Original Research Article

Sustainable Soybean Cultivation Strategies in the NIK Region: Unravelling Climate and Soil Dynamics

ABSTRACT

This study explores the complexities of soybean cultivation in the North Interior Karnataka (NIK), a semi-arid plateau located in northern part of Karnataka, India, characterized by diverse soils ranging from shallow to deep black clay and red sandy loam, and by hot climate and scanty rainfall. Utilizing the FAO CROPWAT model, this work integrated a comprehensive dataset encompassing soybean phenology, climate patterns, and soil characteristics. Robust data wasderived from field experiments on soybean conducted during the *kharif* season of 2020,spread over four distinct sowing dates. The analysis incorporated historical climate records (1991-2020) sourced from NASA and future projections (2021-2050) from the Copernicus Climate Change Service. Soil characteristics were extracted from the ICAR web portal. The study revealed the sensitivity of soybean to climate and soil variations, with black soil exhibiting higher yield reductions. The research underscores the importance of yield reduction under rainfed conditions and implementing precise irrigation scheduling for sustainable agriculture. The study also showed higher irrigation requirements on black clay soil compared to red sandy loam, projecting an increased demand for irrigation in the forthcoming decades. This underscores the urgency of adaptive agricultural practices amidst evolving climatic scenarios. The study contributes valuable insights for policymakers, researchers, and farm managers, offering tailored and sustainable strategies for soybean cultivation in the challenging agro-climatic conditions of the NIK region. As climate patterns undergo transformations, proactive and informed approaches are essential for ensuring the resilience and productivity of agriculture in semi-arid environments.

Key words: *North Interior Karnataka, CROPWAT, Irrigation scheduling, Climate change and Yield reduction*

INTRODUCTION

Soybean [*Glycine max (L.)*] plays a pivotal role in global agriculture due to its significance in food and oil production (Dilwari et al., 2022). The adaptability and productivity of soybean under varying agronomic practices, such as row spacing and seeding systems, directly influence its yield and quality (Jańczak-Pieniążek et al., 2021). Moreover, co-inoculation with rhizobia and azospirilla has been suggested as a sustainable strategy to enhance nitrogen fixation and productivity in soybeans, promoting environmental sustainability (Hungria et al., 2013). Climate change has emerged as a critical factor impacting soybean cultivation, with shifts in phenological patterns observed over the past decades in response to changing climatic conditions (Gong et al., 2021). These changes underscore the need for precise water management strategies and optimizing irrigation for soybean under variable climatic scenario (Jangre et al., 2022). Soybean faces challenges due to limited cultivation and water scarcity, necessitating strategic interventions for future sustainability (Naser et al., 2024). In India, soybean holds a prominent position, particularly in regions like North Interior Karnataka, where it contributes significantly to the agricultural economy. This region, characterized by its semi-arid climate, poses distinct challenges for soybean cultivation, primarily due to water scarcity and variability in rainfall (Thimmareddy et al., 2022). Thus, effective water management and irrigation scheduling are essential for optimizing soybean yields in this area.

Water stress is a critical factor affecting soybean yield. Soybeans are particularly sensitive to water availability during certain growth stages, including germination, flowering, and pod filling (Pejić et al., 2012). Insufficient water supply during these periods can lead to significant yield losses. For instance, water stress during the flowering stage can reduce the number of flowers and pods, while stress during pod filling can adversely affect seed development and size (Molinari et al., 2021).Studies have shown that water stress can lead to a reduction in photosynthetic activity, impair nutrient uptake, and cause physiological changes in soybean plants, ultimately reducing yield (Wang et al., 2022). In regions like North Interior Karnataka, where rainfall is unpredictable and often insufficient, managing water resources efficiently is crucial to mitigate yield reduction due to water stress.

Irrigation scheduling is a critical component of water management in agriculture. It involves determining the timing and amount of water to apply to crops to meet their water needs without wastage. Proper irrigation scheduling ensures that crops receive adequate water at critical growth stages, thus minimizing the adverse effects of water stress (Gu et al., 2020).In North Interior Karnataka, traditional irrigation practices often rely on fixed schedules or visual assessment of crop water needs, which can be inefficient and lead to either over-irrigation or under-irrigation. Therefore, adopting scientific and precise irrigation scheduling methods is essential for enhancing water use efficiency and improving crop yields.

The CROPWAT model, developed by the Food and Agriculture Organization (FAO), is a decision-support tool designed to assist in the planning and management of irrigation in agriculture. It calculates crop water requirements and irrigation schedules based on climatic, crop, and soil data (Allen et al., 1998). CROPWAT uses the Penman-Monteith equation to estimate reference evapotranspiration (ET_o), which is then used to calculate crop evapotranspiration (ET_c) and irrigation requirements.The model also allows for the simulation of different irrigation scenarios, helping to identify the most efficient irrigation strategies under varying climatic conditions (Rudraswamy et al., 2024). By integrating local weather data, soil characteristics, and crop specifics, CROPWAT can guide farmers and agronomists in making informed decisions about irrigation management, thus optimizing water use and enhancing crop productivity.By understanding the soil characteristics and their impact on water availability, CROPWAT helps in optimizing irrigation practices, ensuring that water is applied efficiently to meet the crop's needs without causing waterlogging or excessive runoff (Memon et al., 2018).

The study was undertakenagainst the backdrop of soybean cultivation in the NIK region, exploring the complexities of yield reductions under rainfed conditions, irrigation scheduling strategies, and the influence of changing climatic scenarios on agricultural productivity. By unravelling the complex interplay amongsoil properties, climate variations, and crop responses, this research aims to contribute valuable insights that can inform sustainable agricultural practices in the challenging agro-climatic conditions of the NIK region.

METHODOLOGY

NIK region which is one of the meteorological sub-divisions as per India Meteorological Department (IMD) classification and this sub-division consist mostly semi-arid plateau and constitutes the northern part of the Karnataka state. It consists of 12 districts namely Bagalkote, Belagavi, Ballari, Bidar, Dharwad, Gadag, Haveri, Kalaburagi, Koppal, Raichur, Vijayapura and Yadagiri (Fig. 1). This region is predominantly covered with shallow to deep black clay soil followed by red sandy loam soils. NIK is one of the drier regions of India receiving on average just 668 mm rainfall per annum and has the average annual temperature of around 36˚C. Cereals like bajra, sorghum, maize, paddy, wheat, minor millets and pulses like chickpea, pigeon pea, greengram, soybean, blackgram, cowpea and oil seeds like groundnut, sunflower, soybean, sesame, castor, safflower and commercial crops like sugarcane, chilli and cotton are the major crops grown in this region. Some of the horticulture crops like grapes, pomegranate, mango, guava, lemon, banana along with most vegetables etc., are also grown. The minimum data set to run the FAO-CROPWAT model was collected in this study and is briefed below here.

Crop data*:* The minimum data required to run CROPWAT model, including those on phenology, were collected from a field experiment carried out during *Kharif* 2020 as part of All India Coordinated Research Project (AICRP) on soybean with four dates of sowing starting from 7th June to 28th June at weekly interval, whereas the crop coefficient data of soybean were collected from the FAO chapters. The crop coefficient values (K_c) for initial, mid and late growth stages were borrowed from the publication of Allen *et al.,* (1998) (listed in Table 2).

Climate / Rainfall data: The climate data, including that on rainfall, were downloaded from NASA power web portal for the period from 1991 to 2020 (https://power.larc.nasa.gov/data-access-viewer/) whereas projected climate data for the coming three decades (2021-2050) were downloaded from Copernicus Climate Change Service (IPSLCM5A model), RCP 6.0 climate scenario (https://climate.copernicus.eu). The collected data from 1991 to 2050 were compiled and categorized into six decadal periods and further monthly averages for all these data were also calculated. The data were then averaged to past climate (1991-2020) and projected climate (2021-2050) for the analysis (Table 1). The analyzed weather data along with data on soybean crop were fed into CROPWAT model to calculate reference evapotranspiration (ET_o).

Soil data:Soil characteristics of the two most predominant soils from each district of NIK region *i.e.,* black clay and red sandy loam soils were collected from ICAR web portal (*https://krishi.icar.gov.in/Geo_Portal.jsp*) including from the NBSS&LUP (*http://www.bhoomigeoportal-nbsslup.in/*) (Table 3).

RESULT AND DISCUSSION

The significance of comprehending yield reduction under rainfed conditions and implementing precise irrigation scheduling cannot be overstated in the context of agriculture. In rainfed environments, where climate unpredictability poses a constant challenge, understanding potential yield losses is pivotal for risk mitigation, resource management, and ensuring food security. Simultaneously, effective irrigation scheduling plays a crucial role in optimizing water use efficiency, minimizing wastage, and enhancing crop yields. By aligning irrigation practices with crop water requirements, farmers can mitigate the risks of water-related stress, conserve resources, and promote sustainable agricultural practices. The integration of insights into both yield reduction under rainfed conditions and irrigation scheduling forms a holistic approach, fostering climate resilience, enhancing productivity, and supporting economic development in agricultural communities.

Percent yield reduction (without irrigation)

The highest yield reduction was recorded on black clay soil compared to red sandy loam soil under both past (1991-2020) and projected (2021-2050) climatic scenarios for all districts of NIK (Table 4) (Fig. 2 & 3). These results might be due to the highly responsive traits of soybean under acidic condition (Uguru et al., 2012) as the red sandy loamy soils had lower pH values ranged from moderately acidic to slightly acidic (Malavath and Mani, 2018). A number of studies indicated that soybean yields are not substantially affected until the root zone soil has been depleted below 60 percent of total available water (TAW), provided canopy development has not been hampered by prolonged mild water deficits during the vegetative phase (Doss and Thurlow, 1974). The soil moisture depletion not only dependent on soil characteristic but also on amount of available water present in the root zone, amount of water extracted by the crop, contribution of evaporation to evapotranspiration by the soil, leaching losses etc., which were higher in case of black soil compared to red soil.

Reduction in average yield of soybean across six decades (1991-2050) was simulated with delay in sowing from 7th June to 28th June at weekly interval (Table 5)on both the soil. This was because of the lowestrainfall projected for early sown dates i.e., shift in the rainfall from June so that crop fails to get sufficient water under rainfed condition (without irrigation) as and when required. In some of the districts of NIK (Ballari, Raichur and Gulbarga), reduction in yield decreased with delay in sowing on both clay and sandy loam soils, which had increased irrigation requirement and decreased pattern of ER with delay in sowing (Table 5). These results are also in accordance with the findings of Kumagai and Takahashi (2020), who reported that sowing approximately three weeks late decreases soybean yields.

Results of Sincik et al. (2008) indicated that lower amounts of irrigation resulted in higher per cent of seed yield reduction in soybean. Due to the higher irrigation requirement in projected climates (2021-2050) compared to past climates (1991-2020), the average yield reduction across four DOS in rainfed condition (without irrigation) under projected climate was higher than past climate scenarios on both black clay and red sandy loam soils.

Irrigation scheduling

The highest average number of irrigations required across six decades, were three on black clay soil for Bidar, Kalaburgi, Raichur and Yadagiri districts, and five on red sandy loam soil for Kalaburgiand Raichur districts, simulated for the sowing date of 7th June because of their higher irrigation requirements and lower rainfall on 7th June compared to other dates of sowing (Table 5). The lowest average number ofirrigation required was for the one on black clay soil for Belagavi, Dharwad, Gadag and Haveri districts, and no irrigation on red sandy loam soil for Belagavi (21st and 28th June) and Haveri (28th June) districts, simulated for last date of sowing due to their higher rainfall (Table 1) and lower irrigation requirements with delay in sowing. The overall average number of irrigations required under irrigated condition for all 12 districts of NIK across six decades of climate and four dates of sowing were two irrigations on both black clay and red sandy loam soil i.e., one irrigation at pod initiation stage (40-45 DAS) and another one at gain filling stage (60-65 DAS). Similar findings were reported by Ali et al. (2009) in corn production as conducted to evaluating the effect of three irrigation methods and scheduling.

The numbers of irrigations were higher on black clay soil compared to red loamy soil for some of the districts during decadal climates (Table 4). In CROPWAT model, irrigation scheduling is based on soil moisture depletion (SMD) i.e., 60 percent depletion of total available soil moisture for soybean and it is purely a single day event (Doss and Thurlow, 1974). If a particular day has SMD > 60% of total available water (TAW), then model shows a single irrigation, such days were slightly higher in black clay soil compared to red sandy loam soil due to its higher available soil moisture in the root zone of plants, which was easily extractable, andit also might be to compensate the higher yield losses in black clay soil under rainfed condition without irrigation.

CONCLUSION

The study highlights the critical role of precise irrigation scheduling in mitigating yield reductions of soybean under future climatic conditions. The findings reveal that black clay soils require more frequent irrigation compared to red sandy loam soils due to their higher water retention capacity and greater susceptibility to yield loss under rainfed conditions. Future climatic scenarios (2021–2050) project an increase in irrigation requirements compared to past climates (1991–2020), particularly for early sowing dates when rainfall patterns shift. Optimal irrigation scheduling, with an average of two irrigations across all districts—one at pod initiation (40–45 DAS) and another at grain filling (60–65 DAS)—proves crucial to minimizing water stress and sustaining yields. Adapting sowing dates and irrigation practices based on soil type and rainfall variability can enhance water use efficiency and soybean productivity, fostering resilience to projected climate changes and ensuring sustainable agricultural practices.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

REFERENCE

Ali, M. A., Awal, M. A., & Saleh, A. F. M. (2009). Performance of different varieties of soybean under rainfed condition. World Journal of Agricultural Sciences, 5(1), 27-33.

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration: Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper, 56.

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.

Copernicus Climate Change Service. (2023). IPSLCM5A model, RCP 6.0 climate scenario. https://climate.copernicus.eu

Dilawari, R., Kaur, N., Priyadarshi, N., Prakash, I., Patra, A., Mehta, S., ... & Islam, M. A. (2022). Soybean: A key player for global food security. In Soybean improvement: physiological, molecular and genetic perspectives (pp. 1-46). Cham: Springer International Publishing.

Doss, B. D., & Thurlow, D. L. (1974). Soybean response to early season drought as influenced by soil water and air. Agronomy Journal, 66(5), 556-559.

Gong, L., Tian, B., Li, Y., & Wu, S. (2021). Phenological changes of soybean in response to climate conditions in frigid region in China over the past decades. International Journal of Plant Production, 15(4), 363-375. https://doi.org/10.1007/s42106-021-00145-5

Gu, Z., Qi, Z., Burghate, R., Yuan, S., Jiao, X., & Xu, J. (2020). Irrigation scheduling approaches and applications: A review. Journal of Irrigation and Drainage Engineering, 146(6), 04020007.

Hungria, M., Nogueira, M. A., & Araujo, R. S. (2013). Co-inoculation of soybeans and common beans with rhizobia and azospirilla: Strategies to improve sustainability. Biology and Fertility of Soils, 49(7), 791-801.

ICAR. (2023). Indian Council of Agricultural Research. https://krishi.icar.gov.in/Geo_Portal.jsp

Jańczak-Pieniążek, M., Buczek, J., Bobrecka-Jamro, D., Szpunar-Krok, E., Tobiasz-Salach, R., & Jarecki, W. (2021). Morphophysiology, productivity and quality of soybean (Glycine max (L.) Merr.) cv. Merlin in response to row spacing and seeding systems. Agronomy, 11(2), 403. https://doi.org/10.3390/agronomy11020403

Jangre, N., Sinha, J., Raj, J., & Kamalkant, K. (2022). Estimation of crop water requirement of Kharif maize crop using CROPWAT 8.0 model in Bilaspur district. International Journal of Environment and Climate Change, 12(12), 597-606. https://doi.org/10.9734/ijecc/2022/v12i121497

Kumagai, E., & Takahashi, K. (2020). Effects of sowing date on soybean yield. Agronomy Journal, 112(5), 4194-4203.

Malavath, J., & Mani, A. (2018). Soil pH variation in soybean cultivation. International Journal of Current Microbiology and Applied Sciences, 7(3), 3190-3196.

Memon, A. V., &Jamsa, S. (2018). Crop water requirement and irrigation scheduling of soybean and tomato crop using CROPWAT 8.0. International Research Journal of Engineering and Technology, 5(9), 669-671.

Molinari, M. D. C., Fuganti-Pagliarini, R., Barbosa, D. D. A., Marin, S. R. R., Marin, D. R., Rech, E. L., ... & Nepomuceno, A. L. (2021). Flowering process in soybean under water deficit conditions: A review on genetic aspects. Genetics and molecular biology, 45(1), e20210016.

NASA. (2023). NASA's power web portal. https://power.larc.nasa.gov/data-access-viewer/

Naser, M., Abdelghany, A. M., Wu, T., Sun, S., & Tianfu, H. (2024). Soybean in Egypt: Current situation, challenges, and future perspectives. Discover Sustainability, 5(1), 425.

Pejić, B., Maksimović, L., Cimpeanu, S., Bucur, D., Milić, S., &Ćupina, B. (2011). Response of soybean to water stress at specific growth stages.

Porter, J. R., et al. (2014). Climate change impacts on agriculture in 2050 under a range of plausible socioeconomic and emissions scenarios. Environmental Research Letters, 9(6), 064015.

Rudraswamy, G. K., &Umamahesh, N. V. (2024). Investigating the impact of climate change on irrigation and crop water requirements of Bhadra and Tungabhadra command area: A CMIP-6 GCMs and CROPWAT 8.0 approach. Water Supply, 24(2), 625-642.

Sincik, M., et al. (2008). Irrigation effects on soybean yield. Journal of Agronomy, 7(3), 197-201.

Thimmareddy, H., Sumesh, K. G., Patil, R. H., & Math, G. (2022). Estimation of yield reduction and scheduling irrigation in greengram under changing climate of North Interior Karnataka. Journal of Food Legumes, 35(4), 238-245.

Uguru, M. I., et al. (2012). Soybean yield response to soil acidity in acidic soils. Agriculture, Forestry and Fisheries, 1(1), 24-28.

Wang, X., Wu, Z., Zhou, Q., Wang, X., Song, S., & Dong, S. (2022). Physiological response of soybean plants to water deficit. Frontiers in Plant Science, 12, 809692.

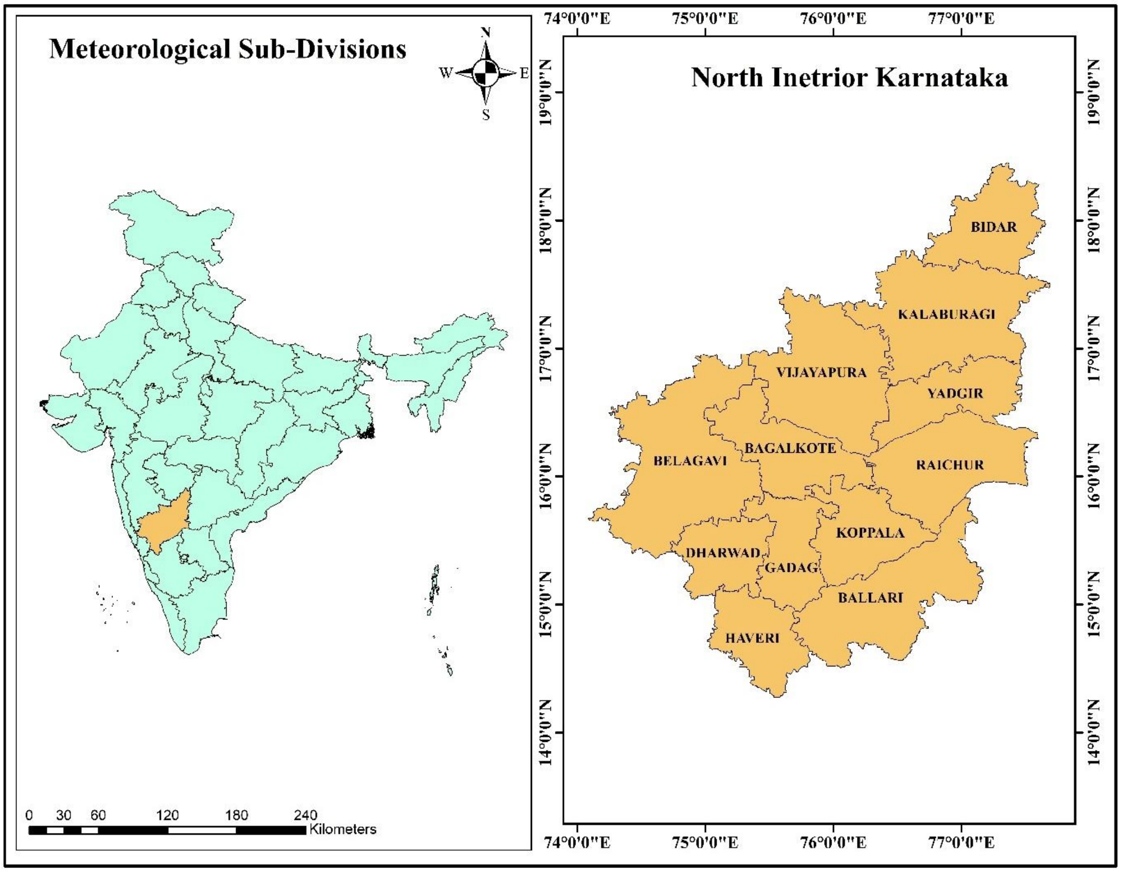

Fig. 1: Spatial map of 12 districts of North Interior Karnataka (NIK)

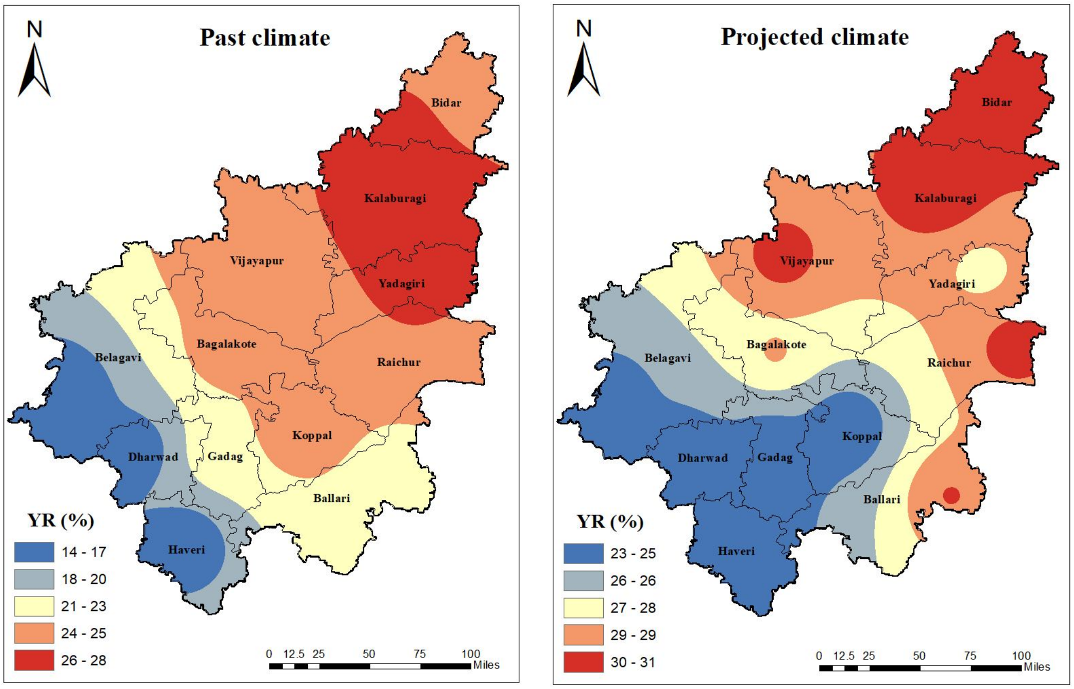

Fig. 2. Spatial distribution of soybean yield reduction (YR) in black clay soil under both past (1991-2020) and projected (2021-2050) climatic scenarios across NIK

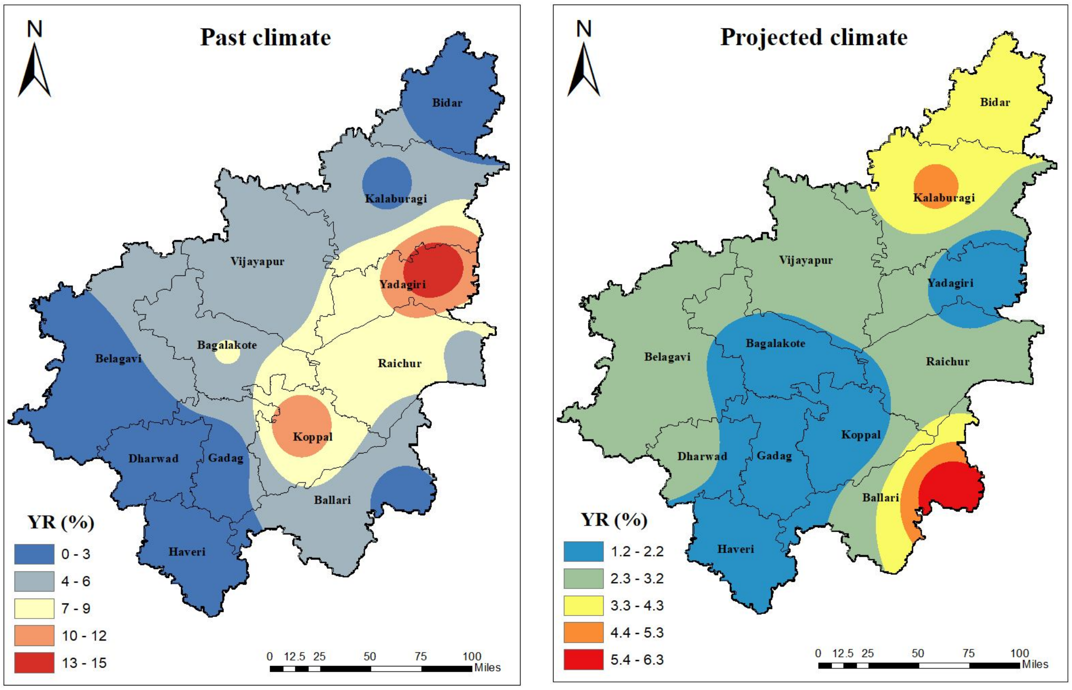

Fig. 3. Spatial distribution of soybean yield reduction (YR) in red sandy loam soil under both past (1991-2020) and projected (2021-2050) climatic scenarios across NIK

Table 1: Average weather data during Soybean cropping period (Jun-Sept) 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	640	26.7	108	812	30.2	81	172	3.6	-27
Bagalkote	444	26.1	95	804	28.4	84	360	2.4	-10
Belagavi	959	25.2	119	637	28.3	85	-322	3.1	-34
Vijayapura	397	27.0	81	819	28.3	87	422	1.4	5
Ballari	419	26.3	82	784	30.1	85	364	3.7	3
Dharwad	870	25.0	117	637	28.3	85	-233	3.3	-34
Gadag	521	25.7	106	652	28.2	88	131	2.5	-19
Kalaburagi	531	27.2	98	809	30.3	79	278	3.1	-19
Haveri	986	25.1	119	652	28.2	89	-333	3.1	-30
Koppal	393	26.2	26	582	28.2	89	189	2.0	63
Raichur	453	27.5	85	802	30.3	84	349	2.8	-3
Yadagiri	461	27.4	93	802	30.3	84	341	2.9	-9
NIK	**589**	**26.3**	**94**	**733**	**29.1**	**85**	**143**	**2.8**	**-9**

Table 2: The crop coefficient values (K_c) for initial, mid and late growth stages of Soybean

Stages/crops	Soybean	
	Days after sowing	$K_c$values
Initial	15	0.40
Development	18	-
Midseason	45	1.14
Lateseason	17	0.50
Total	95	-

Table 3: Soil parameters of black clay and red sandy loam used in the model for all the districts of NIK

Soil name	Blackclay	Redsandy loam
Totalavailablesoilmoisture(FC-WP)(mm/meter)	200	100
Maximumraininfiltrationrate(mm/day)	7	30
Maximumrootingdepth(centimeters)	150	50
Initialsoilmoisturecondition(as%TAM)(%)	30	20
Initialavailablesoilmoisture(mm/meter)	140	80

Table 4. The average yield reduction in soybean (%) without irrigation and number of irrigations required across four DOS in soybean during past 30 years (1991-2020), projected 30 years (2021-2050) and difference between them for all 12 Districts of NIK

Soybean	Black clay soil						Red sandy loam soil						Difference between black and red soils			
	1991-2020 (A)		2021-2050 (B)		Difference (B-A)		1991-2020 (A)		2021-2050 (B)		Difference (B-A)		1991-2020		2021-2050	
	YR	Irr	YR	Irr	YR	Irr	YR	Irr	YR	Irr	YR	Irr	E-A	F-B	G-C	H-D
Bidar	25.1	2	30.9	2	5.8	0	0	1	3.5	2	3.5	1	-25.1	-1	-27.4	0
Bagalkote	24.1	2	27.9	2	3.8	0	6.2	3	2.1	1	-4.1	-1	-17.9	1	-25.8	-1
Belagavi	14.37	1	24.1	2	9.8	1	0	0	2.3	1	2.3	1	-14.37	-1	-21.8	-1
Vijayapur	28.17	2	27.4	2	-0.8	0	15.2	5	1.2	1	-14	-4	-12.97	3	-26.2	-1
Ballari	20.2	1	29.4	2	9.2	1	2.1	2	6.3	2	4.2	-1	-18.1	1	-23.1	0
Dharwad	15.1	1	24	2	8.9	1	0	0	2.7	2	2.7	2	-15.1	-1	-21.3	0
Gadag	21.7	1	23.3	2	1.6	0	1	2	1.4	2	0.4	0	-20.7	1	-21.9	0
Kalaburgi	27.5	2	30.8	2	3.4	0	2.2	2	4.6	4	2.4	2	-25.3	0	-26.2	2
Haveri	15.2	1	23.1	2	8	1	0	0	1.3	2	1.3	2	-15.2	-1	-21.8	0
Koppal	25.1	2	23.2	2	-1.9	0	12	3	1.4	2	-10.6	-1	-13.1	1	-21.8	0
Raichur	24.6	2	29.9	2	5.3	0	5.7	3	2.3	3	-3.4	1	-18.9	1	-27.6	1
Yadagiri	24.5	2	30	3	5.5	1	4.8	3	2.4	3	-2.4	1	-19.7	1	-27.6	1
NIK	22.2	2	27	2	4.9	0	2.9	2	3.8	2	0.9	0	-19.3	0	-23.2	0

***DOS-** Date of sowing, **YR-** Yield Reduction (%),**Irr-** Number of Irrigations

Table 5: District wise average yield reduction in soybean (YR) and number of irrigations (No. of Irr.) required for four dates of sowing in both black clay and red sandy loam soils under projected (2021-2050) climate in Soybean

Decades/ Particulars	Black Clay soil								Red sandy loam soil								Average across DOS			
	Yield Reduction (%)				Number of Irrigations				Yield Reduction (%)				Number 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	Irr	YR	Irr
Bidar	31.3	29.1	26.3	25.4	3	2	2	2	5.6	1.4	0	0	3	2	2	1	28	2	1.8	2
Bagalakote	28.2	26.9	24.5	24.3	2	2	2	2	5.6	3.6	3.5	4	3	2	2	1	26	2	4.1	2
Belagavi	20.8	20.1	17.9	18.4	2	1	1	1	3.5	1.1	0	0	1	1	0	0	19.3	1	1.2	1
Vijayapur	28.2	26.9	24.5	24.3	2	2	2	2	5.6	3.6	3.5	4	3	2	2	1	26	2	4.1	2
Ballari	26.7	26	23.7	23	2	2	2	2	6.4	4.1	3.2	3.1	3	2	2	1	24.8	2	4.2	2
Dharwad	21.1	20.3	18.2	18.7	2	1	1	1	4	1.4	0.1	0	2	1	1	1	19.6	1	1.4	1
Gadag	24	23.2	21.3	21.6	2	2	1	1	2.6	0.5	0.7	1.1	3	2	2	2	22.5	1	1.2	2
Kalaburgi	32.2	30.3	27.4	26.6	3	2	2	2	8.1	3.4	1.2	0.9	5	3	3	2	29.1	2	3.4	3
Haveri	20.1	19.4	17.4	19.7	2	1	1	1	2.5	0.2	0	0	2	1	1	0	19.1	1	0.7	1
Koppal	25.6	24.9	23	23.2	2	2	2	2	8.8	6.4	5.9	5.5	3	2	2	2	24.2	2	6.7	2
Raichur	29.9	28.3	25.7	25.3	3	2	2	2	7.4	4	2.6	2.1	5	3	2	2	27.3	2	4	3
Yadagiri	23.8	24.5	23.7	24.4	2	2	2	2	4.4	3.3	2.3	1.8	2	3	2	2	24.1	2	3	2
NIK	26.0	25.0	22.8	22.9	2	2	2	2	5.4	2.8	1.9	1.9	3	2	2	1	24.2	2	3.0	2