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RESEARCH ARTICLE

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Effect of Changing Climate on Water Requirement of Chickpea in North Interior Karnataka: Cropwat Model based Assessment

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Abstract

Background: Chickpea is one of the major protein rich legume crops predominantly cultivated in North Interior Karnataka (NIK). The study aimed to determine water requirement of chickpea (variety BGD- 103) using CROPWAT model that helps in tapping the potential yields of the crop through proper irrigation management by the farmers of North Interior Karnataka (NIK), which consists of 12 districts with 88,361 km^2 area.

Methods: The crop was simulated by considering recommended practices of UAS, Dharwad across four dates of sowing from 01st October to 15th November at quarterly interval for the past (1991-2020) and projected period (2021-2050), and the decadal analysis was done for the past and projected climate. The analysed climate, crop and soil data were used for simulation using CROPWAT model.

Results: The average crop evapotranspiration (ET_c), effective rainfall (ER) and irrigation requirement (IR) under past climate (1991-2020) for NIK were 292.6, 57.4 and 245.9 mm, respectively. Decrease of 67 mm in ET_c, 91.3 mm in IR and an increase of 40.8 mm in ER were observed under projected climate. Sowing early *i.e.,* on 01st October under projected climate (2021-2050) simulated the lowest water requirement and irrigation requirement for all the 12 districts of NIK.

Key words: Crop evapotranspiration, CROPWAT, Effective rainfall, Irrigation requirement, NIK.

Introduction

Prediction of the crop water requirement is of vital importance in water resource management. Crop water requirements are normally expressed by the rate of evapotranspiration (ET) in mm day^{-1}. The level of ET has been shown to be related to the evaporative demand of the air. The evaporative demand can be expressed as the reference evapotranspiration (ET_o) which when calculated predicts the effect of the climate on the level of the crop evapotranspiration. The effect of the weather variable on the water demand of the crop can be analysed by the CROPWAT model which was developed by the FAO-Land and Water Development Division (Allen *et al.,* 1998). Agrometeorological variables are one of the key inputs required for the operation of the crop simulation models. These include the maximum and minimum temperature, air humidity, wind speed, sunshine hours, solar radiation and total rainfall. Out of these variables temperature and rainfall have direct and maximum impact on crop production.

North Interior Karnataka (NIK) also locally known as 'Uttara Karnataka' is a geographical region consisting of mostly semi-arid plateau from 300 to 730 metres (980 to 2,400 ft) elevation that constitutes the northern part of the South Indian state- Karnataka. It constitutes 12 districts namely Bagalakote, Ballari, Belagavi, Bidar, Dharwad, Gadag, Haveri, Kalaburgi, Koppal, Raichur, Vijayapura and Yadagiri. This region is largely covered with rich black cotton and red sandy loamy soils, gently sloping lands and plains, summits of plateau and table lands. NIK is one of the drier regions of India receiving on an average just 731 mm rainfall per annum (Anonymous, 2016). Chickpea is one of the major pulse crop grown under rainfed conditions in NIK region. Some of the farmers go for one or two irrigation at flowering and pod filling stages if necessary.

The seasonal analysis was done for all the 12 districts of NIK (Fig 1) for chickpea using district level historical weather data of past 30 years (1991-2020) as well as projected weather data of 30 years (2021-2050) to bring about crop evapotranspiration (ET_c), effective rainfall (ER) and irrigation requirements (IR) 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. As above mentioned parameters varied distinctly under decadal scenario for each district and the best date of sowing as an adaptation strategy was identified for chickpea under past and projected weather conditions. These results are represented for each district separately.

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MATERIALS AND METHODS

The immediate past weather data (rainfall, minimum and maximum temperature) for 12 district of NIK (Fig 1) was collected from NASA POWER web portal (https://power.larc.nasa.gov) (Sparks, A. H, 2018) for the period of 30 years from 1991 to 2020 and the projected data for the period of coming 30 years from 2021-2050 was collected from Copernicus Climate Change Service (IPSL-CM5A model) (https://climate.copernicus.eu). According to RCP 6.0 scenario, there would be an increase of 97.4 mm rainfall and 0.1 C temperature while number of rainy days decrease by 12 during the chickpea cropping period (Oct-Feb) under the projected climates (2021-2050) compared to past climates (1991-2020) (Table 1).

The field experiment was conducted at University of agricultural sciences, Dharwad in *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), 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

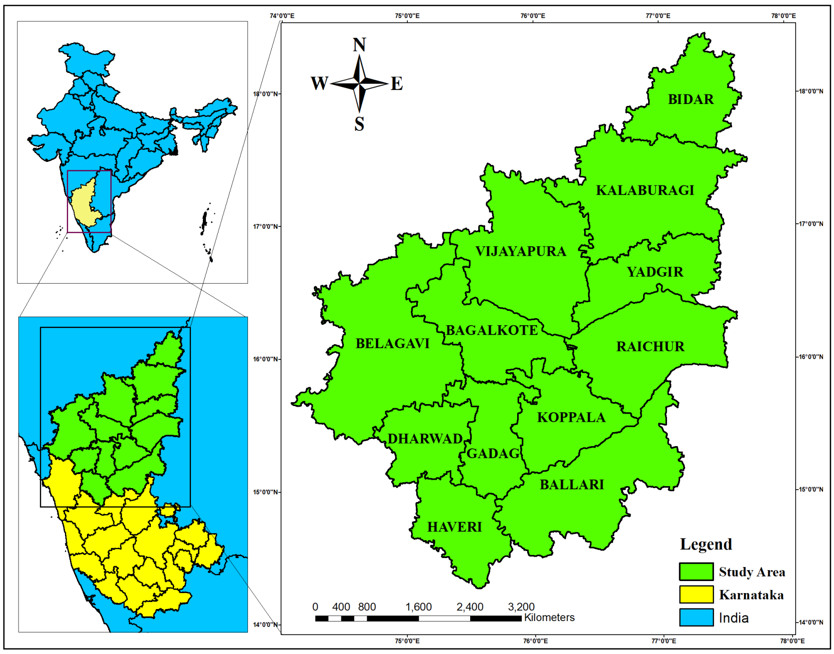

Fig 1: Spatial map of 12 districts of North Interior Karnataka.

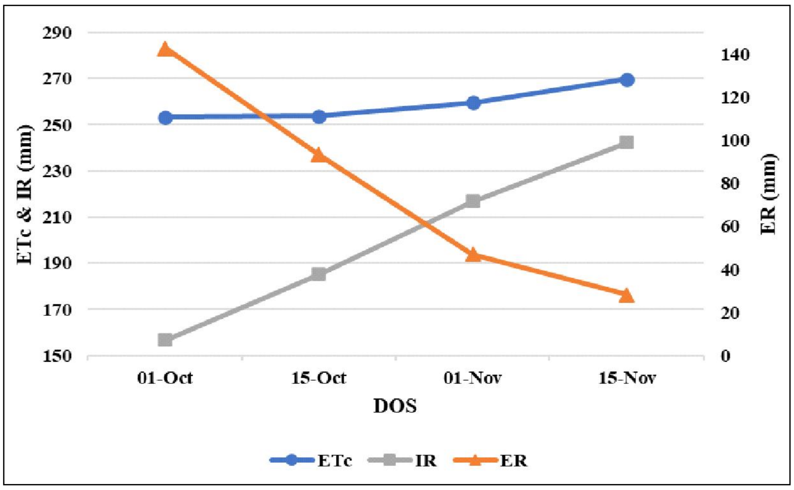

Fig 2: Average crop evapotranspiration (ET_c), effective rainfall (ER) and irrigation requirement (IR) in chickpea for the four dates of sowing (DOS) for NIK.

soil moisture depletion, maximum rooting depth and maximum rain infiltration rate for black clay and red sandy loam soils for all the 12 districts of NIK were collected from the world bank sponsored Sujala Project at UAS, Dharwad (Table 2). The CROPWAT 8.0 model suited for windows was used for the simulation of crop and irrigation water requirements based on soil, climate and crop data for the study. It is a computer program developed by land and development division of FAO. The spatial interpretation of the parameters for all the 12 districts of NIK was done using ArcGIS software.

RESULTS AND DISCUSSION

Correlation analysis

Higher positive correlation at 1% level of significance between ET_o and ET_c was observed for all the 12 districts of NIK. Similarly higher positive correlation at 1% level of significance was observed between ET_c-ER and IR for all the districts of NIK. The relation between ER and IR was non-significant for Ballari district while it was negatively correlated at 5% level of significance for Bidar (0.9), Kalaburagi (0.89) and Raichur (0.878) districts. The remaining districts have shown negative correlation between ER and IR at 1% level of significance Table 3.

Reference evapotranspiration (ET_o) in the past and projected climates

The highest ET_o was recorded for Vijayapur district (1806.8 mm year^{-1}) and the lowest was for Ballari (1598.7 mm year^{-1}) under the past climate (1991-2020). Under projected climate (2021-2050) the highest ET_o was recorded for Kalaburagi district (1648.6 mm year^{-1}) and the lowest was for Koppal district (1526.9 mm year^{-1}). The ET_o under the projected

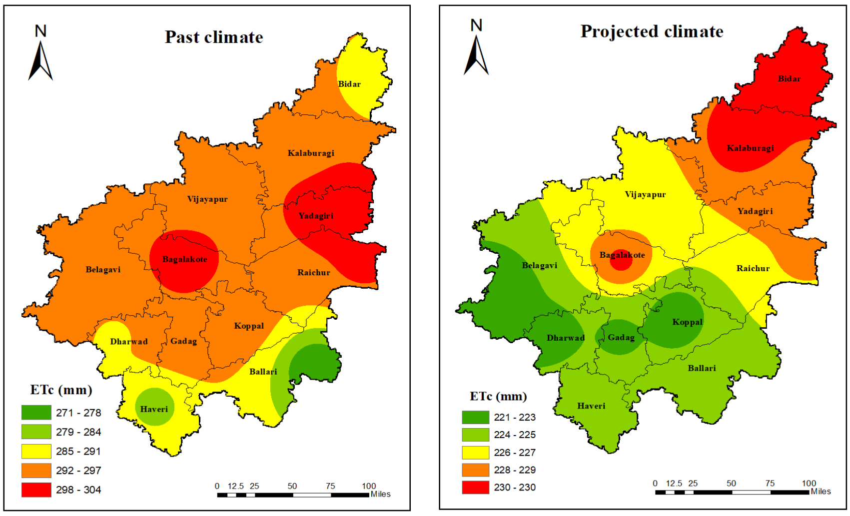

Fig 3: Spatial distribution of crop evapotranspiration (ET_c) of chickpea under past (1991-2020) and projected (2021-2050) climate across of NIK region.

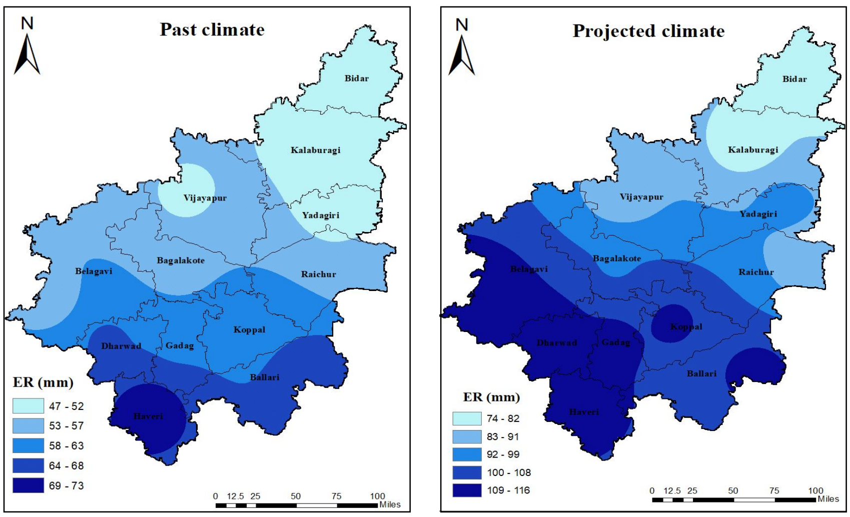

Fig 4: Spatial distribution of effective rainfall (ER) of chickpea under past (1991-2020) and projected (2021-2050) climate across of NIK region.

climates was simulated to decrease by 50-200 mm year^{-1} across districts except for Ballari which showed decrease of only 4.9 mm year^{-1}. The highest reduction in ET_o under projected climate compared to past climate was observed in Koppal district (210 mm year^{-1}) (Table 4).

The ET_o for the past climate (1991-2020) showed the highest value (6.4 mm day^{-1}) in the month of April and the lowest value (3.8 mm day^{-1}) in the month of November for NIK. The highest (6.1 mm day^{-1}) ET_o for projected climate (2021-2050) was for May and the lowest (3 mm day^{-1}) was

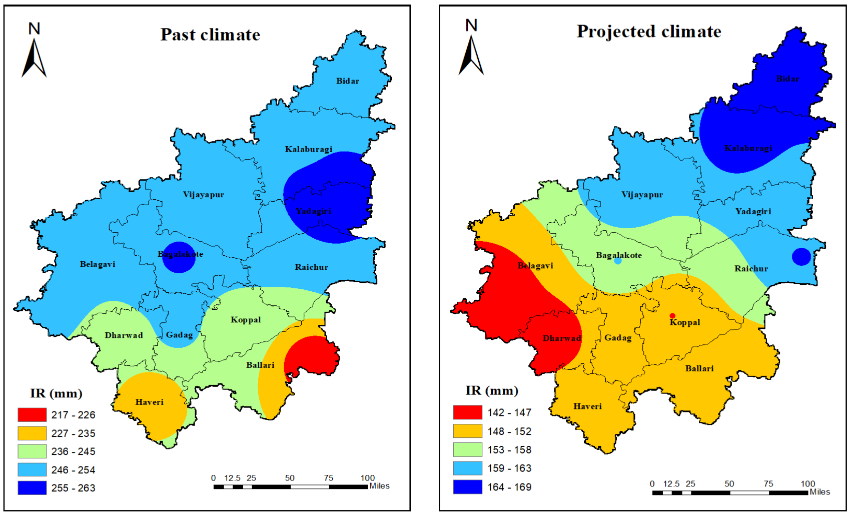

Fig 5: Spatial distribution of irrigation requirement (IR) of chickpea under past (1991-2020) and projected (2021-2050) climate across of NIK region.

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 and 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: Soil parameters of black clay and red sandy loam used in the CROPWAT model for all the districts of NIK.

Soil name	Black clay	Red sandy loam
Total Available Soil moisture (FC-WP) (mm/meter)	200	100
Maximum rain infiltration rate (mm/day)	7	30
Maximum rooting depth (centimeters)	150	50
Initial soil moisture condition (as % TAM) (%)	30	20
Initial available soil moisture (mm/meter)	140	80

(Source: Sujala Project, UAS, Dharwad).

Table 3: Decadal simulated reference evapotranspiration (ET_o; mm year^{-1}) of all the districts of NIK and the difference between projected and past climate.

Districts	1991-2000	2001-2010	2011-2020	2021-2030	2031-2040	2041-2050	Past (1991-2020) (A)	Projected (2021-2050) (B)	Difference (B-A)
Bagalakote	1759.3	1741.1	1759.3	1598.7	1635.2	1649.8	1753.2	1627.9	-125.3
Ballari	1733.8	1704.6	1357.8	1565.9	1606.0	1609.7	1598.7	1593.8	-4.9
Belagavi	1653.5	1638.9	1653.5	1496.5	1522.1	1573.2	1648.6	1530.6	-118.0
Bidar	1748.4	1730.1	1752.0	1620.6	1682.7	1657.1	1743.5	1653.5	-90.0
Dharwad	1657.1	1638.9	1646.2	1496.5	1522.1	1573.2	1647.4	1530.6	-116.8
Gadag	1722.8	1700.9	1722.8	1496.5	1522.1	1573.2	1715.5	1530.6	-184.9
Haveri	1613.3	1595.1	1609.7	1496.5	1522.1	1573.2	1606.0	1530.6	-75.4
Kalaburagi	1781.2	1763.0	1788.5	1613.3	1679.0	1653.5	1777.6	1648.6	-129.0
Koppal	1748.4	1722.8	1741.1	1492.9	1518.4	1569.5	1737.4	1526.9	-210.5
Raichur	1773.9	1770.3	1784.9	1598.7	1653.5	1638.9	1776.3	1630.3	-146.0
Vijayapur	1810.4	1795.8	1814.1	1595.1	1631.6	1646.2	1806.8	1624.3	-182.5
Yadagiri	1766.6	1763.0	1777.6	1591.4	1649.8	1635.2	1769.0	1625.5	-143.6
Average	1730.7	1713.7	1700.6	1555.2	1595.4	1612.7	1715.0	1587.8	-127.2

Table 4: Simulated reference evapotranspiration (ET_o; mm day^{-1}) for the cropping period of chickpea (October- February) under past (1991-2020), projected (2021-2050) climate and difference between both the climates across NIK.

Month	1991-2020 (A)					2021-2050 (B)					Average	Average	Difference
	Oct	Nov	Dec	Jan	Feb	Oct	Nov	Dec	Jan	Feb	(A)	(B)	(B-A)
Bagalakote	4.1	4.0	4.0	4.4	5.2	3.6	3.3	3.1	3.3	3.9	4.3	3.4	-0.9
Ballari	3.7	3.6	3.6	4.0	4.7	3.5	3.2	3.0	3.2	3.9	3.9	3.4	-0.6
Belagavi	3.8	3.8	3.9	4.4	5.2	3.5	3.2	3.0	3.2	3.8	4.2	3.3	-0.9
Bidar	3.9	3.9	3.8	4.1	5.0	3.7	3.3	3.0	3.2	3.9	4.1	3.4	-0.7
Dharwad	3.7	3.7	3.9	4.4	5.2	3.5	3.2	3.0	3.2	3.8	4.2	3.3	-0.8
Gadag	3.9	3.9	3.9	4.4	5.2	3.5	3.2	3.0	3.2	3.9	4.3	3.3	-0.9
Haveri	3.6	3.6	3.8	4.3	5.1	3.5	3.2	3.0	3.2	3.9	4.1	3.4	-0.7
Kalaburagi	4.0	4.0	3.9	4.2	5.0	3.7	3.3	3.0	3.2	3.9	4.2	3.4	-0.8
Koppal	4.0	3.9	3.9	4.3	5.1	3.5	3.2	3.0	3.2	3.8	4.3	3.3	-0.9
Raichur	3.9	3.9	4.0	4.4	5.3	3.6	3.3	3.0	3.2	3.9	4.3	3.4	-0.9
Vijayapur	4.3	4.1	4.0	4.3	5.1	3.6	3.2	3.0	3.3	3.9	4.4	3.4	-1.0
Yadagiri	3.9	3.8	3.9	4.4	5.2	3.5	3.2	3.0	3.2	3.9	4.2	3.4	-0.9
Average	3.9	3.8	3.9	4.3	5.1	3.5	3.2	3.0	3.2	3.9	4.2	3.4	-0.8

for December. The average ET_o under past climate for NIK was 1715 mm year^{-1} and under projected climate it was 1587.8 mm year^{-1}. The ET_o simulated decreased by 127.2 mm year^{-1} under the projected climate compared to the past (Table 4).

The higher ET_o during March to May can be explained by the rising temperature in that particular period. Thus, the air temperature has a direct effect on ET_o. Relative humidity is a function of air temperature. Higher the temperature more is the amount of water vapour that can be held by the atmosphere. The extent of evaporation and transpiration depend on the amount of moisture present in the atmosphere. Ali *et al.* (2009) concluded that the ET_o estimates are most sensitive to maximum temperature and least sensitive to minimum temperature. The order of sensitivity noticed was; maximum temperature > relative humidity > sunshine duration > wind speed > minimum temperature. The decline in ET_o under projected climate for all districts except Ballari was mainly due to increased amount of rainfall and decreased sunshine hours in the projected climates.

There was no significant change in the ET_o during the projected climates showing decreased ET_o in all the districts of NIK compared to past (Table 5) for Chickpea cropping period (October- February). Vijayapur district (1 mm day^{-1}) has shown highest decrease in ET-$_o$, while lowest was for Ballari (0.6 mm day^{-1}). This was because of their respective highest and lowest ET_o respectively among the 12 districts of NIK in past climates.

Crop evapotranspiration (ET_c) in the past and projected climates

The model simulated the highest average ET_c (303.9 mm) in Vijayapur district for the past climate (1991-2020) across four DOS followed by Bagalakote (301.2 mm) (Table 6). This was because of the highest average temperature recorded and average ET_o simulated in the cropping season. The lowest average ET_c of 271.1 mm was simulated for Ballari district followed by Haveri (282.1 mm). This can be explained by the lowest average ET_o during the cropping period in Ballari across districts. The average ET_c simulated for chickpea by Desta *et al.* (2015) in Ethiopia for the period 1973-2007 was 366.6 mm. In the projected climates (2021-2050) the highest ET_c was simulated for Bidar district (230.5 mm) followed by Kalaburagi (230.2 mm) and the lowest was for Belagavi district (221.1 mm) followed by Koppal (221.7 mm). The highest average temperature and average ET_o (13.3 mm day^{-1}) during cropping period (Oct-Feb) in Bidar district and the lowest average temperature and average ET_o (12.8 mm day^{-1}) during cropping period in Belagavi district among the 12 districts in the projected climates of NIK are the influential parameters. All the districts showed decreased ET_c for the projected climates compared to the past due to decreased ET_{o-} and increased rainfall during the cropping period (Table 6 and Fig 3). The highest decrease in ET_o in the projected climates was simulated for Vijayapur district (76.6 mm day^{-1}) as it showed the highest

Table 5: Correlation analysis of reference evapotranspiration (ET_o) with crop evapotranspiration (ET_c), effective rainfall (ER) with irrigation requirement (IR) and actual water requirement (ET_c-ER) with irrigation requirement (IR) of chickpea crop for all the districts of NIK.

Districts/Particulars	Bidar	Bagalakote	Ballari	Belagavi	Dharwad	Gadag	Haveri	Kalaburagi	Koppal	Raichur	Yadagiri	Vijayapur
ETo and ETc	0.999**	1.000**	1.000**	1.000**	0.999**	0.999**	0.999**	0.999**	0.999**	1.000**	1.000**	1.000**
ER and IR	-0.900*	-0.985**	-0.778NS	-0.995**	-0.993**	-0.977**	-0.968**	-0.890*	-0.975**	-0.878*	-0.900*	-0.980**
ETc-ER and IR	0.997**	0.998**	0.991**	1.000**	0.998**	0.998**	0.996**	0.997**	0.998**	0.993**	0.993**	0.998**

*- Correlation is significant at 0.05 level (2-tailed), ** - Correlation is significant at 0.01 level (2-tailed) and NS- Non-significant.

decrease in ET_o among 12 districts of NIK whereas the lowest was for Ballari (46.4 mm day^{-1}). Gilanipour and Gholizadeh (2016) estimated that in the predicted climatic period of 2016-2045, the rice water requirement and irrigation water requirement decreased by more than 9.9%. Further, the rise in rainfall during rice growth period may be the main reason for the decline in crop water requirement, while the significant decrease in irrigation water requirement can be attributed to combined action of rising precipitation and a slight increase in temperature.

Simulated outputs across dates of sowing suggest that ET_c increased with delay in sowing in all the 12 districts of NIK under past climates (Table 7 and Fig 2). This is due to increase in average ET_o and decreased rainfall with delay in sowing *i.e.,* October sowing received more rainfall than November sowing. In case of projected climates there was no significant change in ET_c with delay in sowing (Table 8 and Fig 2). However, the highest ET_c was for Nov-15 sowing because of minimum rainfall during second fortnight of November.

Effective rainfall (ER)

The highest ER simulated in the cropping season was for Haveri district (72.6 mm) during the cropping period followed by Ballari (67.1 mm) and lowest was for Vijayapur district (47.4 mm) followed by Bidar (49 mm) in the past climate (Table 6 and Fig 4). Haveri district recorded rainfall (RF) of 175.8 mm during cropping period (Oct-Feb) with 24 rainy days (RD) in past climates, the highest among all the 12 districts in the past climates while, for Vijayapur district it was 112.1 mm of rainfall during cropping period with 16 rainy days, the lowest rainfall and rainy days among the 12 districts of NIK in the past climates.

For the projected climates all the districts showed increased ER compared to past with the highest ER for Belagavi and Dharwad districts (116.3 mm), whereas the lowest was for Kalaburgi district (75.2 mm) (Table 6 and Fig 4). Belagavi and Dharwad districts recorded rainfall of 281.1 mm during cropping period (Oct-Feb) with 39 RD, the highest among all the 12 districts in the projected climates. Bidar district recorded 159.7 mm rainfall during cropping period with 20 RD (Table 1), the lowest RF and RD among the 12 districts of NIK. The highest increase in ER in the projected climates compared to past was for Belagavi district (61 mm) and lowest was for Kalaburgi (24.3 mm). The increase in ER is proportional to their respective increase in rainfall in projected climates. Kyu and An (2019) from Vietnam found that the ER for the summer-autumn rice crop significantly increased by 6.2, 16.9 and 15.4 per cent, respectively in 2020, 2055 and 2090 (RCP 4.5 scenario) compared to baseline period (2002-2017).

The CROPWAT simulated decline in ER with delay in sowing in both past and projected climates and in all the districts of NIK (Table 7 and 8) (Fig 2). This can be explained by higher North-East monsoon rainfall in the early months (October) and rainfall dissipation of rainfall towards December month.

Irrigation requirement (IR)

Among all the 12 districts of NIK, Vijayapur district (263 mm) simulated the highest IR for chickpea followed by Bagalakote (255.6 mm) in the past climates because of higher ET_c and lowest ER during the cropping period. The Lowest IR was simulated for Ballari district (216.8 mm) followed by Haveri (228.9 mm) (Table 6 and Fig 5). This can be explained by higher ER and lower ET_c during the cropping period. In case of projected climates all the districts showed to require lower IR compared to past climates. Bidar district (168.7 mm) followed by Kalaburagi (167.6 mm) showed to require the highest IR for chickpea and the lowest for Belagavi district (141.5 mm) followed by Dharwad (142.5 mm). Kalaburagi and Bidar districts recorded the highest ET_c, lowest ER and increased average temperatures in the projected climates.

Table 6: District wise average crop evapotranspiration (ET_c), effective rainfall (ER) and irrigation requirement (IR) for the 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)		
	ET_c (mm)	ER (mm)	IR (mm)	ET_c (mm)	ER (mm)	IR (mm)	ET_c (mm)	ER (mm)	IR (mm)
Bagalakote	301.2	53.9	255.6	229.2	98.5	157.9	-72.0	44.6	-97.8
Ballari	271.1	67.1	216.9	224.7	110.3	148.8	-46.4	43.2	-68.1
Belagavi	292.7	55.3	249.7	221.3	116.3	141.5	-71.4	61.0	-108.1
Bidar	287.6	49.0	246.3	230.5	73.8	168.7	-57.1	24.8	-77.6
Dharwad	290.1	63.3	242.1	222.3	116.3	142.5	-67.7	53.0	-99.6
Gadag	296.9	62.0	245.8	222.7	109.3	147.7	-74.3	47.4	-98.1
Haveri	282.1	72.6	228.9	224.4	109.3	149.3	-57.6	36.7	-79.6
Kalaburagi	295.2	50.9	252.8	230.2	75.2	167.6	-65.1	24.3	-85.2
Koppal	295.1	62.3	243.0	221.7	109.3	146.9	-73.4	47.0	-96.1
Raichur	298.7	54.4	253.5	227.1	83.4	163.6	-71.6	28.9	-89.9
Vijayapur	303.9	47.4	263.0	227.3	93.5	158.6	-76.7	46.1	-104.5
Yadagiri	296.2	51.0	253.5	225.3	83.4	162.0	-70.9	32.4	-91.5
Average	292.6	57.4	245.9	225.6	98.2	154.6	-67.0	40.8	-91.3

Table 7: District wise average crop evapotranspiration (ET_c), effective rainfall (ER) and irrigation requirement (IR) for four dates of sowing under past climate (1991-2020) in Chickpea.

Districts	ET_c (mm)				ER (mm)				IR (mm)				Average		
	01-Oct	15-Oct	01-Nov	15-Nov	01-Oct	15-Oct	01-Nov	15-Nov	01-Oct	15-Oct	01-Nov	15-Nov	ET_c (mm)	ER (mm)	IR (mm)
Bagalakote	290.6	294.2	303.6	316.6	105.5	66.5	28.9	14.8	207.5	238.1	274.6	302.2	301.2	53.9	255.6
Ballari	261.1	264.5	273.4	285.5	125.1	82.1	39.7	21.5	167.6	200.1	235.1	264.7	271.1	67.1	216.9
Belagavi	277.0	284.2	297.1	312.4	113.2	68.3	27.0	12.8	196.9	231.7	270.1	300.0	292.7	55.3	249.7
Bidar	279.0	281.6	289.1	300.8	95.1	57.5	26.3	17.2	207.0	232.1	262.5	283.5	287.6	49.0	246.3
Dharwad	272.6	280.5	295.2	311.9	126.4	78.4	32.5	15.8	185.5	222.9	263.4	296.5	290.1	63.3	242.1
Gadag	282.9	288.6	300.6	315.4	117.9	75.9	35.4	18.6	193.0	226.9	265.6	297.6	296.9	62.0	245.8
Haveri	264.4	272.3	287.3	304.2	142.5	89.6	39.1	19.1	169.7	208.8	251.0	285.8	282.1	72.6	228.9
Kalaburagi	286.1	289.1	297.0	308.7	101.1	61.1	26.3	15.2	209.9	237.4	270.5	293.6	295.2	50.9	252.8
Koppal	283.3	287.4	297.9	311.7	117.6	76.5	36.1	19.1	191.8	224.6	262.1	293.3	295.1	62.3	243.0
Raichur	283.9	290.1	302.8	318.0	105.8	65.7	29.7	16.5	203.5	235.7	273.0	301.9	298.7	54.4	253.5
Vijayapur	297.9	298.6	304.3	315.0	95.4	58.2	23.8	12.3	220.7	248.2	280.4	302.9	303.9	47.4	263.0
Yadagiri	282.5	288.0	299.8	314.5	100.2	61.4	27.2	15.1	205.7	236.1	272.5	299.6	296.2	51.0	253.5
NIK	280.1	284.9	295.7	309.6	112.2	70.1	31.0	16.5	196.6	228.5	265.1	293.5	292.6	57.4	245.9

Table 8: District wise average crop evapotranspiration (ET_c), effective rainfall (ER) and irrigation requirement (IR) for four dates of sowing under projected climate (2021-2050) in Chickpea.

Districts	ET_c (mm)				ER (mm)				IR (mm)				Average		
	01-Oct	15-Oct	01-Nov	15-Nov	01-Oct	15-Oct	01-Nov	15-Nov	01-Oct	15-Oct	01-Nov	15-Nov	ET_c (mm)	ER (mm)	IR (mm)
Bagalakote	229.6	226.1	227.2	234.0	175.3	117.0	61.7	39.8	120.3	144.6	171.8	194.7	229.2	98.5	157.9
Ballari	224.0	221.1	223.1	230.4	196.9	132.2	68.9	43.2	107.6	135.7	163.9	188.0	224.7	110.3	148.8
Belagavi	221.7	218.1	219.2	225.9	202.2	139.7	76.5	47.0	99.5	128.0	157.0	181.6	221.3	116.3	141.5
Bidar	234.1	228.4	227.0	232.6	127.3	84.8	49.8	33.4	139.1	156.8	179.1	199.6	230.5	73.8	168.7
Dharwad	222.7	219.2	220.3	227.1	202.2	139.7	76.5	47.0	100.3	128.9	158.0	182.7	222.3	116.3	142.5
Gadag	222.5	219.3	220.9	228.0	192.4	130.9	70.0	44.0	106.3	134.5	163.8	186.1	222.7	109.3	147.7
Haveri	224.1	221.0	222.8	229.9	192.4	130.9	70.0	44.0	107.6	136.0	165.5	188.0	224.4	109.3	149.3
Kalaburagi	233.7	228.0	226.7	232.2	129.8	86.6	50.6	33.8	137.8	155.7	178.1	198.9	230.2	75.2	167.6
Koppal	221.5	218.3	220.0	226.9	192.4	130.9	70.0	44.0	105.6	133.7	163.0	185.2	221.7	109.3	146.9
Raichur	228.0	224.0	224.8	231.6	149.3	98.0	52.3	33.8	128.3	151.4	176.6	198.0	227.1	83.4	163.6
Vijayapur	227.5	223.9	225.3	232.4	166.8	110.8	58.4	38.0	121.2	145.8	172.3	194.9	227.3	93.5	158.6
Yadagiri	226.4	222.4	223.0	229.5	149.3	98.0	52.3	33.8	127.0	150.0	174.8	196.0	225.3	83.4	162.0
NIK	226.3	222.5	223.4	230.0	173.0	116.6	63.1	40.1	116.7	141.8	168.7	191.1	225.6	98.2	154.6

The highest decline in IR for projected climates compared to the past was simulated for Belagavi district (108.1 mm) and the lowest was for Ballari (68.1 mm). The decrease in IR was simulated directly proportional respective decrease in ET_c and inversely to increased ER.

The IR increased with delay in sowing in both past and projected climates in all the districts of NIK because of decreased ER and increased ET_c during the cropping period (Table 7 and 8) (Fig 2). Early sowing (October) receives more rainfall due to North-East monsoon onset which dissipates towards December. Desta *et al.* (2015) observed that IR increased in the range of 134-372 mm with delay in sowing (01-July to 30-Aug, quarterly interval) for the period 1973-2007 in DebreZeit, Ethiopia.

CONCLUSION

The study for Northern Interior Karnataka revealed that during chickpea cropping period (October- February) increased rainfall under projected climate (2021-2050) compared to past climate decreased crop evapotranspiration and irrigation requirement. Sowing chickpea early *i.e.,* on 01st October under projected climate simulated the lowest water requirement and irrigation requirement for all the 12 districts of NIK. In this context, however, further research needs to be taken up on adaptability of pulses to the climate variability expected under the future climates for their, performance, sustenance and improved productivity.

Conflict of interest: None.

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