small land holding, repair and maintenance, system suitability, lack of awareness and trainings, absentee land owner and non-feasibility in the respective area. These constraints in the above categorization were similar as recorded by professionals of different departments. These professionals included representatives from OFWM, agricultural extension and SSCs. According to professional's perceptions, financial issue alike non-adopters remained major constraint in the adoption process. Professionals further emphasized that most of the non-adopters were highly motivated from HEIS but they did not adopt it merely due to lack of financial assets.

DESCRIPTIVE RESULTS

***Socioeconomic characteristics*:** The social and demographic characteristics are important for adoption and operation of HEIS. Quantitative results of different socio-economic and farm characteristics variables are presented in this section of study. As discontinued category was merged into adopters as they were once adopters of HEIS (drip and sprinkler) and their demographic characteristics did not show any substantial difference compared to adopters. However, Table 3 shows average values of socio-economic and demographic characteristics of adopters and non-adopters of HEIS. This shows the data based on mean values of continuous variables including age, farming experience, level of education as schooling, family size, distance from market and operational land holding.

Table 3. Average characteristics of adopters and non-adopters (continuous variables)

General Information	Category	
	Adopters N=111	Non-adopters N=86
Age (years)	43.0	52.0
Farming Exp. (years)	13.3	16.9
Schooling (years)	11.2	7.3
Family Size (no.)	7.3	8.8
Distance from market (km)	15.5	20.1
Operational land holding (acres)	62.3	19.2

The data analysis indicated that average age of HEIS adopters was 43 years respectively, as compared to non-adopters of HEIS having age of 52 years. Alike age variable, summary statistics explained that young adopters possessed less farming experience (13 years) compared to their counterparts (17years). The results showed that adopters of HEIS had higher education level i.e. 13 years of schooling compared to non-adopters having 7 years of schooling. This shows that education is a crucial factor as it enables them to learn and adopt drip irrigation. Moreover, better educated farmers tended to be more innovative and can use the resources efficiently (Fakoya *et al*., 2007).

It is evident from the Table 3 that average number of family members in adopter's category was less as compared to non-adopters i.e. 7 and 9, respectively. The results further depicted that non-adopters were far distant from market i.e. 20 km. On the other hand, average house hold's distance for adopters was 15 km from their farms to input/output market. The summary statistics also shows that adopters possessed average large land holdings (averg. 62 acres) compared to their counterparts (19 acres). Larger land holdings show financial conditions, which seem to be crucial factor in adoption of HEIS.

***Factors affecting adoption of HEIS*:**

Full Information Maximum Likelihood (FIML) technique estimates of endogenous switching regression are presented in Table 4. This table is drawn from preceding results given in Table 3. The results of other variables (Categorical) included in the model are given in Table 5 and Table 6. In this model, two dependent variables such as adoption and average net revenues were employed. One having value 1 for the farmers who adopted the HEIS (N=96) and 0 for non-adopters (N=86). The other dependent variable was net revenues calculated as difference of total revenue and total cost of production. The independent variables drawn in this model were taken from inferential as well as descriptive results (Table 4).

The empirical results of probability of adoption showed that education of farm decision maker significantly increased the probability of choosing HEIS. The results of FIML showed that coefficient of age was negative and significant, indicating

Table 4. Full information maximum likelihood estimates of the endogenous switching regression*(N=182)*.

Variables	Description	Adoption (1/0)	
		Coefficient	p – value
Age	Age in years of farm decision maker	-0.009	0.012*
Farm Experience	Years of experience of farm decision maker	-0.017	0.414
Education	Years of schooling of farm decision maker	0.040	0.045*
HH Size	No. of House Hold members	-0.043	0.210
HH Distance	Distance of farm from market	-0.015	0.428
Operat. Land	Acres of land used for cultivation	0.001	0.096*
Skilled Workers	Number of skilled operator	0.084	0.029*
Minor Location	1=Head, 2=Middle, 3=Tail	0.160	0.581
Soil quality	Quality of soil; 1= Low, 2=Medium., 3=High	-0.159	0.548
Primary occupation/ Presence at farm	1=Agriculture, 0= Off farm	-0.510	0.433
Contact professionals/ Backup support	1= Yes, 0=No	0.013	0.080*
Financial issues	1= Yes, 0=No	-0.560	0.001*
Log (sigma)		-1.407	0.000

Dependent variable: Adoption of HEIS and Net Revenue

Table 5. Tractor ownership and contact with professionals of adopters and non-adopters of HEIS in different zones (categorical variables on % basis)

Variable	Unit (Dummy)	Mixed Cropping N=43		Cotton-Wheat N=39		Thal N=42		Rice-Wheat N=30		Pothowar N=39	
		Ad. N=28	Non. N=15	Ad. N=21	Non. N=18	Ad. N=20	Non. N=22	Ad. N=17	Non. N=13	Ad. N=23	Non. N=28
Tractor	Own	93	87	90	67	95	77	88	77	83	56
	Rented	7	13	10	33	5	23	12	23	17	44
Regular contact	Yes	86	7	81	17	90	18	71	23	83	31
with profs	No	14	93	19	83	10	82	29	77	17	69

Ad.= Adopters, Non. = Non-adopters & N=Number of respondents

Table 6. Characteristics of farm location of adopters and non-adopters (categorical variables on % basis)

Variable	Unit (Dummy)	Mixed Cropping N=43		Cotton-Wheat N=39		Thal N=42		Rice-Wheat N=30		Pothowar N=39	
		Ad. N=28	Non. N=15	Ad. N=21	Non. N=18	Ad. N=20	Non. N=22	Ad. N=17	Non. N=13	Ad. N=23	Non. N=28
Irrigation	Canal	25	27	48	28	15	23	0	0	N/A	
system	TW	14	7	14	17	65	50	100	100	74	69
	[1]Both	61	67	38	56	20	23	0	0	26	0
	Rainfed	0	0	0	0	0	4	0	0	0	31
Location	Head	8	36	29	44	15	18	N/A		N/A	
(canal)	Middle	29	43	5	50	10	14				
	Tail	63	21	67	6	75	64				
Soil quality	Low	29	0	48	44	75	73	12	23	0	0
	Medium	57	80	48	22	10	18	53	15	4	50
	High	14	20	0	33	15	9	35	62	96	50

Ad.= Adopters, Non. = Non-adopters, N=Number of respondents& TW = Tube Well, [1] Both= Canal + TW for mixed cropping, cotton-wheat, Thal, rice-wheat & TW+Rainfed for Pothowar zone

that young farmers were more likely to adopt this technology as compared to old aged farmers. The education coefficient was positive and significant indicating that higher literacy level played a significant positive role in the adoption of HEIS. Educated farmers were likely to have more access to literature provided by different extension agencies on the benefits and managements of HEIS. Thus, education of the household head is a powerful source that lead farmers to adopt the HEIS.

Another important factor that affected farmers' decision to choose these systems was the ability to afford skilled labor. The study found that farmers who had permanent trained labor working at their farm, had significantly higher probability of adopting the HEIS. This is perhaps that the farmers who afforded to hire the skilled labor for operating the system at relatively more wage were more likely to adopt the system. Thus, availability of labor having technical knowledge could be another important factor towards enhancing the adoption process.

Financial issues were included in the model as dummy variable having 1 value for those who had financial issue whether it belonged to adopters or non-adopters and 0 for otherwise. The coefficient of this variable was found to be negative in magnitude and highly significant. This shows that more occurrence of financial issue decreases the chances of system being adopted by farmers. The financial issue for non-adopters contributed in the non-adoption whereas adopters also claimed this issue as increased cost of production when they changed their cropping pattern from conventional crops to vegetables. These empirical results in fact complimented those outlined under descriptive analysis.

Other variables in the model such as farm experience, family size, distance from farm to market, soil quality, outlet location and presence of decision makers at farm were found to be non-significant as they did not play any significant role in probability of adoption.

***Conclusions*:** The data analysis prioritized the factors as those financial issues, less backup support/repair and maintenance, intensive supervision, availability of skilled operator, small land holdings, absentee land-owner and operational problems were found as the main constraints in adoption of HEIS. The results of ESR analysis revealed that enabling environment including young farmers having more landholding, and access to education (formal and informal) with other indicators such as availability of skilled labors with high wages, contact with professionals and non-existence of financial issues increases the chances to adopt HEIS.

Recommendations: Keeping in view results of the study, following policy recommendations are made for policy makers, stakeholders and farmers with the purpose to overcome constraints for wide adoption of HEIS to improve crop productivity and net returns to farmers:

There is a dire need for creating awareness among the farming community. It is a need of the time to train and educate farmers regarding the HEIS so that dissemination and adoption of HEIS can be ensured on sustainable basis. Capacity building of the implementing team is necessary, which, in turn, can train farmers on the use of drip irrigation system (design, routine operation and maintenance). In this regard, master trainer can be trained in each district/tehsil and should be well-equipped with the latest technology and techniques of HEIS. Agricultural extension department, government of Punjab and Center for Advanced Studies in Food Security and Agriculture (CAS-FSA, UAF) can play an effective role in this regard without any extra financial liabilities.

The data analysis showed that adopters of HEIS were facing problems of backup support to keep HEIS functional as well as make it profitable. For this purpose, professionals and suppliers should ensure the backup support to solve technical issues, misconceptions and R&M including timely provisions of good quality material. The mobile field workshops can be established to provide backup support for drip irrigation scheme. For sustainability, emphasis should be given beyond provision of water management services to include productivity and profitability per unit of water applied. As an outcome of the study, one of the major recommendations is the need for technical back up support.

There is a dire need to indigenize the manufacturing of drip irrigation components and parts locally so that it becomes cheaper and easy to provide spare parts at village level. Service centers in rural areas need to be established for providing training as well as backup support for repair and maintenance to the needy farmers. The focus of trainings should be given to such workers who can continue to serve at farm for long time. The government should encourage local manufacturers to stock spare parts for drip and sprinkler systems by making the initial orders and signing supply contracts. The systems should be designed simple, cost effective with preference given to local manufacturing.

Financial solutions should be sought to address the financial constraint. For this reason, subsidy should be increased to address this issue. Potential and interested farmers could also be provided loans on easy installments. The microfinance or the cooperative credit schemes can be proven helpful in this regard.

There is a need to provide enabling environment in the form of Public Private Partnership (PPP) joint venture for providing comprehensive training starting from repairing and maintaining the system, applying ISO-certified best management practices to grow vegetables and fruits leading to export including irrigation scheduling, fertigation, processing, packing, storage, transport in the form of value chain. More efforts should be made for those areas where HEIS is more feasible as per climatic, soil and water conditions, marketing rather to fulfill the targeted numbers only.

All market-oriented greenhouses for high value crops should be encouraged to include drip systems, since this low additional investment can bring high and immediate returns, which motivates the farmers to take proper care of the systems. Solar powered drip irrigation for tunnel farming can also increase the productivity and will also generate employment opportunities for rural youth provided marketing of the tunnel produce is ensured and youth is trained fully at the demonstration and training farms.

Agro-processing zones should be developed by PPP to ensure storage, handling, sorting, packing, value addition and purchasing of farmers produce. It would provide access to small-scale farmers to export markets. Collective processing and marketing will cut costs and increase profitability. Adoption by farmers to high value crop production will enhance incomes of the farmers. Subsurface drip irrigation system can be practiced under deficit irrigation in water scarce areas. It will be more beneficial for these areas where surface drip irrigation system is unable to fulfill the crop water requirements in hot summer conditions while keeping in view the site specific soil and water conditions.

A task force may be established to manage the required resources for effective implementation of the aforementioned recommendations in true letter and spirit by engaging all the concerned stakeholders to create win-win situation.

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