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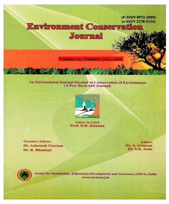

Impact of different quantity and quality of irrigation water on crop yield and biomass of winter maize using FAO-Aqua crop model

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ABSTRACT

Irrigation has a major role to play in the productivity of winter maize. Precise information about the quantity and quality of irrigation water is the key for higher productivity of winter maize. In the present study attempt has been made to assess the impact of different depth of irrigation water on crop yield and biomass of winter maize using FAO-Aquacrop Model. In the first case crop yield and biomass was simulated for irrigation water depth varied from 20 mm to 80 mm, keeping the irrigation water quality constant. Similarly, in another case the optimum irrigation depth was kept constant and irrigation water quality varied from 1 to 10 ds/m. The simulated crop yield and biomass increases up to 40 cm depth of irrigation water application for all three seasons. When a similar comparison was made for 30 cm depth of irrigation water application the simulated yield reduction was only 0.79%, 2.2% and 2.4 % for the year 2016-17, 2017-18 and 2018-19 respectively. The analysis suggested that this yield reduction can easily be compromised for saving 10 cm of irrigation water. This study indicated that 30 cm depth of irrigation water is optimum for Winter maize in BurhiGandak river basin of North Bihar in case of deficit irrigation of 20 cm depth of irrigation water application the simulated yield reduced by 14.4 %, 25.4 % and 11.4 % for the year 2016-17, 2017-18 and 2018-19 respectively. Assessment of response of different quality irrigation water on simulated crop yield and biomass of *winter* maize using FAO-Aquacrop model suggests that simulated yield was found maximum with 1 ds/m. The reduction in simulated yield with 10 ds/m water quality was observed maximum with a value of 41.3 %, 44.4 % and 38.4 % respectively for the year 2016-17, 2017-18 and 2018-19. FAO-Aquacrop model can be used as an important tool for efficient planning of irrigation water under diminishing water supply and deteriorating water quality.

Introduction

Irrigation water is one of the most important component in Agriculture. The scarcity of high-quality irrigation water is now widely acknowledged as a major impediment to increasing cropping intensification. In many parts of the world, a lack of irrigation water is impeding agricultural development (Barrow, 2016; Elliott *et al.,* 2014; Molden *et al.,* 2010). Water scarcity for agriculture is increasing not only because sources are dwindling, but also because water quality is deteriorating (Elliott *et al.,* 2014; Parsons *et al.,* 2010; Bhutiani *et al.,* 2016; Bhutiani and Ahamad, 2019).Maize is one of the most important crop of the world because of its excellent starch composition, it is quickly becoming a major raw material for food, textile, paper and feed industries (Kang *et al.* 2010; Tian *et al.* 2009). There are three distinct seasons for the cultivation of maize in India : Kharif , Rabi in Peninsular India and Bihar, and Spring in northern India.

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Bihar is a significant maize-producing state, accounting for approximately 6.6 % of total national maize production, with nearly 0.65 million hectares of maize planted each year. Winter maize is grown on a land area of 0.46 million hectares, with a grain production of 1.86 million tonnes and a normal yield of 4.1 t/ha in 2020-21 (Source : Ministry of Agriculture & Farmers Welfar e, Govt. of India. (ON2930). Winter maize in Bihar state has a larger region with a normal productivity of 4.1 t/ha and *Autumn/kharif* maize with a normal productivity of 2.85 t/ha. Winter maize is mostly dependent on the availability of irrigation water. In Bihar, most of the maize-producing area is dependent upon groundwater. Due to the unavailability of electricity in rural areas ground water extraction is mostly done through diesel operated pumps. The cost of operation of tubewell restricts farmers to use less number of irrigation to crop leading to poor productivity of winter maize. Besides this salinity is also one of the major concerns in some of the maize growing areas. Maize is moderately salt tolerant crop. The effect of saline water on crop yield has been studied by a number of researchers. The FAO-Aquacrop model can help to assess the impact of different quantity and quality of irrigation water on crop yield and biomass in winter maize. Aquacrop models have been successfully used to simulate crop growth and yield parameters (Kumar *et al*., 2018; Chandra *et al.* 2022; Chandra and Kumari, 2021) in Eastern India. Effective rainfall in winter season in this part of the world is very deficient and assured irrigation is the key to good production of winter maize. Therefore, it is important to study the impact of different levels of irrigation along with the different level of saline water on crop yield of winter maize in Bihar. Keeping the importance of irrigation water for winter maize this study was undertaken to assess the impact of different levels of irrigation along with the different level of saline water on crop yield of winter maize in Bihar.

Material and Methods

The study was conducted during winter season for the three years 2016-17, 2017-18 and 2018-19. The crop parameters were adopted in this study from one of the studies conducted for performance evaluation of Aquacrop model for *Rabi maize* for North Bihar by Kumar and Chandra , 2018.

Study area

The study region is situated at *Pusa* block of Samastipur district of North Bihar (Fig. 1). The investigation territory is encircled by southern and western bank of the waterway Burhi Gandak at 25°59'N latitude and 85°48'E longitude. The elevation above (MSL) is 52.92 m.

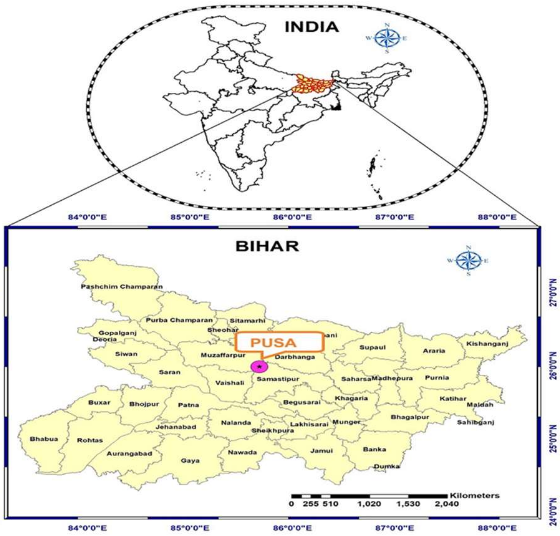

Figure 1: Map of study area

Aquacrop model

Aquacrop is a crop growth model developed by the Land and Water Division of FAO to address food security and to assess the effect of environment and management on crop production. AquaCrop simulates yield response to water of herbaceous crops, and is particularly suited to address conditions where water is a key limiting factor in crop production. When designing the model, an optimum balance between simplicity, accuracy, and robustness was pursued. To be widely applicable AquaCrop uses only a relatively small number of explicit parameters and mostly-intuitive input-variables requiring simple methods for their determination. On the other hand, the calculation procedures are grounded on basic and often complex biophysical processes to guarantee an accurate simulation of the response of the crop in the plant-soil system. The impacts of climate change are often quantified by impact models whereas impact models typically require high resolution unbiased input data, global and regional climate models are in general biased, their resolution is often lower than desired. Thus, many users of climate model data apply some form of bias correction and downscaling. Bias correction of climate model outputs for climate change impact has been assessed in Central Kashmir.

Scenario for simulation

Simulation studies using the FAO-AquaCrop model were done for the assessment of the impact of different depths of irrigation water on crop yield and biomass of winter maize for the years 2016-17,2017-18 and 2018-19. The irrigation water quality was kept constant and depth varied from 20 cm to 80 cm. The model was run separately for different depths of irrigation and details of irrigation combinations between irrigation water depth and quality have been used for simulation studies are presented in Table 1.

Table 1: Different combination of irrigation depth used for simulation studies

2016-17		2017-18		2018-19	
Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Irrigation water quality (ds/m)
20	1	20	1	20	1
30	1	30	1	30	1
40	**1**	**40**	**1**	**40**	**1**
50	1	50	1	50	1
60	1	60	1	60	1
70	1	70	1	70	1
80	1	80	1	80	1

Similarly Simulation studies using the FAO-AquaCrop model were done for the assessment of the impact of different quality of irrigation water on crop yield and biomass of winter maize for the years 2016-17,2017-18 and 2018-19.The irrigation water depth was kept constant and irrigation water quality varied from 1 ds/m to10 ds/m. In this study, the simulate the effect of different quality of irrigation water on crop yield and biomass of winter maize under applied a standard irrigation depth of *winter* maize (40 cm) with varies irrigation water quality from base water quality 1 ds/mto respectively increased 2, 4, 6, 8 and 10 ds/mby using FAO-Aquacrop model. The model was run separately for different quality of irrigation displayed in Table 2.

Table 2: Different combination of irrigation water quality used for simulation studies

2016-17		2017-18		2018-19	
Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Applied irrigation depth (cm)
1	**40**	**1**	**40**	**1**	**40**
2	40	2	40	2	40
4	40	4	40	4	40
6	40	6	40	6	40
8	40	8	40	8	40
10	40	10	40	10	40

Results and Discussion

The response of change in amount of irrigation water applied was analyzed using FAO-AquaCrop model for three *winter* seasons of 2016-17, 2017-18 and 2018-19. The results are presented in Table 3 to Table 5. The simulated crop yield and biomass increases as depth of water application increases. The simulated crop yield and biomass increases till 40 cm depth of irrigation water application for all three seasons. This analysis will also help in understanding the impact of deficit irrigation on *winter* maize. In case of deficit irrigation of 20 cm depth of irrigation water application the simulated yield reduced by 14.4 %, 25.4 % and 11.4 % for the year 2016-17, 2017-18 and 2018-19 respectively. The similar trend was observed for simulated biomass with biomass reduction of 12.3 %, 24.5 % and 10.6 % for the year 2016-17, 2017-18 and 2018-19 respectively for deficit irrigation depth of 20 cm. The lowest simulated yield reduction of 11.4 % was reported for the year 2018-19 is due to good amount of effective rainfall 31.0 mm during the cropping season compared to 2016-17 and 2017-18 respectively. The highest simulated yield reduction was found for the year 2017-18. When the similar comparison was made for 30 cm depth of irrigation water application the simulated yield reduction was only 0.79 %, 2.2% and 2.4% respectively for the year 2016-17, 2017-18 and 2018-19 respectively. The analysis suggests that this yield reduction can easily be compromised for saving 10 cm of irrigation water. There is no increase in simulated yield beyond 40 cm depth of irrigation water application for all the three *winter* seasons of 2016-17, 2017-18 and 2018-19. Kumar

Table 3: Response of different depth of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2016-17

Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change
20	1	8.62	-14.39	17.97	-12.34
30	1	9.99	-0.79	20.33	-0.82
40	**1**	**10.07**	**-**	**20.50**	**-**
50	1	10.10	0.29	20.54	0.19
60	1	10.07	0	20.49	-0.04
70	1	10.06	-0.09	20.47	-0.14
80	1	10.05	-0.19	20.44	-0.29

Table 4: Resp0nse of different depth of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2017-18

Applied irrigation depth (cm)	Irrigation water quality(ds/m)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change
20	1	7.03	-25.37	15.42	-24.48
30	1	9.21	-2.22	20.07	-1.71
40	**1**	**9.42**	**-**	**20.42**	**-**
50	1	9.40	-0.21	20.40	-0.09
60	1	9.39	-0.31	20.38	-0.19
70	1	9.38	-0.42	20.37	-0.24
80	1	9.35	-0.74	20.35	-0.34

Table 5: Response of different depth of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2018-19

Applied irrigation depth (cm)	Irrigation water quality (ds/m)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change
20	1	8.87	-11.38	18.48	-10.63
30	1	9.77	-2.39	20.30	-1.83
40	**1**	**10.01**	**-**	**20.68**	**-**
50	1	9.99	-0.19	20.66	-0.09
60	1	9.96	-0.49	20.63	-0.24
70	1	9.93	-0.79	20.59	-0.43
80	1	9.90	-1.09	20.55	-0.62

et al., 2018 reported that irrigation up to 75 % of crop water requirement for rabi maize was optimum. In one of the studies by Chandra and Tyagi , 2006 , SWAP model was successfully used for assessment of impact of different depth of irrigation water on crop yield. This study indicated that 30 cm depth of irrigation water is optimum for winter maize in Burhi Gandak river basin of North Bihar.

Effect of change in the quality of irrigation water on simulated crop yield and biomass of *winter* maize

The effect of change in quality of irrigation water applied was analysed using FAO-AquaCrop model for three *winter* seasons of 2016-17, 2017-18 and 2018-19. The results are presented in Table 6 to 8 and observed that the simulated crop yield and biomass decreases as irrigation water quality deteriorates. The crop yield was found maximum with 1 ds/m. The reduction in yield with 10 ds/m water quality was observed maximum with a value of 41.3 %, 44.4 % and 38.4 % respectively for the year 2016-17, 2017-18 and 2018-19. Similarly, the reduction in simulated biomass of *winter* maize with 10 ds/m water quality was observed maximum with a value of 39.9 %, 43.8 % and 37.9 % respectively for the year 2016-17, 2017-18 and 2018-19.Minimum decrease in simulated crop yield and biomass was observed during 2018-19 growing season compared to growing seasons of 2017-18 and 2016-17. The less reduction in yield during 2018-19 may be due to probable less salt accumulation in root zone to more effective rainfall (31.0 mm) in the year 2018-19 compared to 10.0 mm of effective rainfall in the year 2017-18. The other researchers also corroborated the similar findings (Chandra *et al.,* 2009; Kang y. *et al.,* 2010; Fang and Su, 2019).

Table 6: Response of different quality of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2016-17

Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change	ET productivity (kg/m3)
1	40	10.07	-	20.50	-	4.73
2	40	9.99	-0.79	20.33	-0.82	4.73
4	40	9.59	-4.76	19.68	-4.00	4.62
6	40	8.46	-15.98	17.60	-14.14	4.32
8	40	7.27	-27.80	15.16	-26.04	3.96
10	40	5.91	-41.31	12.31	-39.95	3.56

Table 7: Response of different quality of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2017-18

Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change	ET productivity (kg/$m^{-3)}$
1	40	9.42	-	20.42	-	4.28
2	40	9.22	-2.12	20.13	-1.42	4.21
4	40	8.83	-6.26	19.36	-5.19	4.14
6	40	7.96	-15.49	17.45	-14.54	4.00
8	40	6.68	-29.08	14.64	-28.30	3.71
10	40	5.24	-44.37	11.48	-43.78	3.36

Table 8: Resp0nse of different quality of irrigation water on simulated crop yield and biomass of *winter* maize during crop growing season 2018-19

Irrigation water quality (ds/m)	Applied irrigation depth (cm)	Crop yield (t/ha)	% change	Biomass (t/ha)	% change	ET productivity (kg/m^3)
1	40	10.01	-	20.68	-	4.58
2	40	9.78	-2.29	20.32	-1.74	4.51
4	40	9.46	-5.49	19.69	-4.78	4.84
6	40	8.63	-13.78	17.98	-13.05	4.28
8	40	7.43	-25.77	15.48	-25.14	4.01
10	40	6.17	-38.36	12.85	-37.86	3.64

Crop yield and biomass of *winter* maize crop was diminished because of minimal and low-quality water in furrow watersystem framework. The inferior quality water would have influenced the plant development and soil structure legitimately and in a roundabout way. This may be attributed to high concentration of salt in low quality water, which caused soil salinity in soil profile. Salt concentration brought about high osmotic capability of soil arrangement, due to that plant utilized more vitality to ingest water. Gang *et al.,* (2009) also found decrease in both transpiration and photosynthesis due to limited carbon dioxide uptake under salt stress. ThChandrae analysis of results from Table 6 to 8 suggested that rate of evapotranspiration is decreasing with increase in salinity level and evapotranspiration productivity has reduced from 4.73 to 3.56, 4.28 to 3.36, and 4.58 to 3.64.

Conclusion

The optimum quantity and quality of irrigation water are most important for *winter* maize. This study has given insight into decision-making regarding irrigation water application for *winter* maize under different scenarios. FAO-AquaCrop model was used for this study. The simulated crop yield and biomass increases upto 40 cm depth of irrigation water application for all three seasons. When a similar comparison was made for 30 cm depth of irrigation water application the simulated yield reduction was only 0.79%, 2.2% and 2.4 % for the year 2016-17, 2017-18 and 2018-19 respectively. The analysis suggested that this yield reduction can easily be compromised for saving 10 cm of irrigation water. This study indicates that 30 cm depth of irrigation water is optimum for winter maize in Burhi Gandak river basin of North Bihar. In case of deficit irrigation of 20 cm depth of irrigation water application, the simulated yield reduced by 14.4 %, 25.4 % and 11.4 % for the year 2016-17, 2017-18 and 2018-19 respectively. Assessment of effect of different quality of irrigation water on simulated crop yield and biomass of *winter* maize using FAO-Aquacrop model suggests that simulated yield was found maximum with 1 ds/m. The reduction in simulated yield with 10 ds/m water quality was observed maximum with a value of 41.3 %, 44.4 % and 38.4 % for the year 2016-17, 2017-18 and 2018-19, respectively. The FAO-Aqucrop model can be used effectively to estimate the agricultural crop water requirement, crop yield and irrigation scheduling for different crops for North Bihar conditions under changing climatic scenario.

Conflict of interest

The authors declare that they have no conflict of interest.

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