

## Comparison of Flooding and Raised Bed Irrigation Systems for Wheat Crop at Samoo (Village Bilawal Khan Jamali) District Jaffarabad Balochistan Pakistan

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### Abstract

Wheat is considered as the chief cereal crop of Pakistan. Most of the farmers in Jaffarabad use flooding irrigation system for wheat crop which causes waterlogging and salinity in the area. Therefore, this research work was conducted at Village Bilawal Khan Jamali, union council Samoo, District Jaffarabad, Balochistan, Pakistan. Aim of this research work is to determine water saving and optimum crop yield by comparison of flooding and raised bed irrigation systems. In Flooding and Raised bed Irrigation Systems, Management Drawn Depletion (MDD) level was used. Study results revealed that the net irrigation (I) was applied 320 mm for flooding irrigation system, for raised bed irrigation system, 277 mm of net irrigation was calculated and 50 mm rainfall occurred in the fields. The yield production of flooding and raised bed irrigation systems were calculated 1368 kg/acre and 1656 kg/acre respectively. The yield of raised bed irrigation system was calculated 17.2% greater than flooding irrigation system. According to these results, the maximum yields have been obtained and waterlogging and salinity were controlled from raised bed irrigation with efficient usage of water.

**Keywords:** Flooding; Raised bed; Waterlogging; Salinity; Water use efficiency; Management drawn depletion

### Introduction

Among the crops in Pakistan wheat is considered as the most significant cereal crop. However, its production is less due to shortage of irrigation water, insufficient farm resources, improper use of fertilizers and due to salinity and water logging. Unwise use of irrigation water through traditional irrigation method has further constrained the cropping intensities and crop yields [1]. Thus, without judicious use of irrigation water and other farm resources, the yield potential of wheat crop cannot be obtained satisfactorily. There must be a bona-fide irrigation procedure to enhance Water Use Efficiency (WUE) in terms of yield of the crops. It is observed that Water Use Efficiency (WUE) decreases with amount and time of application of water per irrigation season. At the start of 21<sup>st</sup> century, resources of water were of great importance to the majority of the world. Water requirement is highly increasing to meet the demand of crop production and it needed to be expanded horizontally and vertically to compensate the shortage in most irrigating crops [2]. Addressing the issue of shortage of water, the government of Pakistan has taken serious initiatives in the country by launching various water management projects, which include lining of minors and watercourses, command area water management and groundwater development projects etc. However, these alternatives are still dependent upon a limited available water supply. Various techniques of irrigation are used for water saving in agricultural sector throughout the world; a few of these are correlated to preparation of beds for seed to availability of water accordingly. The surface flooding method of irrigation has been practiced since centuries in Pakistan. After introducing raised beds method the conservation and efficiency of water was increased as compared to flat basin sowing which was the great breakthrough performance [3]. There are various irrigation management needs of Pakistan. Therefore, it is needed to study the efficient water consumption and water distribution patterns. So, a good pattern of crop area and water consumption is required. Water supplies are not only used to the field exactly for crop consumption but also has some proportion for recharge to the aquifer [4]. In many areas of Pakistan, irrigation is a mean of optimizing plant water use and optimizing crop production. In Pakistan, seasonally 25 to 30 cm of water is needed for wheat production and about 1.5 to 4 mm for

daily evapotranspiration [5-9]. As water is a most serious aspect for crop production, so it should be utilized economically so that it gives optimum yield. Modern high yielding crop methods can be utilized only with excellent management and utilization of water should control for growing of crops at the field [9-12].

### Problem Statement

In Jaffarabad district farmers are using flooding irrigation system for wheat crop which is increasing waterlogging and salinity in the area. Therefore this research work will be conducted out to compare of flooding and raised bed irrigation systems in terms of water saving and crop yield with consideration of decreasing waterlogging and salinity.

### Research Objectives

The main objective of this study is to enhance Water Use Efficiency (WUE) and crop yield by applying raised bed irrigation system instead of traditional method of irrigation. Following are the specific objectives of the study:

- To determine water saving by comparison of flooding and raised bed irrigation systems.
- To calculate the crop yield through flooding and raised bed irrigation systems.
- To share study result outcomes with farmers of Village Bilawal Khan Jamali, union council Samoo, District Jaffarabad Balochistan, Pakistan.

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## Study Area

District Jaffarabad is located in South East of Balochistan province which is spread on an area of 2,445 km<sup>2</sup> and the population of 513,813 (2018 census). District Jaffarabad has 38 union councils. I am conducting a research study at Village Bilawal Khan Jamali, union council Samoo, district Jaffarabad, Balochistan.

### Location of study area

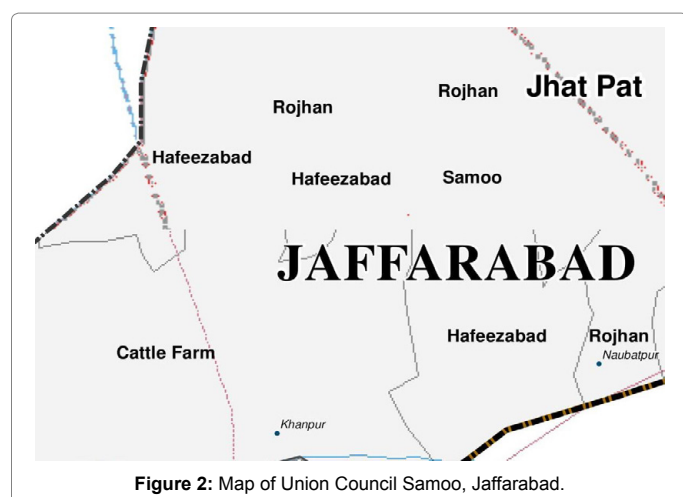
The research study was carried out on an area of 2 acres (0.810 hectares) at the study field at Village Bilawal Khan Jamali, union council Samoo, District Jaffarabad. Experimental field was situated at Village Bilawal Khan Jamali near the office of union council Samoo, at latitude 28° 22'28.11" N and longitude 68° 20'55.8" E at about 57.6 meters over mean sea level (Figures 1-3). Plot selected for the experiment is the size of 1 acre (66 × 66 ft<sup>2</sup>). Plot size for both irrigation systems was same. One acre was analyzed for flooding irrigation system and one acre for raised bed irrigation system.

### Preparation of land

Mould Board Plough was used in the preparation of land for



**Figure 1:** Map of district Jaffarabad Balochistan.



**Figure 2:** Map of Union Council Samoo, Jaffarabad.



**Figure 3:** Satellite view of study area.

flooding irrigation system. To preparing the land for raised bed irrigation system, bed planter was used in the study area.

### Sowing

The seed of wheat was sown in flooding and all raised beds in the month of December, 2016. The seed was sowed on top of raised bed using bed planter. When ploughing of land was done then after a known quantity of water was applied to the fields of flooding and raised bed irrigation systems. The seed started germination after 5 days from sowing under flooding and raised bed irrigation systems.

### Variety of wheat

Inqalab was the variety of wheat which has been cultivated in the study area.

### Seeding rate

Wheat variety was seeded on 20<sup>th</sup> December 2016. A seeding rate of 80 kg/acre was used in flooding irrigation system and 70 kg/acre for raised bed irrigation system.

### Sowing method for flooding irrigation system

Broadcasting technique is one of the oldest and most important techniques of sowing the seed, where the seeds are just spread on the soil; the seeds may or may not be covered with soil. It is only suitable for small crops where plant to plant distance does not matter or is small. For flooding irrigation system, broadcasting method was used for sowing of wheat crop in the study area.

### Sowing method for raised bed irrigation system

Bed planter was used in the field of raised bed irrigation system for sowing the wheat crop.

### Cut throat flume

Cut throat flume is an instrument which measures the flow of water. The dimensions of cut throat flume are 18" and 8" length and width respectively. Cut throat flume is used to measure the flow of water at the study area (Figure 4).

### Tensiometer

Tensiometer is a device which is used for soil moisture status or to monitor the water potential for scheduling the water application in the study area (Figure 5).



**Figure 4:** Installation of cut throat flume at the channel for flow measurement.



**Figure 5:** Installation of tensiometer at the field.



**Figure 6:** Non-modular irrigation outlet.

## Outlet

Outlet is a hydraulic structure which conveys the water for irrigation from a canal (distributary) to a watercourse. To deliver the water to the fields through watercourses, non-modular outlet is installed at the bank of canal (Figure 6).

## Computation Equations

### Water balance approach

For irrigation scheduling, soil water balance approach was used

which is widely accepted and adapted by irrigation professionals and researchers. It is the major governing equation to maintain daily soil water balance for applying irrigation to the fields. The water balance equation is as under:

$$D_{ri} = D_{ri-1} + ET_{ci} + DP_i - \frac{I_i}{f_w} - R_i \quad (1)$$

### Modified Penman-Monteith Equation (FAO-56)

Modified Penman-Monteith (FAO-56) was used for calculating reference evapotranspiration ( $ET_o$ ). The equation is given as:

$$ET_o = \frac{0.408\Delta [R_n - G] + \gamma \frac{900}{T + 273} u_2 [e_s - e_a]}{\Delta + \gamma [1 + 0.34 u_2]} \quad (2)$$

**Air temperature:** For air temperature, daily maximum and minimum data of temperature will be required. Humidity data has also required in the Penman-Monteith method which is find out from the following equation:

$$T_{mean} = \frac{T_{max} + T_{min}}{2} \quad (3)$$

## Results

### Physical and chemical properties of soil

**Soil texture:** Soil at the study area was silty clay loam and class is medium in texture.

### Chemical properties of soil

The chemical properties of the soil can show in Table 1.

### Crop evapotranspiration and irrigation scheduling

The seasonal computed evapotranspiration of wheat at management drawn depletion MDD 55%, ( $ET_{c55}$  and  $ET_{c55}$  respectively) by flooding and raised bed irrigation systems were collected 358, and 320 mm while actual  $ET_{ca55}$ , were calculated 350 and 309 mm respectively by flooding and raised bed irrigation systems (Tables 2 and 3).

### Crop evapotranspiration and irrigation scheduling

The computed evapotranspiration and actual evapotranspiration on daily basis in the experimental fields which are constructed in Figures 7 and 8. The maximum actual evapotranspirations at management drawn depletion 55% was calculated 5.81 mm day<sup>-1</sup> at the field of flooding irrigation system and calculated evapotranspiration was obtained 4.70 mm day<sup>-1</sup> on 102<sup>th</sup> and 77<sup>th</sup> day of sowing (Figure 7). Maximum actual evapotranspirations at management drawn depletion 55% at the field of raised bed irrigation system, 6.11 mm day<sup>-1</sup> was calculated and actual 6.10 mm day<sup>-1</sup> was calculated on the same day i.e. 102<sup>nd</sup> day of sowing (Figure 8).

The daily depletion rate ( $D_r$ ) for the total period of the crop at MDD 55% i.e. flooding and raised bed irrigation systems are plotted together with Total Evaporable Water (TAW) and Readily Available

S.No	Parameter	Values
1	pH	7.8
2	EC (dSm <sup>-1</sup> )	0.87
3	Available nitrogen (%)	0.028
4	Available phosphorus (ppm)	2.8
5	Available potassium (ppm)	77

**Table 1:** Chemical properties of soil.

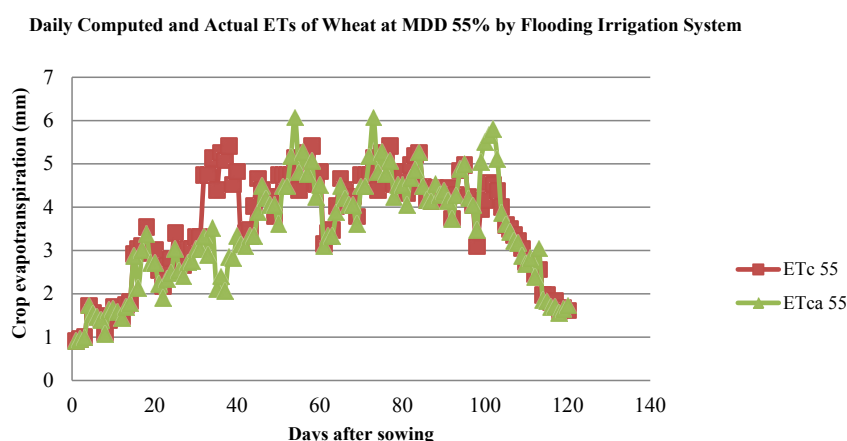


S#	Date	Day/yr	T <sub>max</sub> °C	T <sub>min</sub> °C	T <sub>dew</sub> °C	U <sub>2</sub> m/s	Sunshine hr	ET <sub>o</sub> mm	TAW mm	RAW mm	Dri Start mm	R mm	I/fw	Kcb	Ke	Kc	Kca	ET <sub>c</sub> mm	Dp mm	Dri end	ET <sub>ca</sub> mm
1	20/12/2016	354	27	16	12	0	6	1.47	52	29	19	0	50	0.62	0	0.62	0.62	0.91	0	20	0.91
2	21/12/2016	355	28	16	13	0	6	1.5	57	31	20	0	0	0.64	0	0.64	0.64	0.96	0	21	0.96
3	22/12/2016	356	26	18	15	0	5	1.5	62	34	21	0	0	0.66	0	0.66	0.66	1	0	22	0.99
4	23/12/2016	357	27	19	16	1	8	2.51	68	37	22	0	0	0.69	0	0.69	0.69	1.73	0	24	1.73
5	24/12/2016	358	26	18	15	1	5	2.18	73	40	24	0	0	0.71	0	0.71	0.7	1.56	0	26	1.53
6	25/12/2016	359	22	15	12	1	6	2.02	78	43	26	0	0	0.74	0	0.74	0.73	1.5	0	28	1.47
7	26/12/2016	360	21	16	13	1	5	1.87	83	46	28	0	0	0.76	0	0.76	0.75	1.43	0	29	1.4
8	27/12/2016	361	18	11	12	0	6	1.39	88	48	29	0	0	0.78	0	0.78	0.78	1.09	0	30	1.08
9	28/12/2016	362	17	12	11	2	5	1.71	94	52	30	0	0	0.81	0	0.81	0.95	1.39	0	31	1.62
10	29/12/2016	363	16	13	10	3	5	2.04	99	54	31	0	0	0.83	0	0.83	0.81	1.7	0	33	1.65
11	30/12/2016	364	17	12	10	2	5	1.86	104	57	33	0	30	0.86	0	0.86	0.85	1.6	0	35	1.58
12	31/12/2016	365	16	13	10	1	6	1.66	109	60	35	0	0	0.88	0	0.88	0.86	1.47	0	36	1.43
13	1/1/2017	1	16	13	10	2	5	1.92	114	63	36	0	0	0.9	0	0.9	0.88	1.74	0	38	1.69

**Table 2:** A sample of daily data collection and processing for wheat experimented at MDD 55% by flooding irrigation system.

S#	Date	Day/yr	T <sub>max</sub> °C	T <sub>min</sub> °C	T <sub>dew</sub> °C	U <sub>2</sub> m/s	Sunshine hr	ET <sub>o</sub> mm	TAW mm	RAW mm	Dri Start mm	R mm	I/fw	Kcb	Ke	Kc	Kca	ET <sub>c</sub> mm	Dp mm	Dri-1 end	ET <sub>ca</sub> mm
1	20/12/2016	354	27	16	12	0	6	2.76	34	21	0	0	50	0.5	0.5	1	0.37	2.76	29	3	1.02
2	21/12/2016	355	28	16	13	0	6	3.49	34	21	3	0	0	0.5	0.6	1.1	0.4	3.84	0	7	1.4
3	22/12/2016	356	26	18	15	0	5	2.44	34	21	7	0	0	0.5	0.5	1	0.5	2.44	0	9	1.22
4	23/12/2016	357	27	19	16	1	8	2.15	34	21	9	0	0	0.5	0.44	0.94	0.64	2.04	0	11	1.38
5	24/12/2016	358	26	18	15	1	5	2.81	34	21	11	0	0	0.5	0.41	0.91	0.71	2.56	0	14	2
6	25/12/2016	359	22	15	12	1	6	2.74	34	21	14	0	0	0.5	0.22	0.72	0.6	1.98	0	16	1.64
7	26/12/2016	360	21	16	13	1	5	1.68	34	21	16	0	0	0.5	0.07	0.57	0.59	0.97	0	17	0.99
8	27/12/2016	361	18	11	12	0	6	2.65	34	21	17	0	0	0.5	0.03	0.53	0.53	1.41	0	18	1.4
9	28/12/2016	362	17	12	11	2	5	2.77	34	21	18	0	0	0.5	0	0.5	0.5	1.38	0	19	1.39
10	29/12/2016	363	16	13	10	3	5	1.73	34	21	19	0	0	0.5	0	0.5	0.5	0.86	0	20	0.87
11	30/12/2016	364	17	12	10	2	5	1.64	34	21	20	0	0	0.5	0	0.5	0.48	0.82	0	21	0.79
12	31/12/2016	365	16	13	10	1	6	2.63	34	21	0	0	30	0.5	0.6	1.1	0.97	2.89	9	3	2.55
13	1/1/2017	1	16	13	10	2	5	1.89	34	21	3	0	0	0.5	0.5	1	0.96	1.89	0	5	1.81

**Table 3:** A sample of daily data collection and processing for wheat experimented at MDD 55% by raised bed irrigation system.

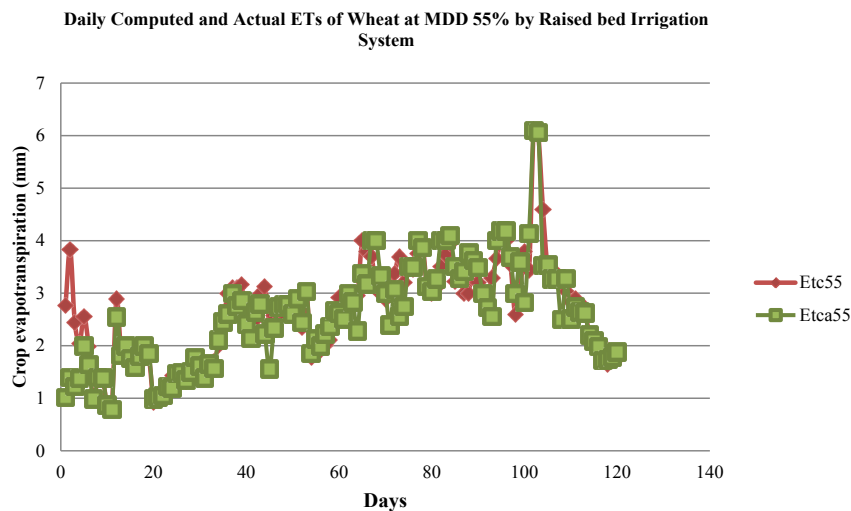


**Figure 7:** Daily computed and actual ET<sub>s</sub> of wheat at MDD 55% by flooding irrigation system.

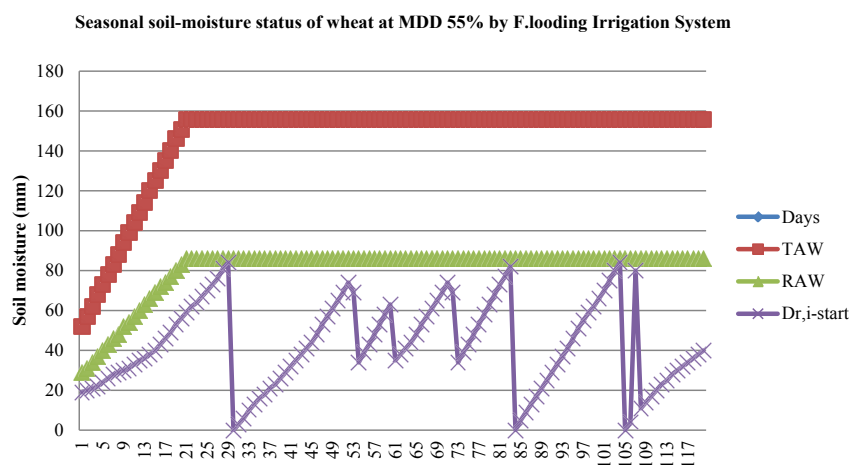
Water (RAW) on daily basis respectively shown in Figures 9 and 10. The total 370, and 327 mm water i.e. irrigation and rainfall was used during cultivation of the wheat experimented in field at MDD 55% for flooding and raised bed irrigation systems, respectively (Tables 4 and 5 respectively).

First irrigation water of 50 mm as a soaking dose was applied

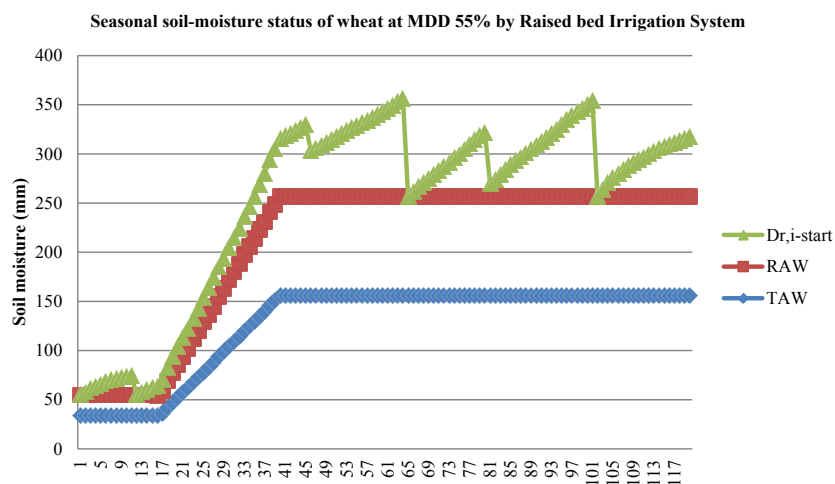
for both irrigation systems. After initial stage due to crop maturity, the depth of root depth and hence readily available water (RAW) slowly enhanced. The final irrigation was applied to the field, fourteen days before harvesting. The quantity of irrigation water was applied according to the computation of soil moisture depletion and the status of actual crop evapotranspiration ET<sub>ca</sub> demand on the field. The



**Figure 8:** Daily computed and actual  $ET_s$  of wheat at MDD 55% by raised bed irrigation system.



**Figure 9:** Seasonal soil-moisture status of wheat at MDD 55% by flooding irrigation system.



**Figure 10:** Seasonal soil-moisture status of wheat at MDD 55% by raised bed irrigation system.

irrigations and rainfalls during consecutive experiments are shown in Figures 11 and 12 respectively.

### Yield of flooding irrigation system and raised bed irrigation system

The yield of Flooding Irrigation system was 1368 kg/acre obtained and 1656 kg/acre was obtained in the field of Raised bed Irrigation System. Comparison of both irrigation systems in terms of yield is determined as below in the graph: The Water Use Efficiency (WUE) was calculated 5.06 kg (acre/mm) from raised bed system under management drawn depletion (MDD) 55% and Water Use Efficiency (WUE) from flooding irrigation system under management drawn depletion (MDD) 55%, 3.70 kg (acre/mm) was calculated. Comparatively highest Water Use Efficiency was obtained in raised bed

irrigation system under management drawn depletion (MDD) 55%. At the field of flooding irrigation system, under management drawn depletion 55%, 377 mm of irrigation water was used and management drawn depletion 55%, at the field of raised bed irrigation system 327 mm of irrigation water was used. The raised bed irrigation system consumed 50 mm less irrigation water (Figure 13).

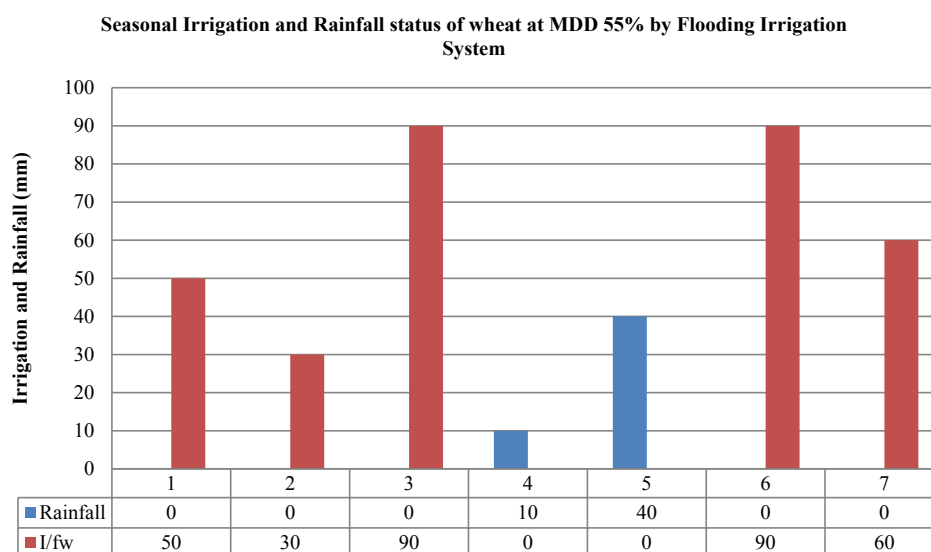
The preliminary evaluation recommends that averagely 320 to 370 mm of irrigation water required for seasonal evapotranspiration (ET) and requirements of deep percolation for wheat to be grown in Jaffarabad, Balochistan. The optimal level of management drawn depletion (MDD) for wheat grown in silty clay loam soil in the climate of Jaffarabad indicated 55% averagely. Since highest WUE is obtained for the wheat experimented at the field of raised bed irrigation system at MDD 55%, therefore this is more focussed.

S. No	Date	Rainfall (mm)	Irrigation Interval	Irrigation (mm)
1	20/12/2016	0	0	50
2	30/12/2016	0	9	30
3	6/2/2017	0	38	90
4	1/3/2017	10	-	0
5	2/3/2017	40	-	0
6	13/3/2017	0	33	90
7	3/4/2017	0	20	60
Total		50		320

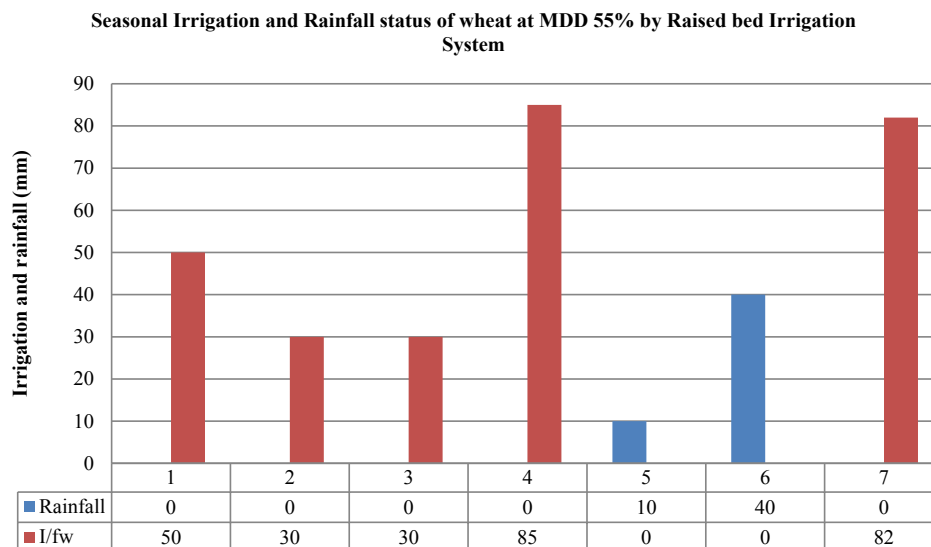
**Table 4:** Irrigation schedule of wheat at MDD 55% by flooding irrigation system

S. No	Date	Rainfall (mm)	Irrigation Interval	Irrigation (mm)
1	20/12/2016	0	0	50
2	31/12/2016	0	10	30
3	2/2/2017	0	32	30
4	22/2/2017	0	20	85
5	1/3/2017	10	-	-
6	2/3/2017	40	-	-
7	31/3/2017	0	37	82
Total		50		277

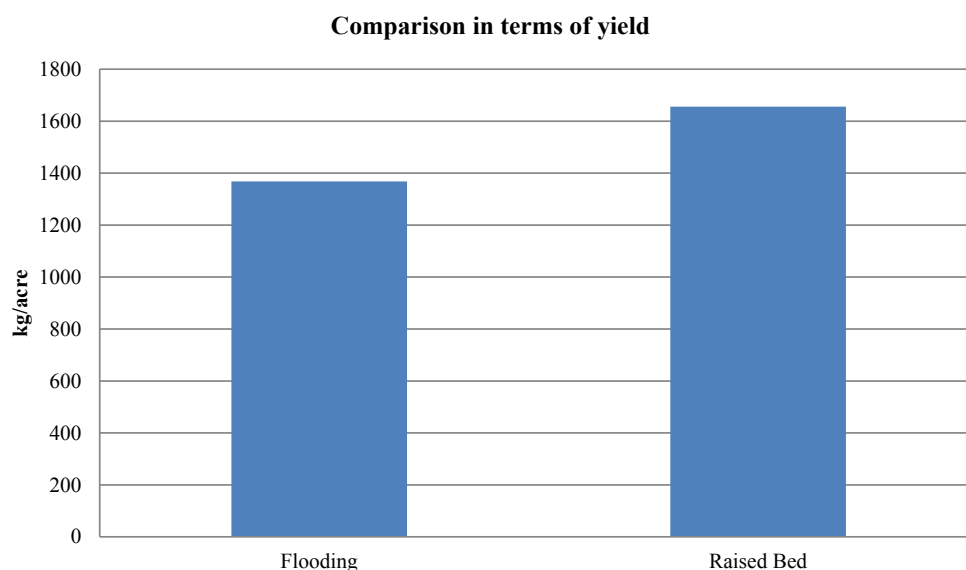
**Table 5:** Irrigation schedule of wheat at MDD 55% by raised bed irrigation system.



**Figure 11:** Seasonal irrigation and rainfall status of wheat at MDD 55% by flooding irrigation system.



**Figure 12:** Seasonal irrigation and rainfall status of wheat at MDD 55% by raised bed irrigation system.



**Figure 13:** Comparison of flooding and raised bed irrigation in terms of yield.

## Conclusion

This study work was carried out to compare flooding and raised bed irrigation systems for wheat crop in terms of water saving and crop yield with consideration of decreasing waterlogging and salinity. The following conclusions are revealed:

- The net irrigation (I) was applied 320 mm for flooding irrigation system and 50 mm rainfall occurs in the field, and for raised bed irrigation system, 277 mm of net irrigation was calculated and 50 mm rainfall occurred.
- The yield production of flooding irrigation system was 1368 kg/acre and 1656 kg/acre was obtained in the field of raised bed irrigation system.
- The yield of raised bed irrigation system was calculated 17.2% greater than flooding irrigation system.

In this study, main objectives of the study have been obtained. For seasonal growth of wheat crops the estimation of total water requirements (depth of irrigation) has been determined as 370 and 327 mm respectively for flooding and raised bed irrigation systems. According to these results, the maximum yields have been obtained from raised bed irrigation and minimum water has been consumed. The minimum water consumption helps for controlling water logging and salinity in the study area. The minimum fertilizers have been used in raised bed technique however; there is still need of proper adaptation and demonstration of the raised bed irrigation system for the benefits of growers in the study area.

## Recommendations for Future Research and Developments

Based on this research, further studies that can be carried out in future are as follows:

- Comparison of Sprinkler Irrigation System and Drip Irrigation System for Wheat crop at Samoo (V: Bilawal Khan Jamali), District Jaffarabad Balochistan.
- Irrigation frequency impact on Wheat water productivity with sub surface drip irrigation system in District Jaffarabad Balochistan.
- Precise agricultural monitoring based on sensor network and satellite remote sensing: saving water usage of wheat crop in Balochistan.
- Irrigation scheduling for surface rotational irrigation with limited water in Balochistan.
- Additional research and development are needed to work in connection with Automatic Meteorological Station, Remote Sensing Techniques, and GIS.

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