Soil & Environ. 27(1): 105-108, 2008

An economic evaluation of negative impact of water-logging and salinity on wheat productivity

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Abstract

Water is the mainstay of agricultural economy of Pakistan. Irrigated agriculture provides 90 percent of our food and fiber requirements from 42.5 million acres that is around 80 percent of the cultivated area. The Indus basin irrigation system has a very large set-up and the Indus river delta is the seventh largest in the world. It involves a complex network of three large reservoirs, 16 barrages, two head works, 12 inter-river link canals, 44 canal systems and over 107,000 watercourses. Although the development of irrigation system has increased the productivity overtime but has also caused the problems of water-logging and salinity. These are the major problems limiting crop production in Pakistan. The present study has analyzed the impacts of water-logging and salinity on wheat productivity and ultimately on farm incomes by using econometric approach in District Muzaffargarh, Punjab-Pakistan. Results showed that salinity and water logging were negatively associated with wheat production. The co-efficients of sodium and chloride were negative but non-significant but the co-efficient of saturation percentage was highly significant.

Key words: Economic evaluation, negative impact, wheat productivity, water-logging, salinity

Introduction

Land degradation due to water logging and salinity, has recently become a global and urgent issue and is now being considered with high priority, especially in the developing counties, to meet food and fiber demands of accelerated population pressure with the limited available resources. Secure balance in the global supply and demand for food has forced humans to develop agriculture in semi-arid to arid lands, which are generally less suitable for agriculture and sensitive to environmental changes. Irrigation systems have always been considered as an effective way of increasing agricultural production since ancient times to bridge the gap of water shortage. Owing to irrigation systems, the farmers have obtained quite stable productivity but they started facing an acute problem of water logging caused by the very high water table even water standing on the surface of earth and salinity due to residual salts accumulated on earth surface by seepage from the huge system in most of the developing countries. The farmers and many local and international organizations are trying to rectify the so-called "white death" *i.e* salt accumulation on soil surface of lands. Land degradation due to water logging and subsequent salinization has been so enlarged that it is now being regarded as a global environmental problem. It is, therefore, important to monitor land and water management scenarios causing severe land degradation and low productivity (WAPDA, 1997).

According to the FAO (2000) Land and Plant Nutrition Management Service, over 6 percent of the world's land is affected by either salinity or sodicity. The term salt-affected refers to soils that are saline or sodic, and these cover over 400 million hectares. Much of the world's land is not cultivated, but a significant proportion of cultivated land is salt-affected. Out of current 230 million ha of irrigated land, 45 million ha are salt-affected (19.5 percent) and of the 1,500 million ha under dry land agriculture, 32 million (2.1 percent) are salt-affected to varying degrees (Ghassemi *et al.,* 1995).

Agriculture is the mainstay of Pakistan's economy. It accounts for about 21 percent of the gross domestic product and generates about 65 percent of Pakistan's total foreign exchange earnings (Government of Pakistan, 2007). The salt affected area in Pakistan is 6.67 million hectares (Khan, 1998), of which 80 percent lies in Punjab. About 60 percent of total salt affected area in Pakistan is saline-sodic in nature (Muhammad, 1983). Each year 0.2-0.4 percent of the total arable land in Pakistan is being put out of cultivation because of salinity and water logging (Sandhu and Qureshi, 1986). But according to the Govt. of Pakistan, in 2003, the total area under salinity and water logging was 6.14 million hectares (Government of Pakistan, 2006).

Land salinization is one of the major desertification processes in Pakistan; about 6.14 million hectares are affected. About half of this lies in the canal command area. Salt has always been part of Pakistan's environment. The Indus Plain is composed of alluvial sediments, which were deposited by rivers into a shallow sea. The receding sea has left behind residues of salt, both in the soil profile and in the

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groundwater aquifer. In addition, weathering of parent rocks can release significant amounts of salts into the soil.

Accumulation of salts at the soil surface is characteristic of arid and semiarid environments, especially where pumped groundwater irrigation is practiced. Salinization occurs both naturally (primary salinity) and as a result of human activity (secondary salinity) (Sandhu and Qureshi, 1986).

Primary salinity on the Indus Plain occurs around the margins of natural depressions in the landscape where rain and floodwater accumulate. These soils become loaded with salts because of the movement of water by capillarity to the soil surface. Land affected by fossil salinity is generally severely saline and is not easily reclaimed. Secondary salinity on the Indus Plain is all related to the development of the modern irrigation system in Pakistan. There are three causes of secondary salinity i.e seepage from irrigation canals, high salt concentrations in irrigation water and insufficient leeching of salts (Ghassemi *et al.,* 1995).

The extent of damage to yield depends heavily on the stage of development as well as on more obvious factors such as duration of water logging and temperature. For most crops, seed germination is probably the most vulnerable, reflecting both the fast metabolic rate of germinating seeds being coupled with complete inundation. Studied examples include peas (Jackson, 1983) and temperate cereals (Lynch *et al*., 1981). Problems are exacerbated if germination takes place in association with decomposing organic matter such as straw residues from the previous crop. Seeds of rice are exceptional in being able to germinate in flooded soil without oxygen.

Water logging and salinity have very adverse social (like migration and diseases) and economic effects (reduction in crop production and increase in poverty) on communities in Pakistan, causing poor living standard in affected areas, health problems for humans and animals, crumbling of mud and brick houses and difficulty in transport. Many people are forced to migrate to other areas (Sandhu and Qureshi, 1986). The paper aims at to study and report the effect of water-logging and salinity on wheat productivity by using econometric approach.

Methodology

The present research was conducted to assess the harmful impacts of water infrastructure, causing water logging and salinity, which ultimately decreased production of wheat crop. In this regard Tehsil Kot Addu was selected from District Muzaffargarh of Punjab. District Muzzafargarh was selected purposively after thorough discussions with officials of agricultural department. The district has wide spread problem of water logging and salinity. It was also one of the key producers of wheat crop. Tehsil Kot Addu was selected randomly from the district.

The study was based on primary data, collected from field survey. Total number of farmers selected for study was 100. The choice of the area for research was made after consultation with the concerned staff of Agriculture Department, working in the region. The selection of site was purposive in nature. All of the area under study was canal-tube well irrigated. Wheat, rice, sugar cane, cotton and barseem were the main crops grown in the area. A major portion of agricultural land was under water logging and salinity. Negative externalities of water infrastructure and their impact on wheat productivity were contributed by non-comparable and non-additive sources. Information on various agricultural and socio-economic aspects was collected by using a pre-tested questionnaire.

Model specifications

In order to determine the relative contribution of different production inputs to output, the data was subjected to production function analysis. For this purpose, yield of wheat output in mounds was considered as a function of seed rate (SR), No. of irrigations (Irri), No. of bags of DAP (DAP), No. of bags of urea (Urea), cultivated land (CL), Saturation Percentage (SP), amount of Sodium (Sod) and Chloride (Chlo). Linear, Quadratic and Cobb-Douglas types of production functions were tried for wheat crop, which covered the highest acreage. However Cobb-Douglas type of production function gave better results as indicated by the highest R square values, T. values, positive correlation, and significance of coefficients. To find the impact of different inputs on wheat yield, regression analysis was carried out by taking their natural logs.

The econometric model used is as under:

$$\ln Y = b_0 + b_1 \ln SR + b_2 \ln Irri + b_3 \ln DAP + b_4 \ln Urea + b_5 \ln CL + b_6 \ln SP + b_7 \ln Sod + b_8 \ln Chlo + e_t$$

Where;

Y = Yield of wheat crop in maunds

SR = Seed rate in kg acre $^{-1}$

Irri = Number of Irrigations

DAP = Number of bags of DAP acre $^{-1}$

Urea = Number of bags of Urea acre $^{-1}$

CL = Cultivated land in acres

SP = Saturation Percentage

Sod = Amount of Sodium in mg $^{-L}$

Chlo = Amount of Chloride mg $^{-L}$

b_0 = Intercept coefficient
b_1- b_8 = Coefficients to be estimated

e_t = Random error term

Results and Discussions

Source of irrigation in the sample area

The source of irrigation in the sample area was divided into three categories: Canal alone, Tube well alone and Canal plus Tube well. Due to the scarcity and non-availability of canal water no farmer had option of using canal water alone. Hence farmers using canal water alone were zero percent; tube well water alone was used on 63.69 percent sample area (944 Acres) or by 68 percent farmers and the area under canal plus tube well irrigation category was 36.31 percent area (538 Acres) or by 32 percent farms, as shown in Table 1.

Table 1. Source of irrigation in the sample area

Source of irrigation	**Area of the farm**		**No. of farms**	
	Acres	**%**	**No.**	**%**
Canal Alone	0	0	0	0
Tube Well alone	944	63.69	68	68
Canal + Tube Well	538	36.31	32	32

Cultivated land types

The total cultivated land was subdivided into four categories: saline, waterlogged, non-saline, and non-waterlogged. The results show that 17.48 percent cultivated sample area was saline, 80.4 percent water-logged (WL), 0.69 percent non-saline and 1.39 percent non water logged, as shown in Table 2.

Table 2. Cultivated land types

Saline (Acres)	Share (%)	WL (Acres)	Share (%)	Non- saline (Acres)	Share (%)	Non WL (Acres)	Share (%)
250	17.48	1150	80.41	10	0.69	20	1.39

Laboratory observations

For the better evaluation of the problem under study, laboratory analysis of soil and water samples of the affected farmers were also under taken. The average results are shown in Table 3 and 4 below.

Table 3 shows the laboratory results of the water samples taken from the respondents of the study. Results of the soil samples taken from the study area have been discussed in the Table 4. Results of the water samples indicated that in the study area there was a severe problem of salinity indicated by the Sodium percentage, EC and SAR. Soil analysis showed that majority of the soil texture was loamy with an average pH of 8.2. So the saturation percentage of the soil can play an important role in determining the wheat yield.

Table 3. Lab analysis of irrigation water

Item	**Unit**	**Value**
Electric Conductivity (EC)		2250
Ca +Mg	mg $^{-L}$	7.03
Sodium	mg $^{-L}$	15.49
Carbonate	mg $^{-L}$	0
Bicarbonate	mg $^{-L}$	9.95
Chloride	mg $^{-L}$	6.02
Sulphate	(%)	8.47
Sodium absorption ratio (SAR)		6.68
Total soluble salts	(%)	0.342

Table 4. Lab Analysis of soil

Item	**Unit**	**Value**
Soil Alkalinity or Acidity	pH	8.47
Loam	No.	62
Sandy loam	No.	38

Production function analysis

To determine the factors affecting the production of wheat, data was analyzed by using the double log (log-log) production function because it gave promising results as compared to other functional forms. Results of analysis with wheat production as dependent variable and quantities of important inputs as independent variables are presented in Table 5.

The value of coefficient of seed rate was 0.177 with positive sign and was significant at 90 percent confidence level. Results show that with 1 percent increase in seed rate, output increases by 0.177 percent. The coefficient of No. of irrigation was positive and significant with value of 0.292. The coefficient of No. of bags of DAP shows that with increase of 1 percent use of this fertilizer increase the wheat output by 0.088 percent. One percent increase in the use of urea fertilizer also increases output by 0.057 percent. The coefficient was significant at 90 percent confidence level. The value of coefficient of cultivated land was 0.061with positive sign and was significant at 95 percent level. The coefficients of saturation percentage (SP), amount of sodium (Sod) and chloride (Chlo) were all negative as par expectations. All these three variables had negative impact on wheat production. The co-efficients of sodium and chloride were negative but non-significant but the co-efficient of saturation percentage was highly significant. The results are in accordance with the results of previous studies like World Bank (1999) and Alam (2002).

Table 5. Estimates of model

Variables	Coefficient	SE
Constant	1.013	0.168
lnSR	0.177*	0.095
lnIrri	0.292**	0.051
lnDAP	0.088**	0.033
lnUrea	0.057*	0.030
lnCL	0.061**	0.030
lnSP	-0.050**	0.017
lnSod	-0.022^{ns}	0.028
lnChlo	-0.014^{ns}	0.010

* Significant at 5 percent, ** Significant at 10 percent,
^{ns} non significant or significant at more than 10 percent
R. Square (R^2) = 0.708
Adjusted R Square = 0.682
F. Value = 27.57

The value of adjusted R Square (R^2) was 0.68, showing that about 68 percent variation in the wheat production was explained by the predictor variables included in the model. The overall result of the model was also significant as was shown by F-value.

Conclusions and Policy Recommendations

On the basis of the results of the paper, the following policy recommendations could be forward for considerations.

- Water logging and salinity both have negative impacts on the wheat productivity. Therefore adoption of new salt tolerant varieties which can grow in high water tables should be developed.
- Water logging in most of the cases can be controlled through good water management practices like lining of the canals / water channels (upto the tertiary level), efficient field application techniques etc. By adopting these modern technologies we can, not only reduce the chances of water logging but also save water.
- Further strengthening of the Extension Services in the area could guide farmers how to control the water-logging and salinity problems.
- Provision of subsidies on soil reclamation activities could also encourage farmers to adapt those technologies.
- Usage of more seed rate is also recommended because high salts and water-logging conditions can cause low germinations.
- Availability of laboratory facilities is needed at Tehsil level, so that farmers could have access to those facilities for testing their soils and water samples.

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