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RESEARCH PAPER

Impact of projected climate on the yield of soybean variety JS-335 in North interior Karnataka

LAVANYA P[1], R. H. PATIL[1], K. G. SUMESH[1] AND B. SANGSHETTY[2]

[1]Department of Agricultural Meteorology, College of Agriculture, Dharwad
[2]Agronomist, AICRP on Safflower, ARS, Annigeri, UAS, Dharwad
University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
E-mail: lavanyaparashuram1807@gmail.com

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Abstract: Soybean is one of the important oilseed crops of north interior Karnataka (NIK) grown under both rainfed and irrigated conditions. Climate change with rising temperature and erratic rainfall patterns is threatening the productivity of the crops. Hence, study was taken up to find the effect of projected climate for the period from 2020 to 2050 on the productivity of soybean crop across NIK. Experimental data required to calibrate, validate and run the model were collected from experiments conducted during 2006 and 2012 at AICRP-Soybean scheme MARS, UAS, Dharwad. CROPGRO model was used to run simulations under current (1988-2018) and projected climate (2020-2050) following recommended practices of UAS, Dharwad for two predominant and representative black and red soils of each district of NIK. It was seen that yield of soybean in NIK would improve by 2 per cent under projected climate on black soil and reduce by 6 per cent on red soils compared to under current climate (1988-2018). The maximum yield improved under the projected climate (2020-2050) was on black soils observed in Koppal (85.5 %) district, followed by Vijayapura (29.4 %) and Bidar (18 %) districts whereas, on red soils it was for Haveri (114 %), Belagavi (53.6 %) and Vijayapura (5.4 %) districts. The highest yield reduction under the projected climate (2020-2050) on black soils was observed in Gadag (39.3 %) followed by Raichur (12.8 %) and Yadagiri (11.3 %) districts while on red soils it was in Gadag (55.4 %) followed by Koppal (23.9 %) and Raichur (10.3 %) districts.

Key words: Projected climate, Simulated yield, Soybean

Introduction

Soybean is one of the most widely cultivated legume crops in the world, being referred as "miracle bean". Soybean (*Glycine max* L. Merill) is one of the marvellous world's leading economic oilseed crops ranking first among oilseeds in the world. Soybean ranks top in the world production of both edible oil and oil seeds. It has very high nutritional value. The world-wide popularity of soybean is due to its different characteristics as well as its adaptability to different agro-climatic conditions. (Jency and Kalaimagal, 2015). Globally, this crop is grown in an area of 125.4 million ha with a production of 347.6 million tons at 2,490 kg per ha of productivity. Nearly 85 per cent of the global soybean region and 88.5 per cent of production was accounted for by the countries (USA, Brazil, Argentina, India and China). Production in India is 13.79 million tones from an area of 11.39 million hectares with the productivity of over 1.2 t ha^{-1}. Karnataka ranks seventh in production and occupies an area of 2.71 lakh hectares producing 1.73 million metric tones with a productivity of 745 kg ha^{-1} (Anon., 2018).

Future climate projections by IPCC using newly developed representative concentration pathways (RCPs) under the Coupled Model Inter-comparison Project 5 (CMIP5) for India state that, under the business-as-usual scenario (between RCP 6 and RCP 8.5), mean warming in India is likely to be in the range 1.7–2 ºC by 2030s and 3.3–4.8 ºC by 2080s compared to preindustrial times. Precipitation is projected to increase from 4 to 5 per cent by 2030s and from 6 to 14 per cent by 2080s over 1961–1990 baseline and there is a consistent increasing trend in the frequency of extreme precipitation days (e.g. > 40 mm/day) for decades 2060s and beyond (Chaturvedi *et al.,* 2012).

In this context, field and climate control experiments *viz.,* FACE, FATE, OTP, rainout shelters and other agronomic experiments are being carried all around the world. These types of experiments have their own limitations *viz.,* time consuming, labour intensive and resource demanding. Moreover, it is logistically difficult to include all aspect of climate and its variables into field studies. With the development of crop simulation models (CSMs), it has become easy to predict a living plant through the mathematical and conceptual relationship which regulates its growth in the Soil – Water – Plant - Atmosphere continuum and crop interacts with soil, weather, inputs and management practices bio-physically. Therefore CSMs explain the interaction between the crops and surrounding environment. The crop growth models are useful to assess the impact of climate change on crop production under different management practices.

North Interior Karnataka (NIK) is a geographical region mostly consisting of semi-arid plateau from 300 to 730 metres above mean sea level that constitutes the northern part of the South Indian state of Karnataka. It includes 12 districts namely Bagalakote, Belagavi, Ballari, Bidar, Dharwad, Gadag, Haveri, Kalaburagi, Koppal, Raichur, Vijayapura and Yadagiri.

The existence of regional variations in climate, soil, topography and the crop management conditions in each of the 12 districts of NIK both potential and actual yields vary a lot. Considering this, the understanding of the overall magnitude of the climate change effects on crops has become mandatory. This is critical to choose the right agronomic practices for the given local climate, soil and targeted yield by the farmer. Hence, this study was under taken to study the impact of projected climate (2020-2050) on then yield of soybean variety JS-335 in NIK districts. This work would help to propose advanced climate adaptation strategies, which is essential for regional food security. Crop simulation model *i.e.,* DSSAT was used to assess potential yield under current climatic conditions across each district and then assessed climate change impacts under projected climate. In this background, this study was executed to estimate the performance of soybean variety JS-335 under projected climate using DSSAT model.

Material and methods

Experimental data for modeling

The study was conducted in the year 2019 on soybean variety JS-335 during *Kharif* season under rainfed condition on deep black soils at Main Agricultural Research Station (MARS) of University of Agricultural Sciences, Dharwad, located at 15°26'N latitude, 75°07'E longitude and at an altitude of 678 m above mean sea level. The experimental data on soybean variety JS-335 to calibrate and validate crop simulation model were collected from the AICRP on soybean scheme during *Kharif* season of 2006, 2012 and 2019 under rainfed condition on deep black soils at Main Agricultural Research Station (MARS) of University of Agricultural Sciences, Dharwad, located at 15°26'N latitude, 75°07'E longitude and at an altitude of 678 m above mean sea level.

The data on weather parameters such as daily rainfall (mm), mean maximum and minimum temperature (°C) and solar radiation (MJ m^{-2} day^{-1}) required to build weather file within the DSSAT model were recorded at the Meteorological Observatory, MARS, University of Agricultural Sciences, Dharwad for the experimental year 2006, 2012 and 2019. Historic weather of 31 years (1988-2018) for each of 12 districts of NIK were downloaded from NASA power web portal (www.power.larc.nasa.gov) for solar radiation, Tmax. Tmin. and rainfall for subsequent seasonal analysis. These files were used to run the model for calibration (2006) followed by validation (2012 & 2019) and also for sequential analysis over 31 years (1988-2018) to estimate yield. The model was calibrated using 2006 experimental data and was validated using 2012 and 2019 experimental data for the soybean variety JS-335 using GenCalc software application within DSSAT model with a satisfactory accuracy of 90 per cent for both phenology and yield parameters and the genetic coefficients optimized for JS-335 are presented in Table 1. Further the same historic weather data (1988-2018) were used to create future climate scenarios by altering the daily maximum and minimum temperature and rainfall according to the projections given by the Karnataka Climate Change Action Report of 2011 for the period from 2020 to 2050 for each of 12 districts of NIK (Table 2). The impact of above scenarios on the growth and yield of the crop was assessed, quantified and presented here.

The soil module within DSSAT model requires data / information on texture, colour, slope (%), nutrients like N, P, K (kg ha^{-1}), pH, OC (%) and BD (g cm^{-3}) across depth. The experiment from which the crop data collected were laid out on black clay soil. Composite soil samples were collected before the start of experiment and analyzed. In order to simulate the yield levels across the 12 districts of NIK, soil profile data of both black and red soils up to depth of 125 cm and 35 cm respectively of all these 12 districts were collected from ICAR KrishiGeoportal website (http://geoportal.icar.gov.in). The N, P, K (kg ha^{-1}) data of all the 12 districts for initial management was collected from soil health card web portal of the Ministry of Agriculture and Farmers Welfare, Govt. of India (https: soilhealth2.dac.gov.in/HealthCard).The seasonal analysis simulations were ran for each of 12 districts of NIK both under current climate (1988-2018) and projected climate (2020-2050) to generate average yields of soybean variety JS-335 for each

Table 1. Codes, description and optimized coefficients used in genotype file of CROPGRO for soybean variety JS-335 after calibration.

Coefficient Code	Genetic Coefficient Description (units)	Value
CSDL	Critical Short Day Length below which reproductive development progresses with no day length effect (for short day plants) (in hours)	12.23
PPSEN	Slope of the relative response of development to photoperiod with time (positive for short day plants) (1/hour)	0.330
EM-FL	Time between plant emergence and flower appearance (photothermal days)	21.23
FL-SH	Time between first flower and first pod (photothermal days)	10.0
FL-SD	Time between first flower and first seed (photothermal days)	18.39
SD-PM	Time between first seed and physiological maturity (photothermal days)	26.40
FL-LF	Time between first flower and end of leaf expansion (photothermal days)	22.99
LFMAX	Maximum leaf photosynthesis rate (mg $CO^2/m^2/s$)	1.667
SLAVR	Specific leaf area of cultivar under standard growth conditions (cm^2/g)	459.8
SIZLF	Maximum size of full leaf (three leaflets) (cm^2)	200
XFRT	Maximum fraction of daily growth that is partitioned to seed + shell	2.00
WTPSD	Maximum weight per seed (mg)	0.1996
SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)	11.86
SDPDV	Average seed per pod under standard growing conditions (#/pod)	0.662
PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)	0.0256
THRSH	The maximum ratio of (seed/(seed+shell)) at maturity (per cent)	78.00
SDPRO	Fraction protein in seeds (g(protein)/g(seed))	0.400
SDLIP	Fraction oil in seeds (g(oil)/g(seed))	0.200

Table 2. Projected changes in temperature and rainfall for the period 2020 to 2050 in 12 districts of NIK (Karnataka Climate Change Action Report, 2011)

District	Average increase in projected Tmin. (°C)	Average increase in projected Tmax. (°C)	Change in Rainfall (%)
Bidar	2.3	1.9	27.0
Kalaburgi	2.3	2.0	4.3
Yadagiri	2.3	2.1	-4.1
Raichur	2.3	2.1	-6.8
Ballari	2.2	2.0	0.5
Koppal	2.2	2.1	-1.6
Vijayapura	2.3	2.1	0.6
Bagalakote	2.3	2.1	1.4
Gadag	2.2	2.1	1.9
Belagavi	2.1	2.0	6.2
Dharwad	2.1	2.0	3.7
Haveri	2.0	2.0	5.8

district both under current and projected climate on two predominant representative black and red soils.

Results and discussion

Considerable difference in yield of soybean variety JS-335 (kg ha^{-1}) was simulated between current climate (1988-2018) and projected climate (2020-2050) on both black and red soils and among 12 districts of NIK. Simulated grain yield (kg/ha) of soybean variety JS-335 under current climate (1988-2018) on black soils in rainfed conditions was the highest in Bidar district (1985), closely followed by Haveri district (1908) and Dharwad district (1755) whereas, the lowest yields were simulated in Koppal district (656), followed by Raichur district (1006) and Yadgiri district (1201). The average yield for whole of NIK under current climate (1988-2018) was 1487 kg ha^{-1} which was improved by 2 per cent to 1524 kg ha^{-1} under projected climate (2020-2050) (Table 3). These results are supported by Bao, *et al*., (2015) Results showed that grain yield for all six cultivars increased for the 2011 to 2050 projections compared to reference simulation 1958-2008. The increase in yield was 4-49% based on the GCMs GKMO and GFDL.The increase in yields due to increase in projected rainfall during soybean growing season for this region.

Table 3. Simulated average grain yield (kg ha^{-1}) of soybean variety JS-335 in NIK under current climate (1988-2018) and projected climate (2020-2050) in rainfed conditions on black and red soils (±S.E. n=3348)

Soil type	Current climate (1988-2018)	Projected climate (2020-2050)	% difference
Black	1487 (±122)	1524 (±133)	2 %
Red	1655 (±70)	1551 (±112)	-6 %
Average	3133 (±96)	1537 (±189)	2%

Simulated grain yield under projected climate (2020-2050) on black soils in rainfed conditions was the highest in Bidar (2349), followed by Haveri (1984) and Belagavi (1821) districts whereas, the lowest yield was simulated for Raichur (877), Gadag (1057) and Yadagiri (1065) districts among the 12 districts of NIK. The maximum yield improved under the projected climate (2020-2050) on black soils was observed in Koppal (85.5 %) followed by Vijayapura (29.4 %) and Bidar (18 %) districts whereas the lowest yield gain was simulated for in Dharwad (0.5 %) followed by Kalaburgi (5.8 %) and Haveri (3 %) districts. The highest yield reduction was observed in Gadag (39.3 %) followed by Raichur (12.8 %) and Yadagiri (11.3 %) districts and the lowest yield reduction was simulated in Bagalkote (3 %) followed by Ballari (5 %) districts (Table 4 and Fig.1 i). Lal, *et al*. (1999) Simulated Results showed that a decline in rainfall with anticipated thermal stress leads on an average of total reduction in crop yield by nearly 5% for every 10% decline in rainfall.

Grain yield simulated under current climate (1988-2018) on red soils in rainfed conditions was the highest in Bagalkote district (2228), followed by Dharwad district (2156) and Gadag district (2044) whereas the lowest yield was simulated for Haveri district (701), followed by Belagavi district (992) and Ballari district (1373) among the 12 districts of NIK. The simulated average yield of NIK under current climate (1988-2018) was 1655 kg ha^{-1} which was reduced by 6 per cent to 1551 kg ha^{-1} under projected climate (2020-2050) (Table 3). Grain yield simulated under projected climate (2020-2050) on red soils in

Table 4. Average yield (kg ha^{-1}) and per cent yield difference of soybean variety JS-335 under current climate (1988-2018) and projected climate (2020-2050) on black soil across 12 districts of NIK (±S.E. n=279)

District	Current climate (1988-2018)	Projected climate (2020-2050)	% Difference	Ranking
Bagalkote	1478 (±131)	1433 (±127)	-3 %	VIII
Ballari	1742 (±164)	1654 (±158)	-5 %	IX
Belagavi	1683 (±104)	1821 (±122)	8.2 %	IV
Bidar	1985 (±126)	2349 (±128)	18.3%	III
Dharwad	1755 (±114)	1764 (±114)	0.5 %	VII
Gadag	1743 (±113)	1054 (±197)	-39.3 %	XII
Haveri	1908 (±141)	1984 (±131)	3.9 %	VI
Kalaburgi	1681 (±151)	1780 (±96)	5.8 %	V
Koppal	656 (±44)	1217 (±124)	85.5 %	I
Raichur	1006 (±101)	877 (±279)	-12.8 %	XI
Vijayapura	1015 (±108)	1315 (±122)	29.4 %	II
Yadagiri	1201 (±118)	1065 (±108)	-11.3 %	X

Table 5. Average yield (kg ha^{-1}) and per cent yield difference of soybean variety JS-335 under current climate (1988-2018) and projected climate (2020-2050) on red soil across 12 districts of NIK (±S.E. n=279)

District	Current climate (1988-2018)	Projected climate (2020-2050)	% Difference	Ranking
Bagalkote	2228 (±121)	1899 (±118)	-4.2 %	V
Ballari	1373 (±127)	1306 (±123)	-4.8 %	VI
Belagavi	999 (±65)	1535 (±100)	53.6 %	I
Bidar	1966 (±121)	1475 (±98)	-24.9 %	X
Dharwad	2165 (±96)	1979 (±87)	-8.5 %	VII
Gadag	2044 (±93)	911 (±153)	-55.4 %	XII
Haveri	701 (±43)	1503 (±104)	3.9 %	III
Kalaburgi	2020 (±89)	1965 (±92)	-2.7 %	IV
Koppal	1428 (±103)	1086 (±112)	-23.9 %	XI
Raichur	1551 (±106)	1390 (±113)	-10.3 %	IX
Vijayapura	1581 (±117)	1669 (±110)	5.4 %	II
Yadagiri	1811 (±111)	1631 (±117)	-9.9 %	VIII

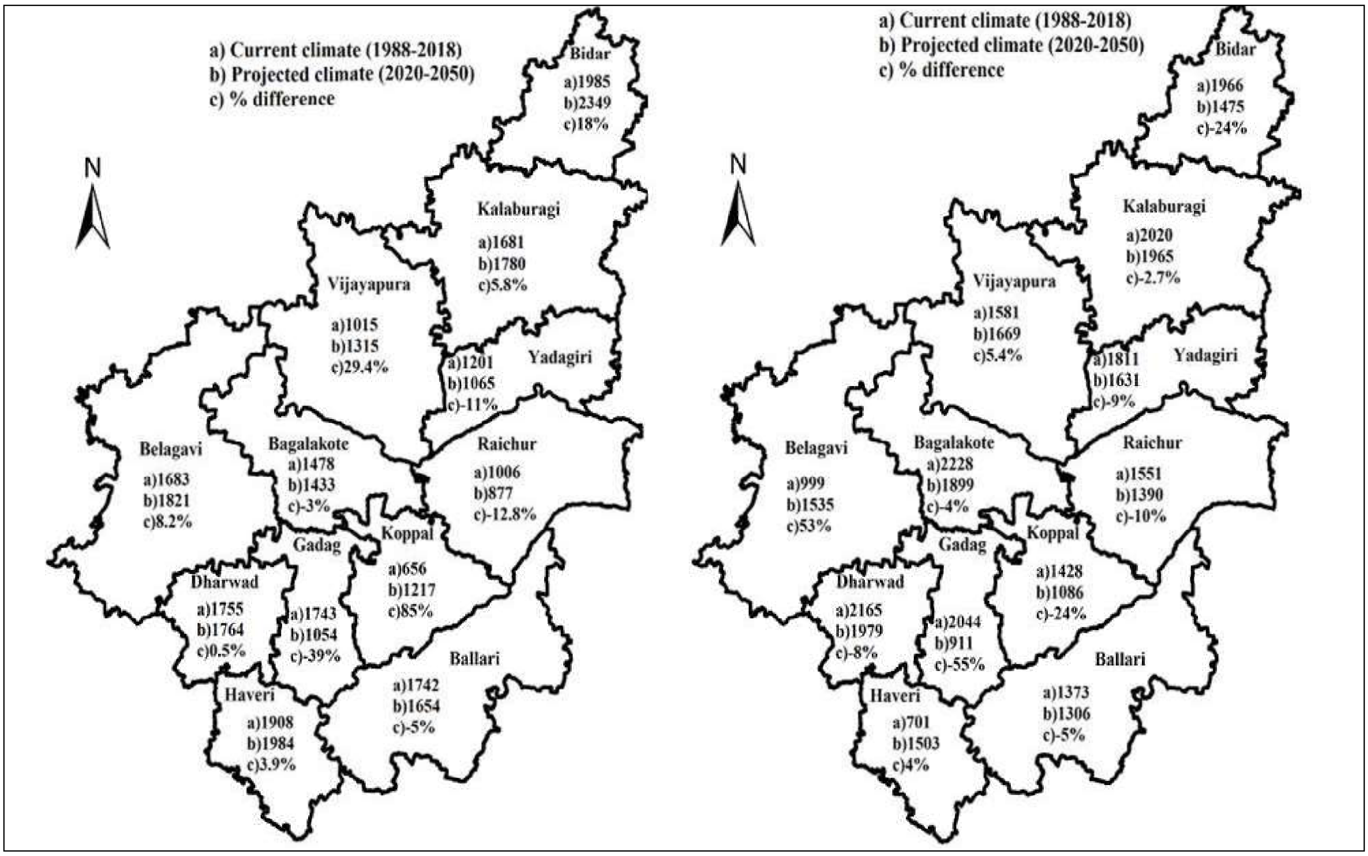

Fig. 1. Simulated difference (c) in grain yield (%) of soybean variety JS-335 under current climate (1988-2018) (a) and projected climate (2020-2050) (b) on black (i) and red soils (ii) across 12 districts of NIK (average of 31 years)

rainfed conditions was the highest in Bagalkote (2134) followed by Dharwad (1971) and Kalaburgi (1964) districts whereas the lowest yield was simulated in Gadag (911) followed by Koppal (1086) and Ballari (1306) Dharwad (6810) districts among the 12 districts of NIK. The maximum yield improved under the projected climate (2020-2050) on red soils was observed in Haveri (114 %) followed by Belagavi (53.6 %) and Vijayapura (5.4 %) districts and the highest yield reduction was simulated in Gadag (55.4 %) followed by Koppal (23.9 %) and Raichur (10.3 %) districts and the lowest yield reduction was simulated in Bagalkote (4.2 %), Bellari (4.8 %) and Dharwad (8.5 %) districts (Table 5 and Fig. 1 ii).

Conclusion

The analysis of impact of projected climate (2020-2050) on soybean variety JS-335 using the DSSAT 4.7 CROPGRO-soybean model in NIK allowed understanding of the magnitude of yield variation due to climate change under projected climate (2020-2050). This study indicated that yield of soybean in NIK would improve by 85 and 114 per cent on black and red soils and reduce by 39 and 55 per cent on black and red soils, respectively, compared to under current climate (1988-2018) which poses challenge to the scientific community to develop and or design adaptation measures to improve the yield in the future climate.

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