

An Implementation of Waterlogging and Salinity Management Control Using Solar Tube Wells: A Comprehensive Case Study

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Abstract- The agricultural economy of Pakistan is severely affected by the twin menace problems including water logging and salinity. Nearly 75% of the population is dependent on the agriculture. There are several factors that contribute to the twin menace problems which include; improper drainage systems, high costs of diesel and electricity, recharge from field percolation, continuous enlargement of the irrigation system, and water logging and salinity operational and maintenance issues. This study was conducted to explore the salinity and waterlogging (twin menace) problems in Pakistan. To evaluate overall usefulness of Solar Tube well Research for the control of waterlogging and salinity problems in the Shaheed Benazirabad District. The implications of solar tube wells were found to be positive, in contrast to the diesel and electricity tube well. This exhaustive analysis for different hypothesis proved that the proposed method worked better for the control and management of salinity and waterlogging compared to other approaches.

Index Terms- Solar Tube well, SCARP Research, District Shaheed Benazirabad, Twin menace problems, Water logging, Salinity, Sindh, Pakistan.

I. INTRODUCTION

Water logging and salinity are known to be a severe twin menace problem faced by agricultural economy of Pakistan [2]. Pakistan is an agricultural economy; however, the twin menace problem has reduced the crop, fruits and vegetable yield to an intense level. This twin menace is causing deprivation for the farmers in Pakistan at an estimate value of 33 billion yearly, as 25% of their possible produce of key harvest is lost [1]. In Pakistan, Sindh province is severely affected with salinity and waterlogging issues [1, 3, 4]. Multiple factors contribute to the waterlogging and salinity concerns in Pakistan. These include: leakage from earthen canals that are unlined, recharge from rainfall, continuous enlargement of the irrigation systems, blockage of drainage systems, and discharges from the drainage system into main field percolation [1]. Farmers on the contrary, are facing a myriad of challenges in the different provinces of Pakistan. They are having limited resources and authority to deal with these concerns. There is a discerned level of awareness

amongst the farmers and lack of effective strategies to cope up with the water logging and salinity challenges. There is a need to explore the challenges faced by the farmers in the discipline of water logging and salinity.

Previous literature has shown that water logging and salinity concerns can be resolved through various methods including integration of tube wells [5-7]. In Pakistan in late 1960s, SCARP was introduced and was used for large scale groundwater extraction and for irrigation/agriculture purposes by reducing soil salinity in Indus Basin Irrigation system [8, 9]. In the current scenario, tube wells are being operated in three ways. Firstly, there are electricity tube wells that are operational with the support of electricity [10-11]. Then there are tube wells that are operational through fuel or gas. Lastly, there are tube wells that are operating by means of solar energy. The first two types of tube wells demand non-renewable resources that are highly costly. Mostly farmers face a challenge of unavailability of fuel or electricity and the crops are suffering. On the contrary, the solar tube wells system is easy to install, and less costly [3]. The resources are depleting rapidly and there is a need to focus on the solar energy / non-renewable resources to deal with the water logging and salinity concerns. Solar Tube wells are the most reliable, economic, environmental and viable solutions in comparison with Diesel and Electrical tube wells [12]. In the current scenario, the agricultural sector of Sindh Province is affected badly due to the dilemma of water logging and salinity concerns. Unfortunately, due to Power/Electricity shortages, operational and maintenance challenges, administrative and governance concerns in SCARP tube wells have further added to this problem [8, 13]. These challenges have diverted the attention towards the consumption of the Solar Tube wells for the discharge of underground brackish water in order to manage the agricultural activities on the fertile lands. The consumption of solar tube wells is solution to the water logging and salinity concerns in Sindh province. Limited research has been carried out in this perspective and therefore, this study brings evidence regarding the implications of solar tube wells in dealing with the twin menace concerns in Shaheed Benazirabad (SBA) district of Sindh.

The basic motive of this research paper is to analyze the awareness of farmers about the seriousness of waterlogging and salinity problems.

To examine the overall usefulness of Solar Tube well Research for the control of waterlogging and salinity problems in the Shaheed Benazirabad District.

To analyze the impact of Solar Tube wells in terms of agriculture yield increase and economic conditions of farmer's / land owners. Recommendations for the further improvement of this research especially in SBA District.

II. BACKGROUND (LIT REV)

This paper discusses the water logging and salinity issues in Pakistan and the usefulness of solar Tube well research in controlling them. The study brings evidence from Shaheed Benazirabad District. Operational and Maintenance issues, electricity concerns and other factors have already shown how the SCARP research for tube wells integration failed. This research was installed to reduce the twin menace concerns of waterlogging and salinity. Notably, SCARP research has shown great impacts in the agricultural sector; nevertheless, it's a major failure especially in Sindh province. Arguably, twin menace problems are increasing the infertility of the land and negatively influencing the agricultural economy. The land is disrupting with the salt water, as the drainage systems have loop holes. Poor drainage systems also play a vital role in the enhancement of salinity and waterlogging effects [14-16].

Salinity and waterlogging impacts the growth of the plants to a large extent and reduces the crops yield [2,17,18]. For instance, the production of Mango has reduced massively by 81% due to the water level depth between 0-1.5 m. Likewise; the salinity issues have significantly reduced the cotton crop yield up to 10%, 25% and 50% in the soils having salinity levels of 5.5, 7.4 and 10.6 dS/m, respectively [2]. In accordance with United Nations (FAO) Food and Agricultural Organization guidelines, if the salinity levels increases above 3000 mg/L, then it's inappropriate for public and agricultural employment [19]. Additionally, World Health Organization (WHO) guidelines recommend that a salinity concentration greater than 1000 mg/L is not suitable for humanly consumption [20].

Salinity Control and Reclamation Research (SCARP) was introduced to deal with the water logging and salinity concerns, in the IBIS system. In 1980's, the program helped in the dissemination of the tube wells and successfully reduced the water level up to 1.5 m in a region of 2 million ha, and in a zone of 4 million ha by 3m, and thereby lessening problem of waterlogging considerably[8]. Further, this research has helped soils through the reduction of salt concentration or effects of such from 7Mha to 4.5Mha [1]. However, regardless of the success of SCARP research in managing the twin menace problems, there were many loop holes in this research. Lack of governance / research management in government owned institutions, operation and maintenance of the tube wells and most importantly the non-availability of electricity in rural areas are the key factors which have limited the operations of these tube wells. Particularly in Sindh province, the failure of SCARP research is more evident. In Sindh, SCARP has completed 11 researches in which total 4543 tube wells were installed. Out of 4543 tube wells, 2483 tube wells were installed under SCARP North Rohri Research Nawabshah (Shaheed Benazirabad). As per the 2013 updates, there are 900 tube wells that turn out to be non-operational [13].

III. PROPOSED RESEARCH DESIGN

The best way to counter the salinity and waterlogging problems in the agriculture / irrigation system with respect to power shortages issue in rural Sindh region, is to use Solar Tube wells. Solar operated Tube wells are the best option even in the comparison of Diesel & electrically operated tube wells. This study primarily explores the effectiveness of Solar tube wells for the control of salinity and waterlogging issue and adopts a quantitative research method. Both; primary and secondary methods of data collection are applied. Quantitative questionnaire was designed to collect the data from the research sites Deductive approach and positivism philosophy is applied to understand the twin menace challenges, specific to Sindh Province. Shaheed Benazirabad (SBA) District is the main sample of research, however, all provinces agricultural lands are the study population. The purpose of selecting SBA district is that this district has solar tube wells at multiple locations and have diesel / electrical tube well as well. Therefore, it is considered to be the best approach to study this area

The study included a sample of 48 individuals from 12 sites having solar tube well installations. From each site, a total of 4 people are surveyed using a quantitative survey questionnaire. These four individuals included: two farmers, one villager and one owner. In South Africa, Iraq etc previously same type of quantitative questionnaire based researches have been done to assess the impacts of salinity and waterlogging and analyze the awareness of farmer's knowledge about this twin menace problem [21-22].

The figure.1 below reveals about the current status of the water logging and salinity sites, in the SBA district. The analysis reveals that majority of the lands (60%) is affected with the twin menace problem for more than ten years.

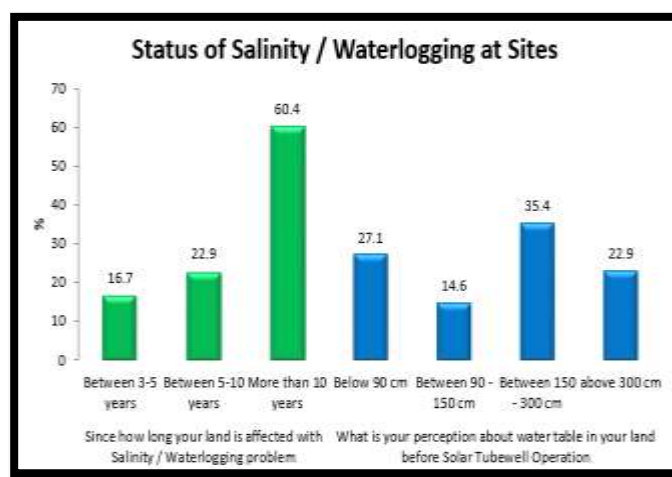


Figure 1- Status of Salinity / Waterlogging at Sites

Majority of the land (35%) is affected with the water table between <150 to 300 cm, before the installation of the solar tube well. Figure 2 below reveals about the reasons for the SCARP research failure. The major reason is the unavailability of power (43.8%).

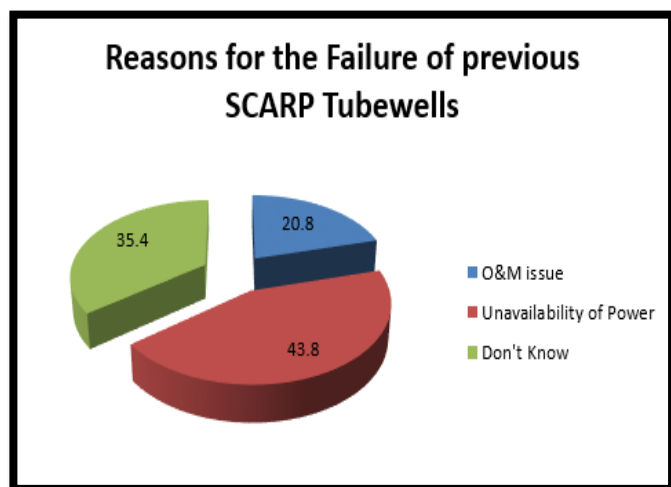


Figure 2 – Reasons for the Failure of Precious SCARP Tube well

IV. RESULTS & DISCUSSION

The graph below reveals about the drainage system at the site of investigation. The analysis reveals that most of the drainage systems are weak in nature (43.8%), while there are many areas having no drainage systems at all (10.4%).

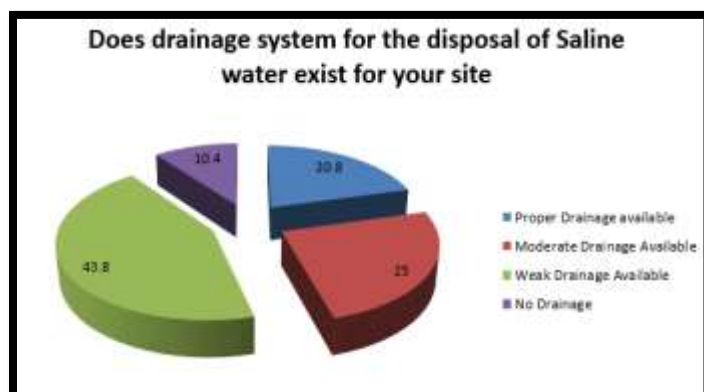


Figure 3 – Drainage system for the disposal of Saline water

Figure 4 reveals about the revenues earned by the farmers or farm owners after the operation of solar tube wells. The analysis reveals that 35.4% gained revenue in between 1 to 2 million, 25% gained between 2-5 million and remaining 39.6% gained revenue of above 5 million.

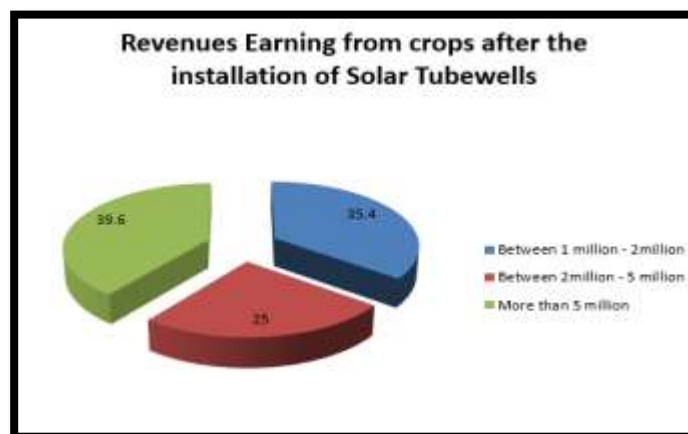


Figure 4 – Revenues earning from crops after the installation of Solar Tube wells

Figure 5 reveals about the difference in revenue earned, before and after the installation of the solar tube well. The highest revenue earned without the installation of solar tube well was 3,33,5000, on site 11. However, after the installation of the solar tube wells, the revenue has increased up to 7,700,000 at site 8, and as low as 2,500, 000. This is a remarkable outcome of the solar tube well installation at the Shaheed Benazirabad district.

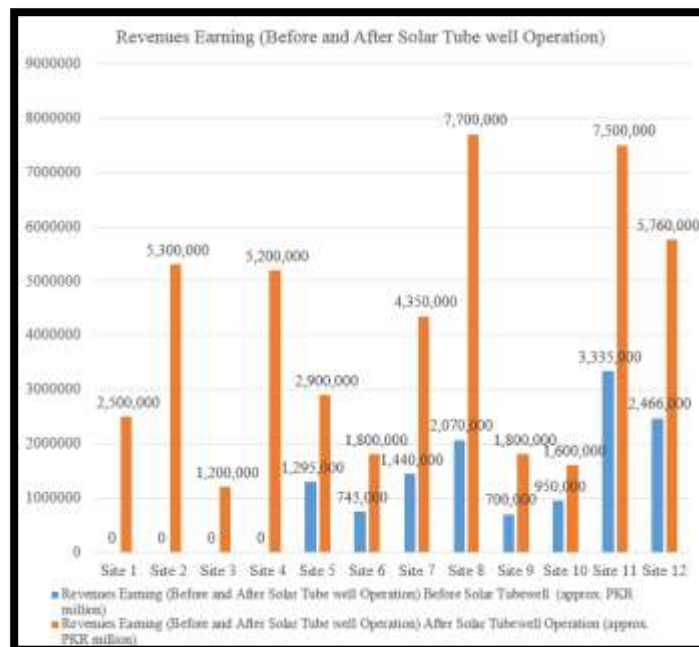


Figure 5 – Revenues earning before and after Solar Tube well Operations

The study explored the perceptions and knowledge of the farmers, regarding water logging and salinity problems. Table 1 reveals that majority of the respondents agree that twin menace problem is a threat to agricultural productivity (56.3%). Sadly, majority of the farmers had limited knowledge regarding these problems and how to deal with them (45.8%). Due to their ignorance, the analysis reveals that lands are facing twin menace concerns for more than ten years (60.4%).

Table 1- Perception and Knowledge on Salinity/ Waterlogging.

Questions	Ranges	n	%
What is your perception about water table in your land before Solar Tube well Operation	Below 90cm	13	27.1
	Below 90 -150 cm	7	14.6
	Below 150- 300 cm	17	35.4
	above 300 cm	11	22.9
Do you consider Salinity / Waterlogging as a threat for the agricultural productivity	Strongly Agree	27	56.3
	Agree	21	43.8
Do you have the knowledge of preventive and corrective measures for combating Salinity and Waterlogging	Slight Knowledge	22	45.8
	Moderate Knowledge	10	20.8
	No Knowledge	16	33.3
Since how long your land is affected with Salinity / Waterlogging problem	Between 3-5 years	8	16.7
	Between 5-10 years	11	22.9
	More than 10 years	29	60.4

The table below reveals about the cultivation of the crops; before and after the installation of the solar tube wells. The table reveals clearly that cultivation of crops (example; sugarcane & cotton, and cotton & wheat) increased after the installation of solar tube wells.

Table 2 - Information of Crops Cultivated in Lands

Crops	Before Installation and Operation of Solar Tube well		After Installation and Operation of Solar Tube well	
	n	%	n	%
Sugar Cane	—	—	—	—
Cotton	—	—	—	—
Wheat	—	—	—	—
Rice	—	—	—	—
Vegetable	—	—	—	—
Cotton and Wheat	9	18.8	8	16.7
Sugar Cane, Cotton and Wheat	4	8.3	4	8.3
Sugar Cane and Cotton	15	31.3	16	33.3
Sugar Cane, Cotton and Banana	4	8.3	4	8.3
Sugar Cane and Rice	—	—	4	8.3
Sugar Cane, Cotton and Rice	—	—	4	8.3
Not Applicable	16	33.3	—	—

Table 3 below reveals the outcomes regarding solar tube well consumption. Mostly, the tube wells installed previously were based on electrical (66.7%) or diesel (8.3%). These tube wells were less operational due to the electricity (43.8%) and diesel

(8.3%) shortages. The satisfaction level regarding solar tube well installation was explored during the study. The analysis reveals that 79.2% of the sample participants are very much satisfied with the sample.

Table 3 - Outcomes on usage of Tube well to Control Salinity / Waterlogging

Questions	Response	n	%
Did you ever use any Tube well at your land to control Salinity / Waterlogging	Yes	36	75.0
	No	12	25.0
Which type of Tube well was under operation before the installation of Solar Tube well	Electrical	32	66.7
	Diesel	4	8.3
	Not Applicable	12	25.0
Was your Tube well a Private Property or under any Government Research (SCARP)	Private	4	8.3
	SCARP Research	32	66.7
	Not Applicable	12	25.0
What was the reason for the failure /Non operation of previous Tube well	O&M issue	10	20.8
	Unavailability of Power	21	43.8
	Don't Know	17	35.4
How much you are convinced with the importance of this New Solar Tube well Research for your land.	Very Much	38	79.2
	Partially Satisfied	10	20.8
Does drainage system for the disposal of Saline water exist for your site	Proper Drainage available	10	20.8
	Moderate Drainage available	12	25.0
	Weak Drainage available	21	43.8
	No Drainage	5	10.4
Are you satisfied with the performance of this New Solar Tube well	Very Much	29	60.4
	Partially satisfied	19	39.6
Do you think there is some improvement needed for this Solar Tube well Research	Yes	48	100.0

The study tested three different hypotheses through the application of Chi-square test [23]. The results are discussed below:

V. HYPOTHESIS

A. Hypothesis 1

Ho1: Farmers don't have knowledge of preventive & corrective measures for water logging & salinity control

H11: Farmers have knowledge of preventive & corrective measures for water logging & salinity control

Table 4- Chi Square test analysis using SPSS for Hypothesis –I

Chi-Square Tests for Hypothesis - H01				
	Value	df	Asymptotic Significance (2-sided)	
Pearson Chi-Square	2.115	2	0.347	
Likelihood Ratio	2.139	2	0.343	
Linear-by-Linear Association	2.044	1	0.153	
No. of Valid Cases	48			

The results reveal that null hypothesis is accepted. The farmers are found to have limited knowledge regarding the water logging and salinity control measures.

B. Hypothesis 2

Ho2: Control of water logging & salinity is not dependent on the renewable energy source (Solar tube well) in comparison to the conventional energy sources (electrical & diesel TWs)

H12: Control of water logging & salinity is dependent on the renewable energy source (Solar tube well) in comparison to the conventional energy sources (electrical & diesel tube well).

The table below affirms that water logging and salinity concerns are greatly resolved through the solar tube well installation in Benazirabad district. Pearson chi square test is less than 0.000 which is less than 0.05 (level of significance), therefore concrete evidence is there to reject null hypothesis Ho2 and conclude that control of water logging & salinity is dependent on the renewable energy source (Solar tube well) in comparison to the conventional energy sources (electrical & diesel tube wells).

Table 5- Chi Square test analysis using SPSS for Hypothesis –II

Chi-Square Tests for Hypothesis - H02				
	Value	df	Asymptotic Significance (2-sided)	
Pearson Chi-Square	92.000	15	0.000	
Likelihood Ratio	95.045	15	0.000	
Linear-by-Linear Association	0.401	1	0.526	
No. of Valid Cases	48			

C. Hypothesis 3

H03: Farmers don't get economic benefits / agriculture yield increase with the operation of solar tube well

H13: Farmers get economic benefits / agriculture yield increase with the operation of solar tube well

The third hypothesis tested the impact of solar tube wells integration in increasing the economic/agricultural benefits for farmers and land owners. The analysis revealed statistically significant results with a p-value of 0.000. This affirms the researcher's hypothesis that solar tube well helps the farmers in their crop yield and increasing revenues.

Table 6- Chi Square test analysis using SPSS for Hypothesis –III

Chi-Square Tests for Hypothesis - H03				
	Value	df	Asymptotic Significance (2-sided)	
Pearson Chi-Square	33.020	6	0.000	
Likelihood Ratio	42.564	6	0.000	
Linear-by-Linear Association	12.445	1	0.000	
No. of Valid Cases	48			

VI. CONCLUSION

This paper revealed about the twin menace problems faced by Pakistan's agricultural sector. Evidence is brought from the SBA district of Sindh province. The analysis reveals that electrical and diesel tube wells were installed previously. However, the operational & maintenance challenges, high costs of diesel and electricity, and lack of farmer's knowledge on dealing with the twin menace problems have further worsen the situation. The study affirms that solar tube wells have many implications for farmers. The very important conclusion of the study is in form of crop growth and revenue earning, after the installation of the solar tube wells. To some extent, the solar tube well, has positively influenced agricultural economy by increasing the crop yield. However, the current number of solar tube wells installed are considerably lower. There is a higher need to install solar tube wells, in the areas of Sindh having severe water logging and salinity concern.

VII. RECOMMENDATION

Future researchers can investigate the influence of solar tube wells in the other districts of Sindh including; Badin, Larkana, Dadu, Thar and Khairpur, where the twin menace problems are at peak. The poor drainage and improper implications of SCARP researches can be further studied to resolve. A SWOT analysis based on the current research is discussed below:

Table 7–SWOT Analysis Table

	Weakness
• Installation of solar tube wells increases crop yield. • Increase revenues and support the economy. • More and more solar tube well researches at effected site will maximize the agricultural yield and economic growth in Sindh province. • No consumption of electricity or diesel as required by previous.	• Lack of knowledge and perceptions of the farmers about Salinity / waterlogging. • Stagnant governmental policies • Lack of government funding to initiate further researches of Solar tube wells for waterlogging / salinity affected sites. • Nonexistence of Public-Private partnership model from the government side for the future Solar tube well research.
Opportunity	Threats
• Low cost of solar panels is an opportunity • Solar tube wells are a form of non-renewable resource that doesn't require larger quantities of diesel and electricity. • Decreasing trend of solar tariffs and solar energy related items will minimize the capital cost of solar system installation at sites.	• Improper drainage if not controlled with appropriate policies and strategies can lead to serious challenges for Pakistan's economy • Bad Research Management and unnecessary delays in research completion. • Lack of training to farmer / land owners to tackle O&M issues (after the handing over of Solar tube well sites over to land owners). • Installation of Solar tube wells at sweet water sites which is totally against the objective of the research. This is due to the lack of due diligence and strict control /monitoring procedures.

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