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Water energy and economic analysis of wheat production under raised bed and conventional irrigation systems: A case study from a semi-arid area of Pakistan

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ABSTRACT

The project's aim was to reduce Pakistan's water use and consequently its costs in semi-arid crop production system by increasing awareness, benchmarking water use and targeting practical solutions for optimising water use with raised bed irrigation system. The aim of this study was to compare water as well as energy used in wheat production on raised bed (RB) and conventional farming systems in Pakistan in terms of energy ratio, energy and water productivity and benefit/cost ratio of the two systems. The values of all energy inputs and output were converted to energy farm. Economic analysis was performed for each crop. The total energy requirement under RB farming on two understudy sites were 3653 kWh ha^{-1} and 4455 kWh ha^{-1}, whereas 3910 kWh ha^{-1} and 4752 kWh ha^{-1} were consumed under conventional farming, i.e. 6% higher energy inputs were used on conventional farming than RB farming system. Average energy ratios of 6.3 and 4.6 were achieved under the RB and conventional farming systems, respectively.

The main conclusion of the study is that in RB farming system, water, seed and fertilizer energies applied were properly utilized but in the conventional (basin) system some parts of the applied energies vanished due to many reasons.

1. Introduction

It is a well-known fact that nothing is more important to human beings than sustainable and reliable food production. In this respect availability of water and energy is and will continue to be an important foundation in agriculture that can assure sustainable and reliable food production. However, the conservation and management of water and energy are the two key issues for researchers who need proper consideration to reduce the cost of these two commodities in such a way that the reduction in price should not result the decrease in agricultural productivity.

Pakistan has experienced a golden era of water resources development during eighties with well-developed canal irrigation system. However, time to time droughts lower down the outcome which could have been achieved in the presence of this marvellous system; the country hardly could come out from eye opening shock of drought, which remained almost 3 years (1999–2002). The drought caused the over use of ground water, which required energy (the country is deficient in this commodity) (Economic Survey of Pakistan, 2008-09). Moreover, it has been noted that water availability to agriculture is expected to fall from 72% in 1995 to 62% by 2020, globally, and 87% to 73% in developing countries (Khan et al., 2006). In agrarian country like Pakistan, agriculture without water or acute shortage of water will have detrimental effects on economy, as the agriculture sector directly contributes almost one-fourth of its GDP and engages more than 40% of the total employed labour force of the country (Economic Survey of Pakistan, 2008-09).

Traditionally crops, especially wheat, in Pakistan are sown on flat basins which are flooded for irrigation. Conveyance and deep percolation losses causing water shortage to crops associated with overexploitation of groundwater has prompted a search for alternative methods of water application to the crops, like raised bed (RB) technology, to meet agricultural water demand.

It is believed that RB technology was first adopted for the wheat crop to save water in Mexico (Sayre and Hobbs, 2004). In Yaqui Valley of Mexico almost all farmers adopted furrow-irrigated bed planting systems for more or less all crops in the last more than 30 years.

In around 1998 the technique of planting various crops, including wheat, on raised bed with irrigation water confined to furrows between the beds was imported to Pakistan from Australia under Australian Centre for International Agricultural Research (ACIAR) program. With this program studies were conducted under a national project to simulate the adaptation of raised bed in wheat, maize and cotton crops in the country.

Besides water saving for the crops, this water application method was also considered as one of the causes of reduced water

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logging and improved seed rate of crops (Hobbs et al., 2000; OFWM, 2002; Talukder et al., 2002; Sayre and Hobbs, 2004). Therefore, it is popular in many developed countries including Australia (Fischer et al., 2005). RB faming system was also considered as energy saving technology, due to improved methods of mechanical weeding and fertilizer application (as water along with fertilizer is delivered more efficiently to the root zone of plants in RB system than many other forms of irrigation system). RB technology also reduced lodging and consequently facilitated harvesting. Singh et al. (2009) understand that the additional benefit of the technology includes zero or reduced tillage and consequently reduction in diesel, labour and machinery cost, with improved soil structure in wheat–rice crops production system. However, almost all the authors confined their studies to see the water saving in RB system of irrigation; whereas, energy is equally an important aspect for study in the system while comparing it with tradition basin method. Moreover, these authors and many other restricted their studies to see the merit of RB. There is no doubt that RB system has been proved better system than basin in many studies but what the demerits of basin are and what the benefit we can take with those demerits, is a big question mark.

A study was conducted with the aim to evaluate the performance of water and energy parameters of raised bed irrigation system for the production of wheat grown on two sites (Mardan and Swabi) of the NWFP, Pakistan having some what different soil conditions. The specific objective of the study was to examine and compare water and energy consumption in crop production operations, in raised bed irrigation system and basin irrigation system, and in result of production process, out put of the crop (grain and biological yields), and water and energy use efficiencies for the above-mentioned irrigation methods. The economic budget provided information in terms of monitory inputs and outputs on farmer side.

2. Materials and methods

The study was conducted on farmer's fields pairs, each of which consists of one raised bed and one conventional irrigation system, i.e. basin, in the two districts (Sawabi and Mardan) of the North West Frontier Province (NWFP) with different soil textures. Each farm pair shared almost a similar biophysical and socioeconomic environment due to their proximity. Since there were fewer raised bed farms than conventional farms in the area, raised bed farms were identified first, followed by selecting comparable nearby conventional counterparts. The conventional farms were selected primarily according to closeness to their respective raised bed counterparts.

Pre-testing of the questionnaire forms prepared was done in some local areas. Therefore, the application of the survey forms facilitated providing sufficient information for the aims of the study. Data were collected for the crop period of 2008–2009 via repeated semi-structured interviews with producers and corroborated with farm visits.

Overall climate of the project locations is arid to semi-arid subtropical continental with mean seasonal rainfall of 200–250 mm in summer (May–September) and almost 300 mm during winter (October–April). The soil texture class and other physical and chemical characteristics of soils of the two sites are given in Table 1.

2.1. Energy analysis

Generally, 50 HP tractors were used for tillage and other cultural practices on both production systems. Soil cultivation activities were performed mainly between November and May. On the farms of Mardan, irrigation source was canal water while on the farms of Sawabi, the irrigation was done with tube-wells. The farmers have installed centrifugal pumps for irrigation. The farmers in these areas usually own electric motors (mostly 7.46 kW) to power irrigation pumps. In some part close to banks of the nearby canal, farmers have diesel engine to power centrifugal pumps usually from November to May. The water table in this area ranged from 3 m to 10 m.

For the calculation of energy inputs from human labour, the product of man hours and the estimated rated power was used. Human labour was rated at 0.075 kW (Panesar and Bhatnagar, 1994). To calculate energy inputs from electric motor, the product of number of motor hours, power rating of a motor and load factor

Table 1
Some physical and chemical properties of soil layers at the two experimental sites.

Location Mardan

Depth (cm)	Texture	EC (mS/cm)		Soil pH	
		Mean	Standard deviation	Mean	Standard deviation
0–10	Clay loam	0.45	0.026	7.40	0.000
11–20	Clay loam	0.40	0.020	7.35	0.058
21–30	Loam	0.38	0.025	7.35	0.058

Depth (cm)	Texture	Organic matter (%)		Available phosphorus (ppm)		Available potassium (ppm)	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
0–10	Clay loam	0.96	0.087	6.27	3.555	268	12.583
11–20	Clay loam	0.83	0.086	5.81	3.490	253	9.574
21–30	Loam	0.71	0.066	5.40	3.315	240	18.257

Location Sawabi

Depth (cm)	Texture	EC (mS/cm)		Soil pH	
		Mean	Standard deviation	Mean	Standard deviation
0–10	Loam	0.39	0.003	7.60	0.028
11–20	Loam	0.32	0.015	7.70	0.038
21–30	Loam	0.18	0.028	7.70	0.038

Depth (cm)	Texture	Organic matter (%)		Available phosphorus (ppm)		Available potassium (ppm)	
		Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
0–10	Loam	0.67	0.007	4.88	0.023	90	1.708
11–20	Loam	0.52	0.003	4.20	0.638	70	12.247
21–30	Loam	0.78	0.041	4.15	1.737	50	4.500