Original Research Article

Cost-Effectiveness and Water Use Efficiency of Groundnut and Wheat under SAT region of Central India

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ABSTRACT

The field experiment was conducted in Parasai–Sindh watershed to evaluate the groundnut yield (rainy season crop), water use efficiency (WUE) and economic value under different topographic condition of watershed, to improve the yield of the wheat crop (winter season), irrigation scheduling of improved irrigation method was compared with the traditional irrigation method. This Experiment was conducted from rainy season 2012 to winter season 2013.

The study was designed to determine the WUE, gross and net return under water scarcity area. The average yield (1205.33 kg ha^{-1}); WUE [1.46 and 3.34 kg ha^{-1} mm^{-1} rainwater use efficiency (WUE_R) and effective rainwater use efficiency (WUE_{ER}), respectively] and benefit: cost (B:C) ratio (2.12) of groundnut were higher in upland as compared with lowland of watershed. Under sprinkler irrigation the yield and B:C ratio of wheat were improved 21.37 and 43.86 % respectively as compared with conventional system (surface irrigation). Sprinkler system of irrigation resulted in 32.21 % less water used and 126.45 % more economic water productivity (WPE) over conventional irrigation method in wheat.

Keywords: Cost-Effectiveness; Irrigation scheduling; Productivity; Water Use Efficiency; Economic water productivity.

1. INTRODUCTION

In the semi-arid region, the uncertainty of dryland agriculture is high due to low and unpredictable rainfall, poor or steep land slope and short cropping period. In arid and semi-arid regions agricultural production will improve if investments are made in soil and water conservation to improve soil fertility, enhance soil moisture status and use of stored water as supplemental irrigation in critical growth stages [1]. In India, approximate 66% of the total cultivated area comes under dryland agriculture and it produces nearly half of the total agricultural output [2]. In general, under dryland condition, 48% food crops are grown while 90% of sorghum as well as millets and 75% of pulses are grown. Therefore, dryland areas are important for the economy of the country and also need to continue in the future. The production potential of dryland system has continued to be low as a result of frequent drought due to high variability in rainfall (amount and distribution) during the growing season, low soil fertility, low plant nutrient use efficiency, small size of farm holding and poor socio-economic condition of the farmers [3].

Water is the most critical input for agricultural production. In India, Agriculture sector is likely to remain the major consumer of water but the share of water allocated to irrigation is likely to decrease by 10-15% in the next two decades. With the fast decline of irrigation water potential and continued expansion of population and economic activity in most of the countries located in arid and semi-arid regions, the problem of water scarcity is expected to be aggravated [4]. Recognizing the fast declining of irrigation water potential and increasing demand for water from different sectors, a number of demand management strategies and programs have been introduced to save water and increase the existing water use efficiency in Indian agriculture. Musick et al. [5] stated that the water use efficiency (WUE) is one of the most important indices for determining optimal water management practices. The term water use efficiency originated in the economic concept of productivity. Thus, water productivity is measured by the volume of water used by plant to produce unit amount of output. Improving water use efficiency and productivity on sustainable basis is an enormous challenge for semi-arid regions of the countries

Through India is food surplus nation at 2014-15 with about 252.00 million tonnes food grain production and expected food grains production during 2015-16 is 252.2 million tonnes [6]. To meet the future demand, need to better planning and resource management as well as intensification of crop production. It is anticipated that in India in the year 2025, total food grain demand will reach 291 million tonnes comprising 109 million tonnes of rice, 91 million tonnes of wheat, 73 million tonnes of coarse grains and 15 million tonnes of pulses against the limitation of expansion of the cultivable land area [7]. India has the second largest area of arable land in the world and is a major producer of a number of agricultural products. Wheat production increased by nearly 150% between the mid-1960s and mid 1970s and the country became self-sufficient in grain production by the end of the 1970s. The increase in agricultural production boosted rural incomes while also causing food prices to fall. This had the effect of reducing rural poverty [8].

The watershed approach aims to take full advantage of crop production with minimum water applied as well as minimized loses of irrigation and rainwater. The crop used here examined the financial implications of adopting each of the Kharif season (rainy season) and Rabi season (winter season) crops with improved irrigation system.

2. MATERIAL AND METHODS

2.1 General Description of Study Area

The field experiment was carried out at farmers' field of Parasai–Sindh watershed of Jhansi district during 2012- 2013. The extent of Parasai-Sindh watershed is 25º 23' - 25º 27' N and 78º 20'- 78º 22' E in Sindh river catchment. The remote point and outlet of watershed are elevated at 315 and 270 m above mean sea level, respectively. The geographical area of watershed is 1246 ha, comprising three villages viz. Parasai, Chhatpur and Bachhauni. The watershed experiences semi-arid sub-tropical climate and is characterized by dry and hot summer, warm and moist rainy season and cool winter with occasional rain showers. Long term weather data shows that the average rainfall in study region was 877 mm with about 85% falling from June to September. The mean summer (April-May-June) temperature has been recorded as 34ºC which may rise to a maximum of 46 to 49ºC during the month of May and June. The mean winter temperature (December-February) has been recorded as 16ºC. The soils of the watershed can be conveniently classified into three grouped viz., upland (red soil-locally *Rakar*) middle land (red soil- locally *Parwa*) and lowland soil (black- locally *Kabar* & *Mar*). In the watershed area, Rakar and Parwa soils dominate. Physico-chemical properties of soil are given below sand (71%), silt (12%), clay (17%), organic carbon (0.44) and bulk density (1.49 gm cc^{-1}).

2.2 Cropping Sequence

The geographical area of Parasai-Sindh watershed was classified in six categories viz. arable land, scrub land, ephemeral drain, road, residential and forest. under the watershed in arable land, the maximum area was covered by groundnut and wheat crops during rainy (Kharif) and winter (Rabi) season respectively (Figure 1). The groundnut trial, was done under the rainfed condition whereas wheat trial, was done under the irrigated condition. The recommended dose of fertilizer with manure was applied for both the crops and better agronomical practices were applied. After harvesting, the crop yield was examined in 9 m^2 area from five random locations and yield was calculated on per hectare basis.

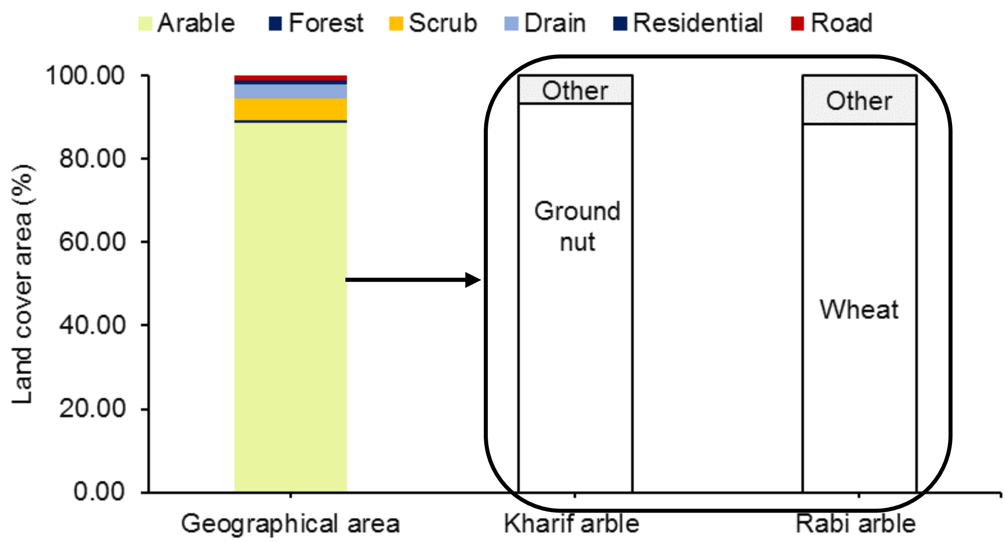

Fig. 1 Classification of geographical area of Parsai-Sindh watershed and arable area covers by groundnut and wheat

2.3 Estimation of Effective Rainfall

For the measurement of rainfall, the rain gauge was installed in watershed and daily rainfall was measured during growing season. The effective rainfall estimated by using U.S. Bureau of Reclamation method [9], which is recommended for arid and semi-arid regions. Percentage marks are given to increments of monthly rainfall ranging from greater than 90% for the first 25 mm or fraction thereof, to 0% for precipitation increments above some 150 mm (Table 1). Rahman et al. [10] was conformity of this method in semi-arid region of Bangladesh.

Table 1 Effective precipitation based on increments of monthly rainfall (U.S. Bureau of Reclamation method)

Precipitation Increment Range (mm)	Percent	Effective Precipitation Accumulated – Range (mm)
0.0 - 25.4	90-100	22.9 - 25.4
25.4 - 50.8	85-95	44.4 - 49.5
50.8 - 76.2	75-90	63.5 - 72.4
76.2 - 101.6	50-80	76.2 - 92.7
101.6 - 127.0	30-60	83.8 - 107.9
127.0 - 152.4	10-40	86.4 - 118.1
Over 152.4	0-10	86.4 - 120.6

2.4 Irrigation Scheduling in Wheat

There were two different irrigation treatments i.e. conventional (border/surface) and sprinkler irrigation was applied. In conventional method, there were four irrigations while in sprinkler method five irrigations were scheduled. The sprinkler spacing was 12 m × 12 m and at 2.0

kg cm^{-2} pressure, flow rate was 10.28 Lh^{-1}. Date and amount of water applied were estimated according to critical stages and available soil moisture in order to avoid crop water stress (Table 2). Irrigation was avoided if the precipitation was adequate. Irrigation was scheduled to match the soil water depletion. The water depth was calculated in order to bring the soil water content to its field capacity. Irrigation was applied at 50% moisture depletion. In conventional method, the irrigation amount applied was measured using V-notch weir with hook gauge arrangement.

Table 2 Irrigation scheduling of different irrigation methods under wheat

Method of Irrigation	Date of sowing	Date of irrigation	Amount of irrigation water applied (mm)
Conventional irrigation	4/11/2012	23/11/12	72
		19/12/12	85
		16/01/13	92
		10/3/2013	77
Total			**326**
Sprinkler irrigation	4/11/2012	22/11/12	39
		15/12/12	44
		8/1/2013	48
		31/01/13	48
		10/3/2013	42
Total			**221**

2.5 Estimation of Water Use Efficiency

Water use efficiency (WUE) is the amount of grain yield obtained per unit of water consumption [11]. Depending on the type of water sources considered, WUE is expressed as yield per unit of total water i.e. rainfall (seasonal and seasonal effective rainfall) and rainfall with irrigation, received during the crop growth period using equation [3, 12, 13].

$$WUE_R = \frac{Y}{SR} \dots (1)$$

$$WUE_{ER} = \frac{Y}{ER} \dots (2)$$

$$WUE_{IP} = \frac{Y}{I + SR} \dots (3)$$

where, Water use efficiency in kg ha^{-1} mm^{-1} of seasonal rainfall (WUE_R), seasonal effective rainfall (WUE_{ER}) and irrigation plus rainfall (WUE_{IP}); yield in kg ha^{-1} (Y); seasonal rainfall in mm (SR); seasonal effective rainfall in mm (ER), water applied through irrigation in mm (I)

2.6 Cost-Benefit Analysis

Due to different economic values and cost of cultivation of various crops, economic water productivity, EWP (INR m^{-3}) was calculated for *Kharif* 2012 and *Rabi* 2012-2013. Cost-benefit analysis is a systematic process and it is an important indicator for assessing economic feasibility of targeted interventions. Gross income generated from the agricultural outputs (grain or pod yield and Stover yield) was estimated from the market price. Subsequently, net economic returns (INR ha^{-1}) and B:C ratio were calculated with help of following equation:

$$\text{Net returns} = \text{Gross returns} - \text{Cost of cultivation} \quad \ldots (4)$$

$$\text{B : C ratio} = \frac{\text{Gross returns}}{\text{Cost of cultivation}} \quad \ldots (5)$$

2.7 Economic Water Productivity

The economic water productivity of crop was calculated by dividing the economic value of crop produce by per unit of consume water from planting to harvest [14].

$$WP_E = \frac{p \times Y}{WU} \quad \ldots (6)$$

Where, Economic water productivity in INR ha^{-1} mm^{-1} (WP_E), market price of produce in INR kg^{-1} (p), Water use by crop in mm (WU) i.e. SR, ER and I+SR.

3. RESULTS AND DISCUSSION

3.1 Effective rainfall of watershed

The rainfall of watershed from sowing of groundnut (rainy season) to harvesting of wheat crop (winter season) was computed 945.60 mm. The seasonal effective rainfall as well as monthly effective rainfall was calculated with the help of U.S. Bureau of Reclamation (U.S.B.R) method. Effective rainfall was estimated 361.6 mm out of 825.60 mm, it was 47.06% of total rainfall during the *Kharif* season (Figure. 2) and rest of precipitation was lost by runoff, deep percolation and evapo-transpiration. In Rabi season, seasonal runoff was assumed zero because of very less rainfall (120.2 mm) was received on four different dates. So, total precipitation was used as effective rainfall (120.20 mm). In this method, the effective rainfall is higher when the intensity of rainfall is low. This method is recommended for arid and semi-arid regions. Sharma et al. [3] and Kumari et al. [12] also supported this method under semi-arid region of Vindhyan region and Bundelkhand region, respectively.

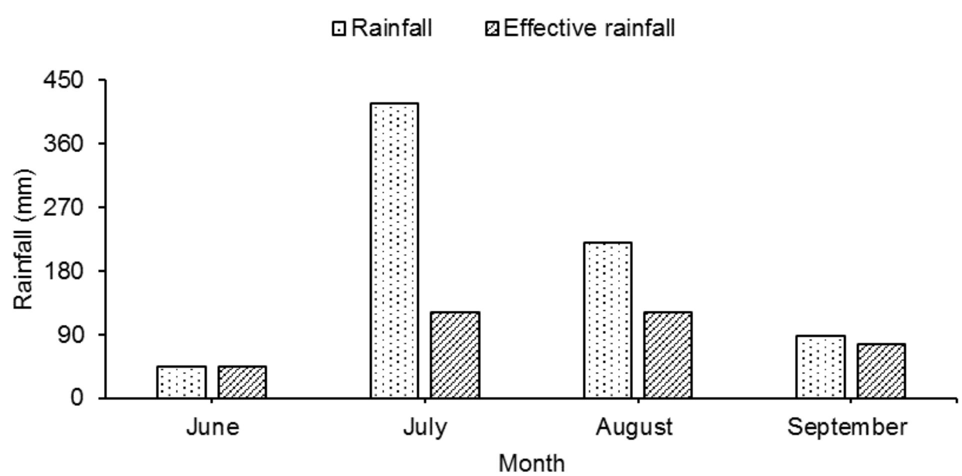

Fig. 2 The amount of rainfall and effective rainfall during *Kharif* season, 2013, using by U.S. Bureau of Reclamation method.

3.2 Yield and WUE for Groundnut

The data shown that the average maximum groundnut yield (1209.07 kg ha^{-1}) was recorded under the upland zone of watershed where red soil is dominated mainly *Rakar*. It was 1.04 and 9.67% higher than middle (red soil-*Parwa*) and low land (black soil- *Mar* & *Kabar*). The WUE_R (1.46 kg ha^{-1} mm^{-1}) and WUE_{ER} (3.34 kg ha^{-1} mm^{-1}) of groundnut were also improve under upland condition (Table. 3) because it is directly proportional to yield under the non-irrigated condition where available water is same for all treatment as like rainfall. In the upland field, groundnut yield was high due to the coarse-textured and medium water retention of the soil. Coarse texture soil improves the peg penetration. Pod development is higher in the coarse-textured soil as compared to highly adhere soil. So, the WUE_{ER} of groundnut observed higher values than WUE_R in all land conditions. Kumari et al. [12] also reported that the effective rain water use efficiency was higher than rain water use efficiency of groundnut of semi-arid regions of Bundelkhand region, India.

Table 3 Water use efficiency of groundnut under different soil type of Parasai-Sindh watershed

Land site	Sample No.	Soil depth (cm)	Total Rainfall (mm)	Effective Rainfall (mm)	Yield (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})	
						Rain	Effective rain
Upland	7	22.14	825.50	361.60	1209.07 ($\pm$211.31$^+$)	1.46 ($\pm$0.26$^+$)	3.34 ($\pm$0.58$^+$)
Middle land	3	28.33	825.50	361.60	1196.60 ($\pm$58.69$^+$)	1.45 ($\pm$0.07$^+$)	3.31 ($\pm$0.16$^+$)
Low land	3	47.67	825.50	361.60	1102.43 ($\pm$38.16$^+$)	1.34 ($\pm$0.05$^+$)	3.05 ($\pm$0.11$^+$)

$^+$Standard deviation

3.3 Yield and WUE for Wheat

The total amount of irrigation water used was 326 and 221 mm in conventional and sprinkler irrigation, respectively. In conventional method of irrigation 48% higher water used was recorded than sprinkler irrigation. Sprinkler irrigation was found to be more efficient with water saving of about 32.21% as compared to conventional irrigation. The grain yields with sprinkler irrigation (3010 kg ha^{-1}) were obtained 18% higher than conventional irrigation. Higher yield with the lower irrigation water resulted in high WUE and it was calculated as 5.56 and 8.82 kg ha^{-1} mm^{-1} for conventional and sprinkler irrigation, respectively (Table 4). As such, high water use efficiency could be achieved either by improving yield or saving water through improved irrigation system. Even with surface irrigation method, good management of irrigation water i.e. better irrigation scheduling could lead to a better water use efficiency. Zhang et al. [15] also reported that optimal irrigation can significantly increase wheat yields. The superiority of sprinkler irrigation over conventional irrigation with respect to higher water use efficiency under wheat has been reported by Bandyopadhyay et al. [16].

Table 4 Application of different irrigation method in wheat crop at Parasai-Sindh watershed

Method of Irrigation	No. of experiment	Applied irrigation (mm)	Rainfall (mm)	Total water use (mm)	Yield (kg ha^{-1})	WUE (kg ha^{-1} mm^{-1})
Conventional	3	326.00	120.20	446.20	2480.00 ($\pm$172.71$^+$)	5.56 ($\pm$0.39$^+$)
Sprinkler	3	221.00	120.20	341.20	3010.00 ($\pm$122.78$^+$)	8.82 ($\pm$0.36$^+$)

$^+$Standard deviation

3.4 Cost Benefit Analysis

The cost incurred in various activities from sowing to harvesting operations has been found INR. 26650, 23480 and 19845 ha^{-1} of Groundnut, conventional irrigated wheat and sprinkler irrigated wheat, respectively (Table. 5). The net return form groundnut was recorded maximum INR. 29717 ha^{-1}, it was 2.25 and 20.84% higher than middle and low land area of watershed. However, in wheat net return was recorded INR. 16720 and 28955 ha^{-1} under conventional and sprinkler irrigated system, respectively. The lowest B:C ratio of groundnut was recorded 1.92 while 2.12 recorded maximum value. The B:C ratio of sprinkler irrigated wheat was recorded 2.46, it was 43.86 % higher than conventional irrigated wheat. Okunade et al. [17] confirmed that the micro-irrigation method (sprinkler) enhanced either gross return or net return as compare to conventional furrow and basin irrigation system. So, result is that B:C ratio is automatically improved under sprinkler irrigation system.

Table 5 Cost-Benefit parameter of groundnut and wheat in Parasai- Sindh watershed

Sl. No.	Particulars	Groundnut			Wheat	
		Upland	Middle land	Low land	Conventional	Sprinkler
1.	Production*					
a.	Grain	1209.07	1196.60	1102.43	2480.00	3010.00
b.	Fodder	1958.69	1866.70	1631.60	3000.00	3650.00
2.	Cost of cultivation **	26650.00	26650.00	26650.00	23480.00	19845.00
3.	Gross return**					
a.	Grain	54408.00	53847.00	49609.00	37200.00	45150.00
b.	Fodder	1959.00	1867.00	1632.00	3000.00	3650.00
c.	Total	56367.00 (±9851.48^{+})	55714.00 (±2732.64^{+})	51241.00 (±1773.58^{+})	40200.00 (±2791.50^{+})	48800.00 (±1949.37^{+})
4.	Net return**	29717.00 (±9509.15^{+})	29064.00 (±2641.08^{+})	24591.00 (±1717.11^{+})	16720.00 (±2556.50^{+})	28955.00 (±1546.35^{+})
5.	B:C ratio	2.12 (±0.37^{+})	2.09 (±0.10^{+})	1.92 (±0.07^{+})	1.71 (±0.12^{+})	2.46 (±0.10^{+})

* Production of the crop is shown in kg ha^{-1}.
**Cost and return are shown in INR (Indian Rupees)
$^{+}$Standard deviation

3.5 Economic Water Productivity [WP_E]

The net return of groundnut and wheat crops was evaluated under different land sequence and irrigation system, respectively. The highest WP_E of the groundnut for seasonal rain was INR. 36.00 and 82.18 ha^{-1} mm^{-1} in upland under total rain and effective rain, respectively, followed by middle and low land area of watershed (Figure 3). However, sprinkler irrigated wheat had maximum WP_E of INR. 84.86 ha^{-1} mm^{-1} and conventional irrigated wheat had WP_E of 37.47 ha^{-1} mm^{-1}. This indicates sprinkler irrigation system enhances WP_E of the crop as compared to conventional irrigation system. High WP_E indices are of little interest if they are not associated with acceptable seed yield, production cost, and total revenue [18, 19].

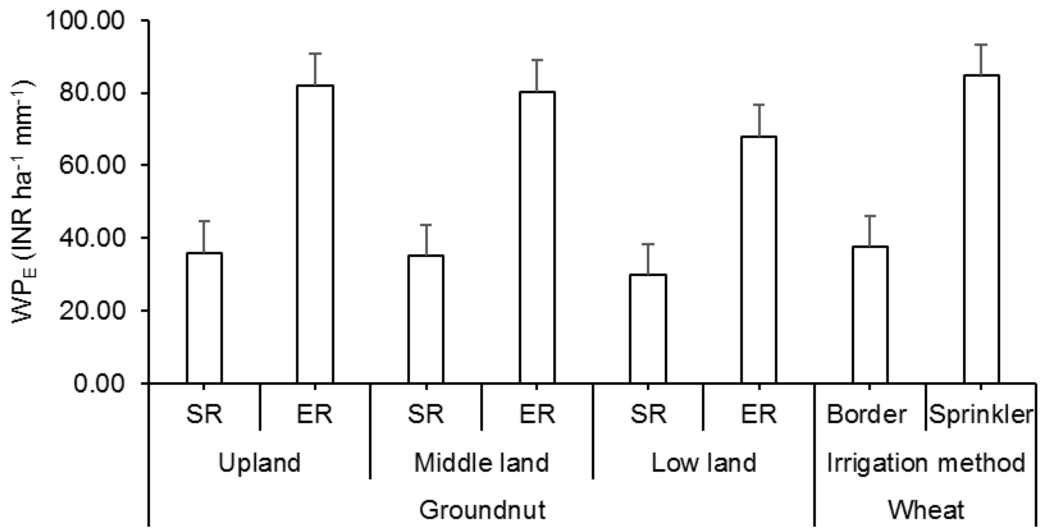

Fig. 3 Evaluation of economic water productive in of groundnut and wheat crops in Parasai-Sindh watershed

4. CONCLUSION

In semi-arid tropics, the lower productivity of crop is directly related to limited water resources. The maximum rain water is lost through the runoff, deep percolation and evapo-transpiration. Time and method of irrigation affect the crop productivity and WUE. Thus, the water conservation and the efficient utilization of stored soil water were taken care off in watershed with sprinkler irrigation for *Rabi* crop for improving WUE in respect of conventional method.

The study reveals that the benefit - cost ratio of groundnut was higher under upland region of watershed. The economic water productivity of groundnut was also higher in upland area of watershed. The sprinkler irrigation had improved B:C ratio of wheat crop as compared to conventional irrigation. Hence, economic water productivity was directly improved under sprinkler irrigated wheat system.

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