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RESEARCH PAPER

Irrigation requirement of greengram and chickpea under changing climates of Dharwad district of Karnataka under rainfed conitions using CROPWAT model

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Abstract: Greengram and Chickpea are the major protein rich grain legumes predominately cultivated in Dharwad district of Karnataka. The present study was aimed to determine the water requirement of greengram and chickpea using CROPWAT model for Dharwad. The decadal analysis was done under past (1991-2020) and projected climate (2021-2050) as per the recommended practices of UAS, Dharwad across four dates of sowing from 07th June to 28th June at weekly interval for greengram and four dates of sowing from 01st October to 15th November at quarterly interval for chickpea. Model simulated an increase of 42.6 mm and 37.5 mm of ET_c and IR respectively, and decrease of 91.4 mm of ER under projected climates for greengram. In chickpea model simulated an increase of 61.0 mm of ER and a decrease of 71.4 mm ET_c and 108.1 mm of IR under projected climates when compared to past for chickpea. Under projected climates in greengram, the yield under rainfed condition and average number of irrigations reduced by 10 % and 8.3 % respectively on black soil and on red soil 3.8 % and 140 %, respectively compared to past climates. In chickpea, under projected climates, the yield under rainfed condition and average number of irrigations reduced by 18.5 % and 42.9 %, respectively. Sowing late *i.e.,* on 28th June in greengram and sowing early *i.e.,* on 01st October in chickpea under projected climate simulated the least reduction in yield and less number of irrigation would be required for Dharwad district of Karnataka State.

Key words: CROPWAT, Crop evapotranspiration, Effective rainfall, Irrigation requirement, Number of irrigations, Yield reduction

Introduction

Pulses are rich source of protein and are essential components of balanced and healthy diet. Food and Agriculture Organization (FAO) recommends 85 g of pulse per day per person for a healthy diet, while, per capita availability of pulses was 75 g per day per person in 1958-59 and presently it is estimated to be less than 35 g per day per capita (Anon., 2020). Increasing pulse production is the need-of-the-hour challenge to overcome malnutrition problems. To address this, production of pulses must increase despite the threat of climate change. Change in expected weather may affect crop water requirement. In this regard water requirement of greengram and chickpea which are the important pulses grown in Dharwad district of Karnataka was analysed for the past 30 years (1991-2020) and projected 30 years (2021-2050) period.

Greengram (*Vigna radiata* L.) popularly known as 'Mung bean or Moong' contains 25 per cent protein. It is the third most important pulse crop in India covering an area of 4.24 m ha with a production and productivity of 2.02 m t and 477 kg ha^{-1}, respectively (Anon., 2020a). In Karnataka, greengram is primarily cultivated as *kharif* crop, however, with development of early maturing and photoinsesitive varieties, it is being grown in summer season too. In Karnataka, its grown on area of 396.70 thousand ha with production of 135.26 thousand tonnes and average productivity of 341 kg ha^{-1} (Anon., 2020). It is a versatile crop grown for different purposes like seeds, green manure and forage as mixed or sole crop either on the residual soil moisture of previous crop or as a catch crop to make use of land left fallow between two main seasons. Likewise, 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 with protein content of around 22-23 per cent. In India, it occupies an area of 10.56 m ha, production of 11.28 m t and productivity of 1078 kg ha^{-1} (Anon., 2020). Karnataka, being one of the major chickpea producing states in the country, constitutes an area of 12.6 lakh ha, production of 7.83 lakh tonnes and productivity of 619 kg ha^{-1} (Anon., 2020).

Dharwad is located in the Northern Transition Zone of Karnataka (Zone-8, as per National Agricultural Research Project classification) at a latitude of 15 25' N and longitude 75 07' E with an altitude of 678 m above the mean sea level. The seasonal rainfall variability of Dharwad during the period 1994-2009 analysed by Halikatti *et al*. (2010) indicated that the months of South-West Monsoon (SWM) season (June to September), the rainfall ranged from the lowest of 72.3 mm in 2003 to the highest of 788 mm in 2007 as against the normal SWM rainfall of 457.7 mm. Rainfall was deficit continuously from 1999 (53.2 %) to 2003 (84.2 %) indicating severe drought like conditions. Mummigatti *et al.* (2013) analysed the rainfall data of 27 years (1985-2011) for Dharwad. The trend indicated that the tract received a mean annual rainfall of 720.2 mm in 54 rainy days with maximum contribution (62.93 %) from SWM (June to September). July was the rainiest month (129.7 mm) with 11 rainy days. On the contrary, during recent the last 7 years (2005-2011) lower standard deviation (97.72) and co-efficient of variation (13.56 %) were observed indicating lesser variability and more dependability.

Climate change with temperature and rainfall variations, resulting in higher oscillations in future water supply and

Table 1. Monthly average weather data of Dharwad district for the past climate (1991 - 2020), projected climate (2021- 2050) and the difference between the two periods

Months	1991-2020 (Past 30 years)			2021-2050 (Projected 30 years)			Difference between 1991-2020 & 2021-2050		
	Rain (mm)	Temp (°C)	RD	Rain (mm)	Temp (°C)	RD	Rain (mm)	Temp (°C)	RD
January	1.1	23.6	0	8.6	23.6	0	7.5	0.0	0
February	2.1	25.9	0	4.9	25.3	0	2.8	-0.6	0
March	9.7	28.7	1	6.9	27.8	0	-2.8	-0.9	0
April	28.6	30.3	1	7.4	30.3	0	-21.3	0.0	-1
May	63.4	29.7	8	19.7	31.2	1	-43.7	1.5	-8
June	237.7	26.1	29	33.3	30.3	2	-204.4	4.1	-28
July	274.3	24.8	31	132.1	28.4	22	-142.2	3.6	-9
August	215.0	24.5	31	263.6	27.2	31	48.7	2.7	0
September	142.5	24.6	26	207.7	27.2	30	65.2	2.6	3
October	117.6	24.4	19	194.3	26.6	30	76.7	2.2	11
November	27.1	23.2	2	58.9	25.2	8	31.8	2.0	6
December	5.3	22.5	0	14.4	23.8	1	9.1	1.2	1
Total / Average	1124.2	25.7	148	951.7	27.2	125	-172.6	1.5	-24

*RD-Rainy day, Temp-Temperature

irrigation water requirement. Water uncertainty could have a considerable impact on the quantity of available crops since it promotes crop output, with greater implications projected for rainfed agriculture (Kumar, 2018). Crop simulation models are used to predict how future climate conditions would affect crop production. The use of dynamic simulation models based on previous and present climate data for predicting future impacts on agriculture production levels could aid policy makers and managers in better understanding the effects of climate change on crop yield. Prediction of the crop water requirement is of vital importance in water resources management. Crop water requirements are normally expressed by the rate of evapotranspiration (ET) in mm day^{-1} or mm period^{-1}. One of the advanced practices adopted by the researchers for estimating water requirement of crops is simulation modeling. For determination of crop evapotranspiration and yield responses to water, CROPWAT model is used which was developed by the FAO-Land and Water Development Division. Several researchers have used the CROPWAT model for estimating the crop water requirement in different parts of the world (Thimme Gowda *et al.*, 2013).

Material and methods

The past data (rainfall, minimum and maximum temperature) for Dharwad district was collected from NASA POWER web portal for the period of 30 years from 1991 to 2020 (https://power.larc.nasa.gov) (Sparks, 2018). Whereas, the projected data for the period of 30 years from 2021-2050 was collected from Copernicus Climate Change Service (IPSL-CM5A model) (https://climate.copernicus.eu), RCP 6.0 scenario (Table 1). The data collected was analysed and sorted based on the CROPWAT model requirement. There would be a decrease of 172.6 mm rainfall and 24 rainy days while temperature is projected to increase by 1.5 °C under the projected climates (2021-2050) when compared to past climates (1990-2020).

The CROPWAT 8.0 model 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 programme developed by land and development division of FAO. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. The CROPWAT 8.0 model can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rain fed and irrigated conditions.

The field experiment was conducted at The Main Agricultural Research Station (MARS), 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 greengram variety DGGV-2 and chickpea variety BGD-103 collected from the field experiment were used in the model. The salient details of greengram (DGGV-2) and chickpea (BGD-103) crops required for the study [Crop coefficients (Kc), Phenological days, Critical depletion fraction (p), Yield Response Factor (Ky]were taken from the available 18 published data of FAO (Allen *et al*., 1998) (Table 2). The soil data [total available soil moisture content (SMC), initial soil moisture depletion, maximum rooting depth and maximum rain infiltration rate]for black clay and red sandy loam soils for Dharwad district were collected from Sujala project, UAS, Dharwad. The crop simulation was done across four dates of sowing from 07th June to 28th June at weekly interval for greengram and four dates of sowing from 01st October to 15th November at quarterly interval for chickpea.

The simulated Reference Evapotranspiration (ET_o), Crop Evapotranspiration (ET_c), Effective Rainfall (ER) and Irrigation

Table 2. The crop coefficient values (Kc) for initial, mid and late growth stages of greengram and chickpea crops

Stages /crops	Greengram		Chickpea	
	Days	Kc values	Days	Kc values
Initial	10	0.40	15	0.4
Development	20	-	25	-
Mid season	35	1.05	35	1.00
Late season	10	0.35	20	0.35
Total	75	-	95	-

Source: Allen *et al.,* 1998

requirements (IR) of both the crops were correlated with each other and results were inferred (Table 3).

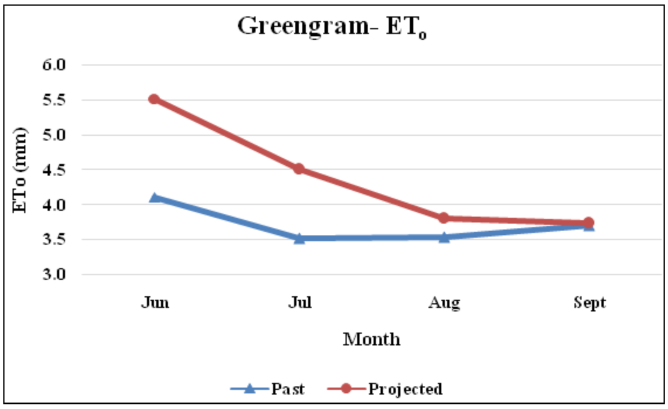
Results and discussion

Correlation analysis

In both greengram and chickpea,reference evapotranspiration (ET_o) is positively correlated with crop evapotranspiration (ET_c) and irrigation requirement (IR) while it is negatively correlated with effective rainfall (ER) at 1 % level of significance. The IR is negative to correlated with ER and positively related with actual water requirement (ET_c- ER) at1 % level of significance (Table 3).

Crop evapotranspiration (ET_c), Effective rainfall (ER) and Irrigation requirement (IR) of greengram and chickpea

For all four dates of sowing, among the six decades starting from 1991-2000 to 2041-2050, the highest average ET_c(267.8 mm) and IR (60.2 mm) were simulated for 2041-2050 decade, and the lowest average ET_c(212.8 mm) was for 1991-2000 and IR (1.1 mm) for the 2000-2010 decade. The highest ER (367.8 mm) was simulated in the decade 2011-2020 and the lowest (242.4 mm) was in 2041-2050 decade. The average ET_c and IR for 60 years showed decreasing pattern with delay in sowing and that of ER increased for greengram (Table 4). The mean ET_c, ER and IR, across four dates of sowing (DOS) in greengram under past climate (1991-2020) were 214 mm, 360 mm and 1.2 mm, whereas under projected climates (2021-2050), they were 256.6 mm, 268.6 mm and 38.6 mm, respectively. An increase of 42.6 mm and 37.5 mm of ET_c and IR, and decrease of 91.4 mm of ER in projected climates were simulated (Table 4). $ET_c$is influenced by ET_o which has also increased under projected climates when compared to past climates (Fig 1) and has decreased with delay in sowing which is because of their respective decrease in the temperature for the cropping period. Decrease in the ER under projected climates was due to decreased amount of rainfall in the month of June when compared to past climates (Table 1). This decrease in the ER under projected climates has influenced on increased IR compared to past climates. Gilanipour and Gholizadeh (2016) estimated that in the predicted climatic period 2016-2045, the rice water requirement and irrigation water requirement decreased by more than 9.9 %. Furthermore, the precipitation rise in rice growth period may be the main reason



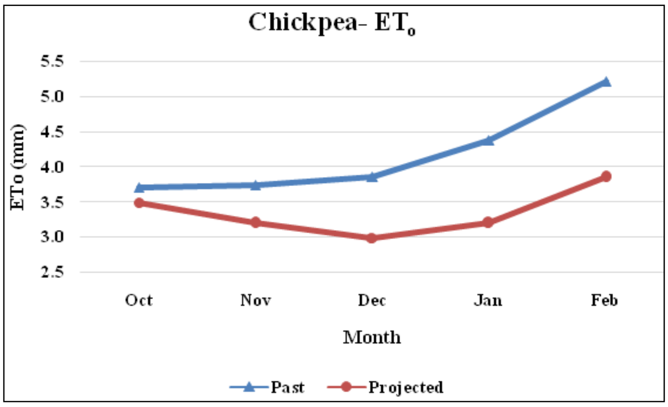


Fig 1. Reference evapotranspiration (ET_o) for the cropping period of greengram and chickpea

Table 3. Correlation analysis of reference evapotranspiration (ET_o), crop evapotranspiration (ET_c), effective rainfall (ER), irrigation requirement (IR) and actual water requirement (ET_c – ER) for both greengram and chickpea crops for Dharwad district

Particulars	ET_c		ER		IR		ET_c- ER		ET_o	
	Greengram	Chickpea	Greengram	Chickpea	Greengram	Chickpea	Greengram	Chickpea	Greengram	Chickpea
ET_c	1	1								
ER	-0.992**	-0.985**	1	1						
IR	0.964**	0.995**	-0.966**	-0.993**	1	1				
ET_c- ER	0.996**	0.997**	-0.999**	-0.995**	0.967**	0.998**	1	1		
ET_o	0.994**	0.999**	-0.987**	-0.986**	0.935**	0.994**	0.991**	0.997**	1	1

** Correlation is significant at the 0.01 level (2-tailed)

Table 4. Decadal crop evapotranspiration (ET_c), effective rainfall (ER) and irrigation requirement (IR) across dates of sowing in Greengram for Dharwad district

Decade	ET_c (mm)				ER (mm)				IR (mm)				Average		
	7-Jun	14-Jun	21-Jun	28-Jun	7-Jun	14-Jun	21-Jun	28-Jun	7-Jun	14-Jun	21-Jun	28-Jun	ET_c (mm)	ER (mm)	IR (mm)
1991-2000	215.7	212.5	211.3	211.5	371.6	363.9	349.8	334.8	0.0	0.0	0.0	4.6	212.8	355.0	1.2
2001-2010	216.7	214.1	213.2	213.0	366.8	361.9	353.4	346.4	0.0	0.0	0.0	4.5	214.3	357.1	1.1
2011-2020	219.0	215.4	213.3	212.4	372.8	371.5	366.1	360.8	0.0	0.0	0.0	4.7	215.0	367.8	1.2
2021-2030	259.6	247.4	236.8	228.6	256.2	283.4	310.0	328.9	49.4	21.3	1.1	6.0	243.1	294.6	19.5
2031-2040	274.2	263.6	253.7	245.3	226.8	254.8	284.6	308.7	77.3	45.5	12.6	9.2	259.2	268.7	36.2
2041-2050	282.0	271.5	262.0	254.3	205.6	231.1	255.9	276.8	103.1	73.6	41.5	22.6	267.5	242.4	60.2
Average	244.5	237.4	231.7	227.5	300.0	311.1	320.0	326.1	38.3	23.4	9.2	8.6	235.3	314.3	19.9

for the decrease in crop water requirement, while significant decrease of irrigation water requirement should be attributed to combined action of rising precipitation and a slight increase in temperature.

For chickpea, the highest average ET_c (291.8 mm), ER (115.1 mm) and IR (252 mm) across four DOS were simulated for the decades 2001-10, 2031-2040 and 2011-2020, respectively. The lowest average ET_c (218.8 mm) and IR (137.6 mm) was simulated for 2031-2040 period and the lowest ER (54 mm) was for the decade 2011-20. Under past climate scenario (1991-2020), the average ET_c, ER and IR across four DOS were 292.7 mm, 55.3 mm and 249.7 mm, and under projected climates (2021-2050) they were 221.3 mm, 116.3 mm and 141.5 mm, respectively, were simulated. An increase of 61.0 mm of ER and a decrease of 71.4 mm and 108.1 mm of ET_c and IR for projected climates compared to past were simulated (Table 5). With delay in DOS, average 60 years ET_c and IR were in increasing trend and ER decreasing. The average ET_c simulated for chickpea by Desta *et al.* (2015) in Ethiopia for the period 1973-2007 was 366.6 mm and also observed that, IR increased with delay in sowing (01-July to 30-Aug, quarterly interval). The respective highest and lowest ET_c for the decades is influenced by the respective ET_o of chickpea cropping period. The decrease in ET_c under projected climates was due to decreased ET_o compared to past climates (Fig 1). Though there was increase in temperature under projected climate (Table 1) which may have influenced on ET_o was overthrown by increased rainfall during the cropping period, therefore increase in the ER compared to past climate. The increased ER was a factor for decreased IR under the projected climate.

Percent reduction in yield (rainfed) and number of irrigations (irrigated) in greengram on black clay and red sandy loam soils

Average yield reduction under rainfed condition showed a considerable difference across four DOS as well as for six decades of climates on black clay soil compared to red sandy loam soil. The highest mean yield reduction on black soil (17.7 %) and red soil (7.2 %) across four DOS was simulated during 2041-2050 and the lowest mean yield reduction on black soil (5.8 %) was for 1991-2000 and in red soil there was no yield reduction for first three decades (1991-2020). Average number of irrigations was one on black soil for all the decades except for 2031-40 where it was 1.25. In red soils highest average no. of irrigation was 2.75 for 2041-2050 and not simulated irrigation for first three decades (1991-2020) (Table 6). Athnere and Kolage (2019) studied irrigation scheduling on growth, yield and quality of summer greengram. The scheduling of irrigation at 40 mm CPE recorded significantly higher growth, yield attributes, seed quality parameters and seed yield of summer greengram (13.31 q ha^{-1}) and it was at par with treatment irrigation at 60 mm CPE (13.08 q ha^{-1}). The maximum consumptive use of water has recorded under scheduling of irrigation at 40 mm CPE (305 mm), followed by the treatment irrigation at 60 mm CPE (223 mm).

Both average yield and no. of irrigation across six decades (1991-2050) decreased with delay in sowing on both black and red soils. The average yield reduction in rainfed condition across four DOS on black soil under past climates (1991-2020) was 6.1 % and under projected climates (2021-2050) it was 16.1 %, an increase of 10 % was simulated. The average no. of irrigations required across four DOS on black soil under past climates was one and under projected climates it was 1.1, an increase of 8.3 % compared to past climates was simulated. On red soil there was no yield reduction across four DOS under past climatic scenario (1991-2020), but under projected climates it rose by 3.8 %. The average no. of irrigations also increased by 1.4 in projected climates compared to past climates (nil) across four DOS. Only black soil has shown yield reduction under past climates and under projected climates black soil has shown highest yield reduction compared to red soil with the difference of 12.3 %. One irrigation was required for black soil under past climate while for red soil it was zero. Under projected climatic scenarios compared to black soil, red soil has shown increased irrigation of 30.8 % (Table 6).

The decrease in yield reduction (YR; %) and no. of irrigations with delay in sowing in both black and red soil in greengram were due to their respective decrease in ET_c and IR. Increased ER with delay in sowing was also influencing factor. The increase in ET_c and IR, and decrease in ER under the projected climate has affected on increased yield reduction and number of irrigation. One compulsory irrigation was simulated at flowering stage (35-50 DAS) on black soil where as on red soil there was no simulated irrigation under the past climates. Under projected climates one early compulsory irrigation on second week after sowing was simulated on both the soils because of decreased rainfall in the month of June when compared to past climates.

Table 5. Decadal crop evapotranspiration (ET_c), effective rainfall (ER) and irrigation requirement (IR) across dates of sowing in Chickpea for Dharwad district

Decade	ET_c (mm)				ER (mm)				IR (mm)				Average		
	1-Oct	15-Oct	1-Nov	15-Nov	1-Oct	15-Oct	1-Nov	15-Nov	1-Oct	15-Oct	1-Nov	15-Nov	ET_c (mm)	ER (mm)	IR (mm)
1991-2000	267.1	276.3	293	311.1	138.4	86.5	33.3	17.2	178.5	218.8	260.1	294.2	286.9	68.9	237.9
2001-2010	274.6	282.3	296.8	313.6	124.2	81.3	41.8	20.7	179.5	215.1	256.8	294.0	291.8	67.0	236.3
2011-2020	276.2	283.0	295.7	310.9	116.7	67.3	22.5	09.6	198.4	234.9	273.2	301.4	291.6	54.0	252.0
2021-2030	219.0	216.8	219.3	226.2	212.6	147.1	79.4	45.7	92.5	127.0	161.6	186.3	220.3	121.2	141.9
2031-2040	219.4	215.7	216.6	223.5	199.8	136.9	75.3	48.3	96.5	125.0	152.6	176.0	218.8	115.1	137.5
2041-2050	229.8	225.0	225.0	231.5	194.1	135.0	74.8	47.0	111.9	134.6	159.9	185.8	227.8	112.7	148.1
Average	247.7	249.9	257.7	269.5	164.3	109.0	54.5	31.4	142.9	175.9	210.7	239.6	256.2	89.8	192.3

Table 6. Decadal yield reduction (YR; rainfed) and irrigations required (numbers) across different DOS on black clay and red sandy loam soils in greengram for Dharwad district

Decades/ Particulars	Black Clay soil								Red sandy loam soil								Average across DOS			
	Yield Reduction (%)				No. of Irrigations				Yield Reduction (%)				No. of Irrigations				Clay		Sandy loam	
	07-Jun	14-Jun	21-Jun	28-Jun	07-Jun	14-Jun	21-Jun	28-Jun	07-Jun	14-Jun	21-Jun	28-Jun	07-Jun	14-Jun	21-Jun	28-Jun	YR (%)	IR	YR (%)	IR
1991-2000	5.7	6.3	5.1	6.1	1	1	1	1	0	0	0	0	0	0	0	0	5.8	1	0	0
2001-2010	5.9	6.6	5.5	6.5	1	1	1	1	0	0	0	0	0	0	0	0	6.6	1	0	0
2011-2020	6.4	6.9	5.6	6.5	1	1	1	1	0	0	0	0	0	0	0	0	6.4	1	0	0
2021-2030	17.8	15	11.1	10.3	1	1	1	1	4.9	0	0	0	2	1	0	0	13.5	1	1.2	0.8
2031-2040	21.3	18.4	14.3	13.7	2	1	1	1	10.1	1.6	0	0	2	1	0	0	16.9	1.3	2.9	0.8
2041-2050	20.7	18.9	15.8	15.3	1	1	1	1	17.8	9.8	1.1	0	5	4	2	0	17.6	1	7.2	0.8
Average	13.0	12.0	9.6	9.7	1.2	1.0	1.0	1.0	5.5	1.9	0.2	0.0	1.5	1.0	0.3	0.0	11.1	1.1	1.9	0.7

Table 7. Decadal yield reduction (YR; rainfed) and irrigations required (numbers) across different dates of sowing on black clay soil in chickpea for Dharwad district

Decade	Yield Reduction (%)				No. of Irrigation				Average	
	01-Oct	15-Oct	01-Nov	15-Nov	01-Oct	15-Oct	01-Nov	15-Nov	YR (%)	No. of Irr.
1991-2000	20.6	27	34.6	40.7	1	2	2	2	30.7	1.8
2001-2010	19.2	25.5	32.8	39.8	1	2	2	2	29.3	1.8
2011-2020	23.6	29.8	36.9	42.4	1	2	2	2	33.2	1.8
2021-2030	5.2	9.3	14.6	21.3	1	1	1	1	12.6	1.0
2031-2040	4.9	7.8	12.4	19	1	1	1	1	11.0	1.0
2041-2050	8.8	11.7	15.2	21	1	1	1	1	14.2	1.0
Average	13.7	18.5	24.4	30.7	1.0	1.5	1.5	1.5	21.8	1.4

Percent reduction in yield (rainfed) and number of irrigations (irrigated) in chickpea on black clay

The highest average yield reduction under rainfed across four DOS (01-Nov, 15-Nov, 01-Oct and 15-Oct) was 33.2 % for 2011-2020 period and the lowest was 11 % (2031-2040). The average no. of irrigations required across the four DOS was 1.75 for first three decades (1991-2020) and it was one irrigation for next three decades (2021-2050). Yield reduction under rainfed condition across six decades (1991-2050) has increased with delay in DOS because of the increased ET_c and IR, and decreased ER with delay in sowing for chickpea. One average no. of irrigation for 01st Oct sowing and 1.5 for the rest dates of sowing was simulated (Table 7). Dissipation of North-East rainfall towards December from October results in more number of irrigation with delay in sowing. Bekele and Zeleke (2009) estimated the YR (%) for onion crop at Sekota, Ehiopia under different water stress conditions in medium textured soil. The study concluded that the CROPWAT model could adequately simulate yield reduction resulting from water stresses.

The average yield reduction across four DOS under past climates (1991-2020) was simulated at 31.1 % and under projected climates (2021-2050) it was 12.6 %. A decrease of 18.5 % under projected climates was simulated. The average no. of irrigations across four DOS decreased by 42.9 % under projected climate (one irrigation) compared to past climate where it was 1.75 (Table 7). The decreased yield reduction and number of irrigation under the projected climates was mainly due to increased rainfall in the months from October – December compared to past climates. Similar results were observed by Desta *et al.*, (2015) where two compulsory irrigation at flowering and pod filling stage were simulated. Bhat *et al.* (2017) calculated yield reduction in maize for silty clay loam soil at critical depletion, irrigate at a given ET_c of crop reduction per stage and irrigate at fixed interval per stage at 70 % field efficiency was found to be 0 %, 14.9 % and 25.1 %, respectively. Also yield reduction at no water stress and at water stress was found to be 0 % and 26.80 %, respectively.

Conclusion

The study for the Dharwad district of Northern Interior Karnataka revealed that the decreased rainfall and increased temperature under projected climates for the greengram cropping period (June- September) compared to past influenced on the increased crop evapotranspiration and irrigation requirement. The increased rainfall under projected climates for the chickpea cropping period (October- February) compared to past influenced on the decreased crop evapotranspiration and irrigation requirement. Sowing late *i.e.,* on 28th June in greengram and sowing early *i.e.,* on 01st October in chickpea under projected climate (2021-2050) simulated the least reduction in yield and less number of irrigation would be required. In this context further research should to taken on adaptability of pulses to the climate variability as well under the future climates for their sustenance and improved productivity.

References

Anonymous, 2020, Food and Agriculture Organization report, www.stratista.com.

Anonymous, 2020a, Area coverage, production and yield of pulses in India and Karnataka. Economic survey of India, New Delhi, www.indiastat.com. p. 19.

Allen R G, Pereira L S, Raes D and Smith M, 1998, Crop evapotranspiration-guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. *FAO, Rome*, 300(9): D05109.

Athnere S and Kolage A K, 2019, Effect of irrigation schedules and foliar application of potash on growth, yield and quality of summer green gram (*Vigna radiata* L.).M.Sc Thesis, MPKV Rahuri.

Bekele S and Zeleke K, 2009, Evaluation of the FAO CROPWAT model for deficit-irrigation scheduling for onion crop in a semiarid region of Ethiopia. *Journal of Applied Horticulture* 11(2): 1-20.

Bhat S A, Pandit B A, Khan J N, Kumar R and Jan R, 2017, Water requirements and irrigation scheduling of maize crop using CROPWAT model. *International Journal of Current Microbiology and Applied Sciences*, 6(11): 1662-1670.

Desta F, Bissa M, and Korbu L, 2015, Crop water requirement determination of chickpea in the central vertisol areas of Ethiopia using FAO CROPWAT model. *African Journal of Agricultural Researc*h, 10(7): 685-689.

Gilanipour J and Gholizadeh B, 2016, Prediction of rice water requirement using FAO-CROPWAT Model in North Iran under future climate change. www.preprints.org.

Halikatti S I, Potdar M P, Hiremath S M and Dineshkumar S P, 2010, Annual and seasonal rainfall variability at Dharwad, Karnataka. *Journal of Agrometeorology*, 12(1): 136-137.

Kumar S, 2018, Assessment of Crop Water Requirement & Irrigation Water Requirement for Vegetable Crops over Uttar Pradesh Using Cropwat Model. Ph. D.Thesis, Sam Higginbottom University of Agriculture, Technology & Sciences Naini, Allahabad, India.

Mummigatti U V, Naveen N E and Ninganur B T, 2013, Rainfall and rainy day trends at Dharwad, Karnataka. *International Journal of Agricultural Sciences*, 9(1): 237-241.

Sparks A H, 2018, nasapower: A NASA POWER Global Meteorology, Surface Solar Energy and Climatology Data Client for R. *The Journal of Open Source Software,* 3(30): 1035.

Thimme Gowda P, Manjunaththa S B, Yogesh T C and Satyareddi S A, 2013, Study on water requirement of Maize (*Zea mays* L.) using CROPWAT model in Northern Transitional Zone of Karnataka. *Journal of Environmental Science, Computer Science and Engineering and Technology*, 2(1): 105-113.