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RESEARCH ARTICLE

Irrigation Scheduling and Estimating Yield Reduction in Chickpea under Rainfed Condition and Changing Climate of North Interior Karnataka

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ABSTRACT

Chickpea is one of the major legumes predominately cultivated in North Interior Karnataka (NIK). This simulation study using CROPWAT model aimed at quantifying yield reduction under rainfed conditions and proper irrigation scheduling in chickpea variety BGD-103. This would help NIK farmers in tapping the potential yields of this crop through proper irrigation management. Crop management input in the model was based on the recommended practices of UAS, Dharwad, across four dates of sowing from 1st October to 15th October at quarterly intervals on black clay soil. The simulated outputs were analyzed at decadal interval for both past (1991-2020) and projected climate (2021-2050). Under past climate, two irrigation was simulated *i.e.*, one irrigation at 40-45 days after sowing (DAS) and another at pod filling stage (70 DAS). The number of irrigations decreased by one under projected climate *i.e.,* only one irrigation at 45 DAS. Yield reduction in rainfed conditions on black clay soil under past climate was 31.6 %, which in contrast, decreased by 16.4 % under projected climate and is presented against spatial distribution across NIK. Sowing early *i.e.,* on 01st October under projected climate (2021-2050) simulated the lowest yield reduction (rainfed) and require fewest irrigations across 12 districts of NIK.

Keywords:*CROPWAT; Yield reduction; Irrigation scheduling; NIK*

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INTRODUCTION

Climate is one of the most important determinants of agricultural output as it is linked to physiological processes and directly impacts output production. This issue has the potential to impact global food security, particularly in underdeveloped countries. Depending on location, climate zone and crop, climate change may have both positive and negative effects on agricultural production in terms of quantity and quality (Gitz*et al*., 2016). The sixth assessment report of the Intergovernmental Panel on Climate Change indicates agriculture projected yield losses of up to 32 per cent by 2100 (RCP8.5) due to the combined effects of temperature and precipitation (Caretta *et al*., 2022). Globally, 11% (±5%) of croplands are estimated to be vulnerable to projected climate-driven water scarcity by 2050 (Fitton *et al*., 2019).It clearly shows that the climate is change is resulting in unstable agricultural production being greatly influenced by the changing climate over time.

The global water consumption doubles every 20 years, more than twice the rate of human population growth. FAO estimates show that, 70 to 80 per cent increase in food demand between 2000 and 2030 will have to be met by increasing irrigation supplyto field crops (FAO, 2017). Irrigated agriculture is practiced on about 300 m ha globally,which accounts for only 20 per cent of the total cultivated area, but contributes substantially tomore than 40 per cent of world's food production (Banik*et al.,* 2014). A scarcity of water resources and growing competition will reduce its irrigation availability. Accurately planning and delivering the necessary amount of water in the time and space can conserve water (Borettiand Rosa,2019). Achieving greater efficiency of water use will be a primary challenge for the near future. It will include employing techniques and practices that deliver a more accurate supply of water to crops.

Chickpea (*Cicer arietinum*) is called as 'King of pulses' as it constitutes one-third of the area and 40 per cent of total pulse production in India, and their protein content is around 22-23 per cent. In India, it occupies an area of 10.56 m ha with a production of 11.28 m t and a productivity of 1078 kg ha^{-1} (Anon., 2020). Karnataka, one of the major chickpeaproducing states in the country constitutes an area of 12.6 lakh ha, production of 7.83 lakh t and productivity of 619 kg ha^{-1} (Anon., 2020). It is cultivated extensively in Northern Karnataka, especially in Dharwad, Belagavi, Vijayapur, Bagalakote and Bidar districts on *Vertisols*during *Rabi* season under residual moisture. Since this legume is grown on residual soil moisture (rarely under any supplemental irrigation), supplying irrigation either fully or as a lifesaving irrigation at critical stages could help achieve the crop's untapped productivity.

Crop simulation models use quantitative descriptions of ecophysiological processes to predict plant growth and development as influenced by environmental conditions and crop management, which are specified for the model as input data (Hodson and White, 2010). Thus, it can help drive efficiency in agricultural production systems by allowing farmers to manage their inputs more efficiently by predicting crop production/food security under a range of projected climate scenarios to subsequently compute the

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economic consequences of the altered production i.e., to compute the water use (irrigation required) involved and to hypothesize possible adaptation/mitigation strategies. With these points in mind, the present study has been taken up to predict the optimum irrigation management strategies for increased production in the NIK region under future climate scenario.

METHODOLOGY

North Interior Karnataka (NIK) is one of the three meteorological sub-divisions of Karnataka state of India classified by the India Meteorological Department (IMD). It consists of a geographical region with a mostly semi-arid plateau from 300 to 730 meters (980 to 2,400 ft) elevation constituting 12 districts, namely Bagalakote, Ballari, Belagavi, Bidar, Dharwad, Gadag, Haveri, Kalaburgi, Koppal, Raichur, Vijayapura and Yadagiri (Fig. 1). This region is largely covered with rich black cotton and red sandy loamy soils, gently sloping lands and plains, summits of plateau and tablelands. NIK is one of India's drier regions, receiving on average just 731 mm rainfall per annum (Anon., 2016).

The immediate past weather data (rainfall, minimum and maximum temperature) for 12 districts of NIK was collected from NASA POWER web portal (*https://power.larc.nasa.gov*) (Sparks, 2018) for the past climatic period of 30 years (1991 to 2020) and the projected climatic data for the period of upcoming 30 years (2021-2050) was collected from Copernicus Climate Change Service (IPSL-CM5A model) (*https://climate.copernicus.eu*).

The field experiment was conducted atUniversity of Agricultural Sciences (UAS), Dharwad during*Rabi*seasons of 2019-20 and 2020-21. The phenological data for initial, mid and late growth stages of chickpea variety BGD-103 collected from the field experiment were used in the model. The salient details of chickpea crop required for the study *i.e.,* crop coefficients (Kc), phenological days, critical depletion fraction (p) and yield response factor (Ky) were also taken from the available 18 published data of FAO (Allen *et al.*, 1998). The soil data on total available soil moisture content (SMC), initial soil moisture depletion, maximum rooting depth and maximum rain infiltration rate for black clay soil for all the 12 districts of NIK were collected from the world bank sponsored Sujala Project at UAS, Dharwad. The CROPWAT 8.0 model suited for windows was used to simulate crop and irrigation water requirements based on soil, climate, and crop data for the study. It is a computer program developed by the land and development division of FAO. The model has been run for all the 12 districts of NIK for chickpea using district-level historical weather data forpast 30 years (1991-2020) as well as projected weather data for30 years (2021-2050) to know the critical stages of irrigation and irrigation scheduling at a proper stage of crop across different dates of sowing (DOS) *i.e.,* four dates of sowing starting from 01st October to 15th November at quarterly interval on black clay soil. The spatial interpretation of the parameters for all 12 districts of NIK was done using ArcGIS software.

RESULTS AND DISCUSSION

Irrigation Scheduling

Vijayapur district has recorded the highest average number of irrigationsi.e., two irrigations in the past climate at 40-45 DAS and at 70 DAS (pod filling stage) as presented in Table 2. The lowest rainfall during the cropping period of chickpea (October to February) is the influential parameter (Table 1). The lowest average irrigations were simulated for Ballari district (1.4) because of its highest rainfall during the cropping period of chickpea among the 12 districts of NIK in the past climate (Table 2). The remaining districts have shown more than 1.5 average of irrigations*i.e.,* one compulsory irrigation at 45 DAS. This is because of increased water requirementsduringthe development stage and less rainfall in December for November sown crops. Similar results were also observed by Desta *et al.*, (2015) where two compulsory irrigations at the flowering and pod-filling stages were simulated. In the projected climate, all the districts have shown one irrigation at 45 DAS,this is because ofthe increased simulated rainfall in October and November months compared to the past climate (Table 1). Single irrigation at 45 DAS is critical as water requirement at this stage initiates flowering in chickpea i.e., the start of the reproductive stage, which is crucial in better development of the economic part of plant.

In the past, climate minimum of one irrigation was simulated for crop sown on 1stOctober in all the districts of NIK,while for all the delayed sowing, datestwo irrigations were simulated irrespective of the districts (Table 3). This was due to more rainfall during October month due to North-East monsoon onset which dissipates towards December.Under the projected climate for all the dates of sowing, only one irrigation was simulated at 45 DAS because of the higher water requirement at this stage i.e., initiation of flowering (Table 3). Only one irrigation was simulated due to increased rainfall under projected climate than the past for all the 12 districts of NIK (Table 1). Athnere and Kolage (2019) reported that the maximum consumptive use of water has recorded under the scheduling of irrigation at 40 mm CPE (305 mm), followed by the treatment irrigation at 60 mm CPE (223 mm).

Yield Reduction under rainfed condition

Vijayapur (34.8 %) followed by Kalaburagi (33.4 %) districts simulatedthe highest yield reduction (YR) under rainfed conditions in past climate. The lowest rainfall during the cropping period has affected the yielddrastically (Table 1). The lowest YR was for Ballari (26.6 %) district, followed by Haveri (28.8 %) because of their higher rainfallreceived during the cropping period compared to other districts. Under the projected climate, every district showed decreased YR compared to past climate (Table 2 and Fig. 2) because of increased rainfallunder the projected climate. The highest YR in the projected climate was for Bidar district (18.1 %), and lowest was for Belagavi (12 %). This was because of associated changes in their respective rainfall and temperatureunder the projected climate. The highest decrease in the YR in the projected climate compared to the past was for the Belagavi district (20.5 %) because of its highest increased October-December rainfall in the projected climate among all the districts under study. Lowest decrease was for Ballari (12.5 %) district. Bhat *et al.* (2017) calculated yield reduction in maize for silty clay loam soil at critical depletion, irrigated at a given ET_c of crop reduction per stage and irrigated at fixed

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interval per stage at 70 per cent field efficiency was found to be 0, 14.9 and 25.1 per cent, respectively. Also, yield reduction at no water stress and at water stress was found to be 0 and 26.80 per cent, respectively.

The YR has increased with delay in sowing in both past and projected climate in all the districts of NIK (Table 3). Since the North-East rainfall dissipates towards the December month,the late sowing crop receives less rainfall, ultimately reflecting increased YR.According to RCP 6.0 scenario, there would be an increase of 97.4 mm rainfall and 0.1˚C temperature. At the same time, number of rainy days decrease by 12 during the chickpea cropping period (Oct-Feb) under the projected climate (2021-2050) compared to past climate (1991-2020) (Table 1).

Table 1: Average weather data during chickpea cropping period (Oct- Feb) of all the 12 districts of NIK for the past climate (1991 - 2020), the projected climate (2021 – 2050) and the difference between the two periods

Districts	Past climate (1991-2020)			Projected climate (2021-2050)			Difference between Past & Projected climate		
	Rain (mm)	Temp (˚C)	RD	Rain (mm)	Temp (˚C)	RD	Rain (mm)	Temp (˚C)	RD
Bidar	119.9	23.5	16	159.7	23.4	20	39.8	-0.1	4
Bagalakote	123.7	24.2	18	234.5	24.0	31	110.8	-0.3	13
Belagavi	135.3	24.1	19	281.1	24.9	39	145.8	0.8	20
Vijayapur	112.1	24.3	16	220.5	24.0	29	108.5	-0.4	12
Ballari	149.2	24.4	25	275.7	24.3	34	126.4	-0.1	9
Dharwad	153.2	23.9	21	281.1	24.9	39	127.9	1.0	18
Gadag	139.1	24.2	19	267.6	24.9	38	128.7	0.7	19
Kalaburagi	123.6	24.3	16	163.4	23.4	23	39.7	-0.9	7
Haveri	175.8	24.0	24	267.6	24.9	37	91.7	0.9	14
Koppal	138.4	24.3	31	243.3	24.9	37	104.8	0.6	6
Raichur	127.3	24.9	17	196.2	24.0	25	68.9	-0.9	7
Yadagiri	120.3	24.6	16	196.2	24.0	25	75.8	-0.6	9
NIK	**134.8**	**24.2**	**20**	**232.2**	**24.3**	**31**	**97.4**	**0.1**	**12**

*Temp- Temperature, RD- Rainy days

Table 2: District wise yield reduction (YR) and number of irrigations (No. of Irr.) required for past (1991-2020), projected (2021-2050) climate and difference between the two climate in Chickpea

Districts	1991-2020 (A)		2021-2050 (B)		Difference (B-A)	
	YR (%)	No. of Irr.	YR (%)	No. of Irr.	YR (%)	No. of Irr.
Bagalakote	31.5	1.8	16.2	1.0	-15.4	-0.8
Ballari	26.6	1.4	14.0	1.0	-12.5	-0.4
Belagavi	32.5	1.8	12.0	1.0	-20.5	-0.8
Bidar	32.6	1.8	18.1	1.0	-14.5	-0.8
Dharwad	31.1	1.8	12.6	1.0	-18.5	-0.8
Gadag	31.4	1.8	14.0	1.0	-17.4	-0.8
Haveri	28.8	1.6	14.4	1.0	-14.5	-0.6
Kalaburagi	33.4	1.8	17.9	1.0	-15.5	-0.8
Koppal	30.9	1.8	13.8	1.0	-17.1	-0.8
Raichur	33.0	1.8	17.3	1.0	-15.7	-0.8
Vijayapur	34.8	2.0	16.2	1.0	-18.6	-1.0
Yadagiri	33.2	1.8	16.9	1.0	-16.2	-0.8
Average	**31.6**	**1.8**	**15.3**	**1.0**	**-16.4**	**-0.8**

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Table 3: District wise average yield reduction (YR) and number of irrigations (No. of Irr.) required for four dates of sowing in both black clay soil under both past (1991-2020) and projected (1991-2020) climate in Chickpea

Districts	Yield Reduction (%)								No. of Irrigation							
	Past climate (1991-2020)				Projected (2021-2050)				Past climate (1991-2020)				Projected (2021-2050)			
	01-Oct	15-Oct	01-Nov	15-Nov	01-Oct	15-Oct	01-Nov	15-Nov	01-Oct	15-Oct	01-Nov	15-Nov	01-Oct	15-Oct	01-Nov	15-Nov
Bagalakote	24.7	30.1	36.4	35.0	9.9	13.3	17.9	23.6	1.3	2.0	2.0	2.0	1	1	1	1
Ballari	17.6	23.1	29.7	35.9	7.5	10.9	15.8	22.0	1.0	1.0	1.7	2.0	1	1	1	1
Belagavi	23.0	29.1	36.2	41.7	6.1	9.4	13.9	18.8	1.0	2.0	2.0	2.0	1	1	1	1
Bidar	24.8	30.1	35.8	39.7	12.1	15.5	19.7	25.1	1.3	2.0	2.0	2.0	1	1	1	1
Dharwad	21.1	27.4	34.8	41.0	6.3	9.6	14.1	20.4	1.0	2.0	2.0	2.0	1	1	1	1
Gadag	22.2	27.9	34.7	40.6	7.3	11.0	15.8	21.9	1.0	2.0	2.0	2.0	1	1	1	1
Haveri	18.6	24.9	32.6	39.3	7.6	11.3	16.2	22.3	1.0	1.3	2.0	2.0	1	1	1	1
Kalaburagi	25.4	30.7	36.6	40.9	12.0	15.3	19.5	24.9	1.3	2.0	2.0	2.0	1	1	1	1
Koppal	22.1	27.6	33.8	40.0	7.1	10.8	15.6	21.7	1.3	2.0	2.0	2.0	1	1	1	1
Raichur	24.1	29.9	36.5	41.6	10.6	14.3	19.2	25.0	1.0	2.0	2.0	2.0	1	1	1	1
Vijayapur	27.2	32.1	37.8	42.1	9.8	13.3	18.0	23.8	2.0	2.0	2.0	2.0	1	1	1	1
Yadagiri	24.4	30.1	36.6	41.5	10.2	14.0	18.9	24.6	1.3	2.0	2.0	2.0	1	1	1	1
NIK	**22.9**	**28.6**	**35.1**	**39.9**	**8.9**	**12.4**	**17.0**	**22.9**	**1.2**	**1.9**	**2.0**	**2.0**	**1**	**1**	**1**	**1**

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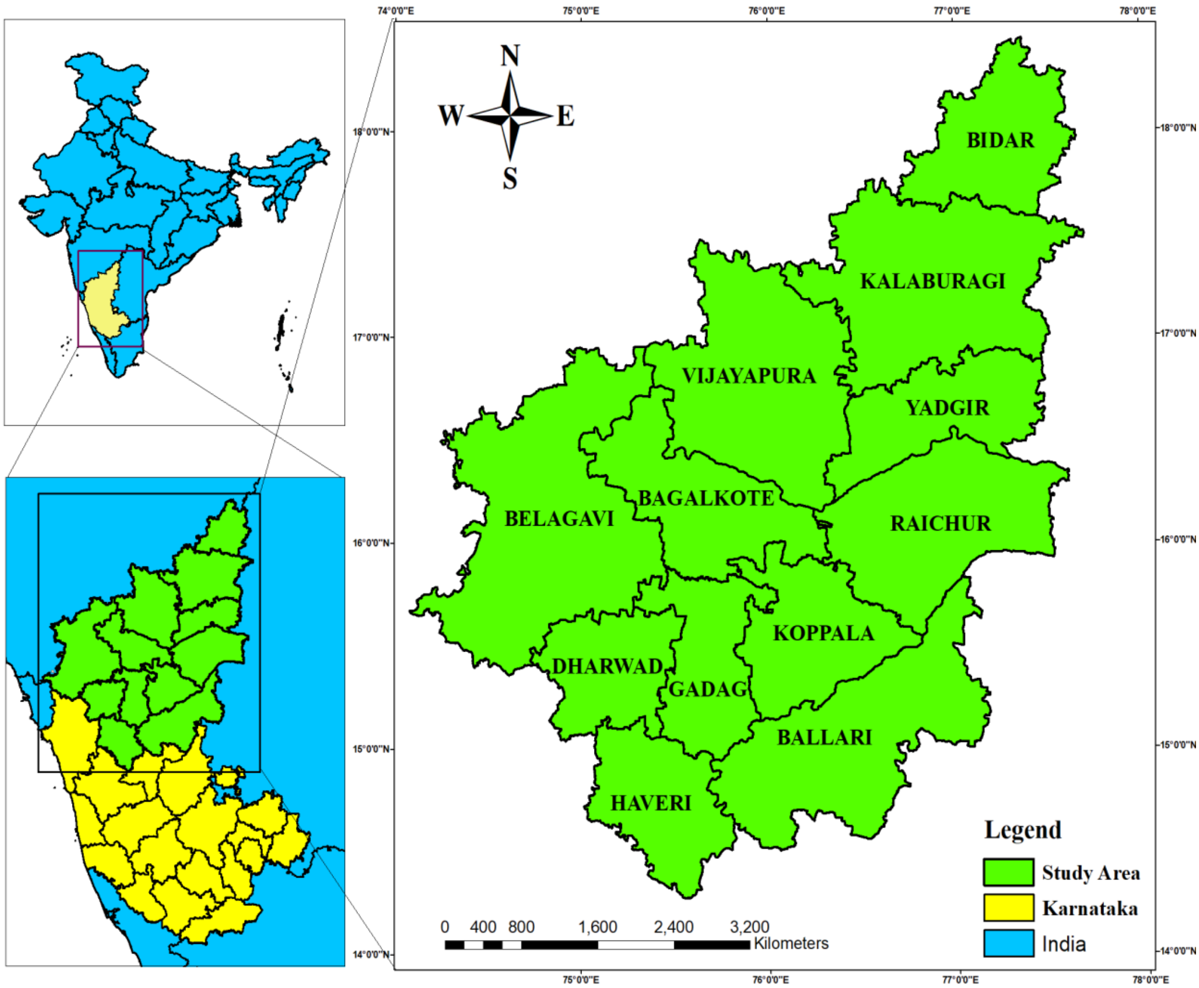

Fig. 1: Spatial map of 12 districts of North Interior Karnataka

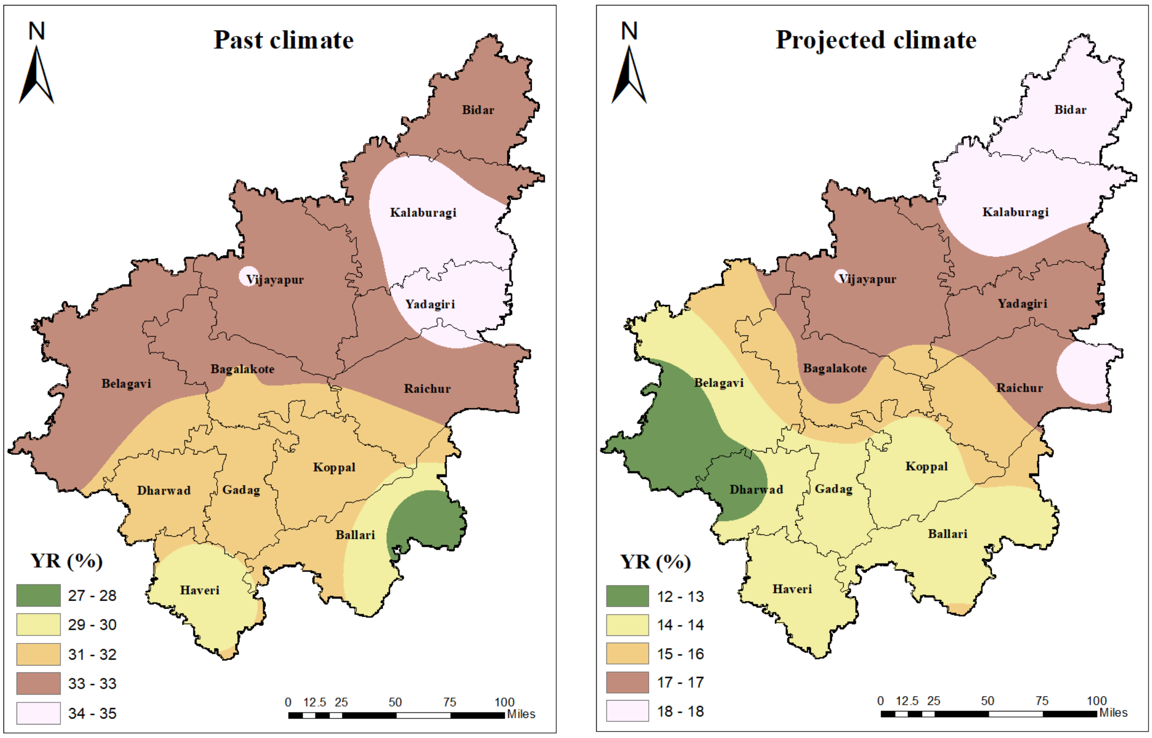

Fig 2:Spatial distribution of yield reduction (YR) in chickpea simulated in black clay soil under past (1991-2020) and projected (2021-2050) climate for all districts of NIK

CONCLUSION

The study for Northern Interior Karnataka revealed increased rainfall under the projected climate during the chickpea cropping period (October- February) compared to past climate. This increased rainfall resulted in the decreased number of irrigations and yield reduction. Early sowing of chickpea *i.e.,* on 1st October under projected climate (2021-2050) simulated the lowest number of irrigations i.e., one irrigation at 45 DAS (at flower initiation stage) and decreased yield reduction for all the 12 districts of NIK on *Vertisol*. In this context, further research should betaken up on the adaptability of pulses to the climate variability under the future climate for their sustenance and improved productivity.

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Ethics statement

No specific permits were required for the described field studies because no human or animal subjects were involved in this research.

Consent for publication

All the authors agreed to publish the content.

Conflict of interest

The authors declare no known conflict of interests that could have appeared to influence the work reported in the present paper.

Data availability

The data presented in the present research paper is self-explanatory and for any further data accessibility do contact the corresponding author.

Author's contribution

Research grant-HT,Idea conceptualization-HT, MBN, Guidance -MBN, PK, SG, PP, Writing original draft –HT, MBN, Writing- reviewing &editing -PK, SG, PP.

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