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ORIGINAL PAPER

Assessment of future climate variability and potential adaptation strategies on yield of peanut and *Kharif* rice in eastern India

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Abstract

Temperature and CO_2 are the two most important climate parameters that affect crop yield directly. In this study, the impact of these two parameters on the productivity of peanut and rice under the sub-humid and sub-tropical condition of Eastern India were assessed using experimental data and the DSSAT v4.5 CROPGRO-Peanut and CERES-Rice model. Experimental results of peanut and rice with four sowing dates of each were used as the baseline scenarios. The future weather data from the CSIRO-Mk3–6.0 model for RCP 4.5 and 8.5 was used to the peanut and rice crop model to simulate the yield using future weather data for the periods 2020, 2050, and 2080, and change in yield was compared with the baseline (1980–2013) at Kharagpur, West Bengal, India. The results reveal that rising temperature has negative effect on the growth and developmental phases of crop, and it brings early flowering. Concurrently, increase in temperature causes reduction of crop yield due to pollen sterility and poor pollen growth during reproductive growth stage. The CO_2 concentrations used in the model, as projected by IPCC, were 390, 420, 530, and 650 ppm for the years 1980–2013 (baseline), 2020, 2050, and 2080, respectively. However, simulation was made using the model for percent change in mean temperature of 3.36 °C for 2020, 7.59 °C for 2050, and 10.4 °C for 2080. The model simulation reveals that elevated CO_2 concentration of 420, 530 and 650 ppm showed gradual increase in the grain yield and biomass yield with shifting in sowing dates for peanut crop. On the other hand, for rice crop, though the crop yield increases gradually, the total biomass yield would reduce in future climate change scenario.

Keywords CROPGRO-Peanut · CERES-Rice · Baseline · Climate change · CO_2 concentration · Representative concentration pathways

1 Introduction

Agriculture is quite vulnerable to the adverse effects of climate variability. Though technological developments have occurred in terms of improved crop varieties, irrigation methods, weather parameters are the major factors which play important role in agricultural crop production. Therefore, the adverse impact of climate variability on agriculture is of concern, particularly for India, where agriculture is the major source of livelihood and mainly depends on the weather parameters. The direct impact of climate variability, largely due to changes in precipitation and temperature, would affect plant growth, development, and yield. Studies reveal that increased temperature would reduce crop growth duration and increase crop photosynthesis rate. However, increased CO_2 levels are expected to favor growth and increase in crop yield and thereby would be helpful in counteracting the adverse effects of temperature rise in future (Varshneya 2009).

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Peanut (*Arachis hypogaea* L.), which is a C3 crop and one of the major oilseed and cash crops, needs long, warm growing season; abundance of sunshine; and high temperature for optimum crop growth. In India, area under peanut is around 5.31 M ha with 6.93 MT of production, with an average productivity of 1.30 MT/ha, during winter season (Agriculture at a glance 2012). In eastern part of India, rice (*Oryza sativa*) is mainly taken as rainfed crop during the monsoon months (June to October) and rice-based cropping system is predominant. For conventional method of rice cultivation high amount of water, chemical fertilizers and pesticides are applied to get maximum return, which leads to over-exploitation and contamination of groundwater resources as well as deterioration of soil health. Therefore, alternate cropping system could be considered as best management practices to restore the natural resources. Peanut by adding atmospheric nitrogen through symbiotic nitrogen fixation, can improve the soil health and may be a best replacement for the potential rice cultivated areas, as water use efficiency (WUE) is very high in peanut which results water saving. Summer peanut crop (January to April) instead of rice crop can improve the economic status of the country.

However, rice (*Oryza sativa*) is considered to be the most essential food crops of two thirds of the world's population living in Asia, including India, feeding more than 3 billion populations. About 40% of the world and 65% of Indian population use rice as a major staple food (Ghosh and Bhat, 1998). India's target for rice production by 2025 is 120–130 million tons, with an annual increase of 2.0 million tons with enhancements in resource use efficiency and productivity (Mangala Rai 2006). In India, rice is mainly cultivated in humid tropical climate, under the influence of local environment. Though over the last 15 years rice yield has increased significantly, there is potential to raise them further. There are several factors that impact rice production, including management practices such as cultivar use, transplanting date, plant density, fertilizer application, and irrigation. Moreover, environmental factors (temperature, rainfall, solar radiation, humidity) directly affect the crop growth and yield. In India, rice is mainly cultivated as rainfed crop, so deviation of rainfall or delay in onset of monsoon affects the production. Similarly, the temperature variation from germination to harvest also influences the production. Therefore, identification of suitable crop management practices with respect to the varying weather condition could provide information for designing a plan to increase the rice yield of this production area.

Eastern India is facing troubles due to the variation of weather parameters during the recent years which is the major contributors to the food production of the country. Most of the farmers of this region are small to marginal and mainly depend on the rainfed farming. As per the report of intergovernmental panel on climate change (IPCC), in the near future, increase in temperature will be high for South Asian countries and dry period will be more as compared to wet (IPCC 2007).

IPCC has also projected a rise of global surface temperature within the range of 0.4–2.6 °C in 2046–2065 and 0.3–4.8 °C in 2081–2100 relative to the reference period of 1986–2005 (IPCC 2014). Recent study shows that temperature increase (2–4 °C) will reduce the crop yield, and eastern parts of India are predicted to be mostly affected, resulting in relatively fewer grains and short grain filling stage (Chattopadhyay 2011). The annual mean temperature increase will range between 3.5 and 5.6 °C by 2080, which will have profound effect on crop productivity (Lal et al. 2001). To obtain the required quantity of production, it is important to understand the impact of climate change and take possible adaptation measures to tone down its impact in a given environment. For climate change scenario, daily weather data is mostly projected from general circulation models (GCMs) and regional climate models (RCMs). Although there is considerable uncertainty about the future, the changes in spatial and temporal pattern in climatic variables due to global warming and their impact on crop productivity have been studied in different parts of the world (Jalota et al. 2014; Vashisht et al. 2013; Tubiello et al. 2000).

Ramachandana et al. (2017) evaluated the impacts of future plausible climate change on major crops yield such as rice, groundnut, and sugarcane using DSSAT, under the scenarios of IPCC RCP 4.5. For rice crop, the CERES-Rice model predicted yield loss of 8.8%, 13.1%, and 18.73% for near (2010 ± 2040), mid (2041 ± 2070), and end (2071 ± 2098) scenarios, respectively. The decline in rice yield was also noticed by 6.4%, 4.7%, and 4.4% for the CO_2-enriched scenario. Similarly, the simulation study for peanut shows that the pod yield was reduced by 5.1 and 9.6% for the mid and end century and during the end century, yield change was negative. However, yield increased until the 2060s under a CO_2-enriched scenario after which it begins to decrease.

The present study was undertaken to simulate the yield of peanut and rice through the CROPGRO-Peanut and CERES-Rice models for Kharagpur representing a sub-humid climatic environment, with the objective to simulate yield changes under future predicted scenarios to assess ideal management strategies.

2 Methodology

2.1 Experiment site

Field experiments were conducted at the experimental farm of the Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, India (22°19′N latitude and 87°19′E longitude). The soil is lateritic type with sandy loam texture. Kharagpur is situated at sub-humid and subtropical climate. During April and May, hot and humid summer prevails. However, rainy season remains during June to October. A reasonably hot and dry autumn prevails between October and November, whereas cool and dry winter prevails in December and January and moderate spring in February and March. The average rainfall of this area is 1664 mm (1980–2013) and most of the rain occurs during the monsoon period from June to October. The average temperature varies between 21 and 32 °C. The variation in monthly total rainfall and average maximum and minimum temperature during the peanut and rice crop growing season (2012 and 2013) for Kharagpur is presented in Figs. 1 and 2. The daily weather data for the base period (1980–2013) was used for the past yield simulation.

2.2 Experiment details

Two field experiments were conducted during the summer (January–April) and wet seasons (June to October) of 2012 and 2013 with 16 treatment combinations (four planting dates and four fertilization levels) on peanut and rice crop. The experiments were laid out in split plot design with three replications, where planting dates are considered as main plot factor and levels of fertilization as sub plot factor for both the field experiments. The details are depicted below:

1. Experiment I

    Crop: peanut
    Cultivar: TMV-2

    Treatment details:

    Factor I (Planting dates): (i) 14 January, (ii) 29 January, (iii) 14 February, (iv) 28 February
    Factor II (Fertilization levels): (i) control (no fertilizer), (ii) 20: 40: 40 kg NPK ha^{-1}, (iii) 20: 60: 40 kg NPK ha^{-1}, and (iv) 20: 80: 40 kg NPK ha^{-1}

2. Experiment II

    Crop: rice
    Cultivar: IR-36

    Treatment details:

    Factor I (planting dates): (i) 30 June (ii) 15 July (iii) 30 July (iv) 15 August

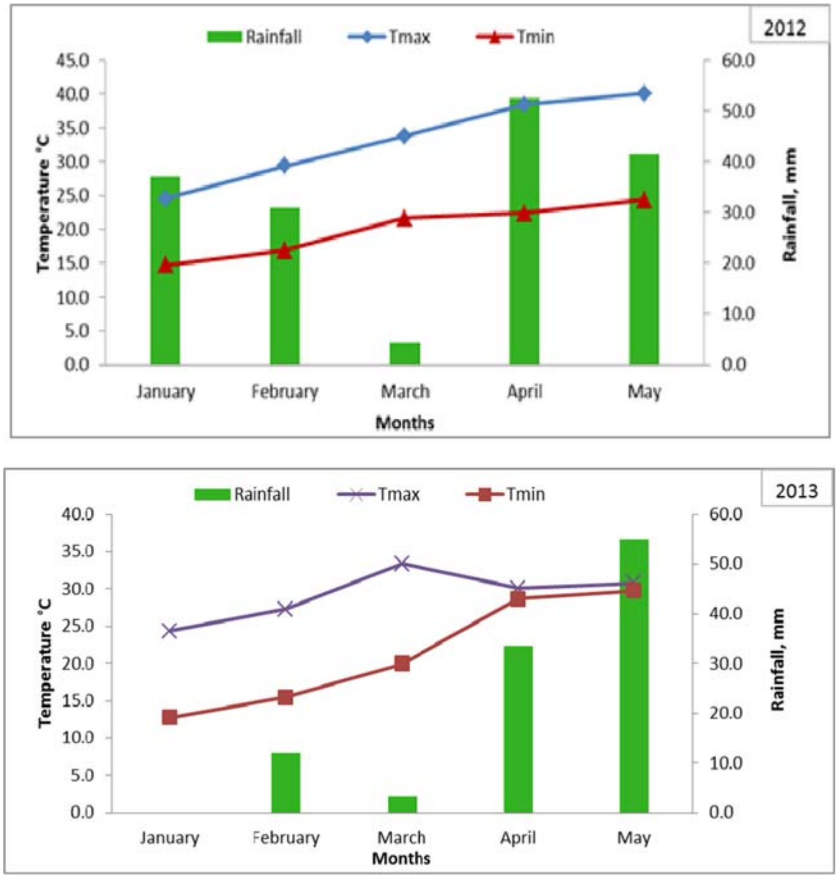
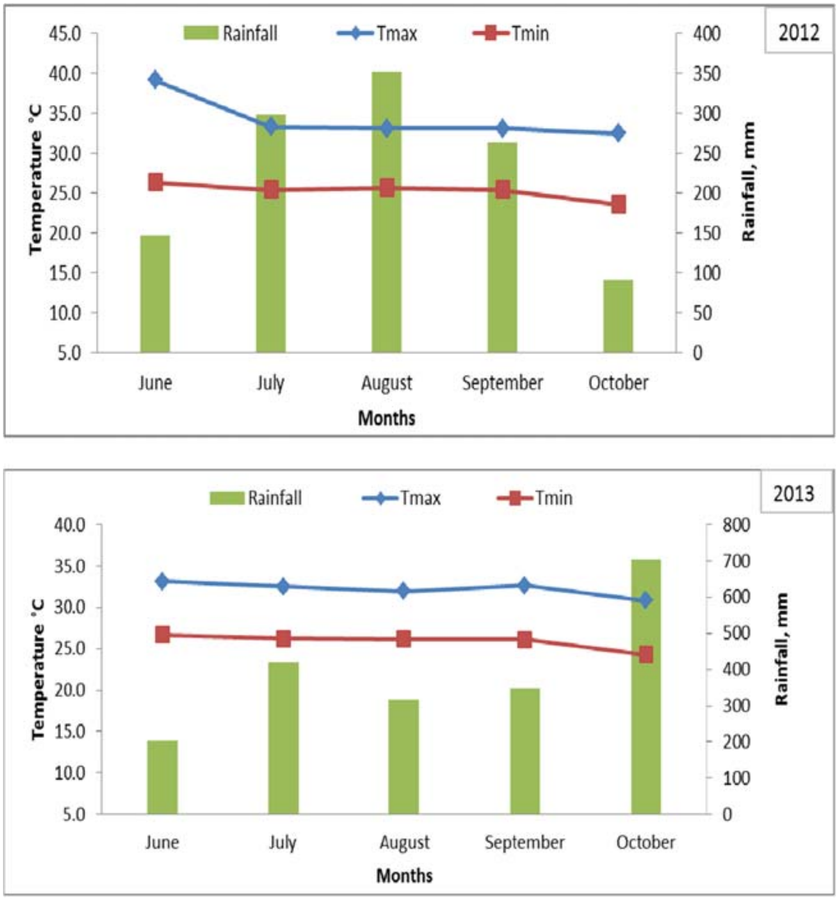


Fig. 1 Monthly total rainfall and average monthly temperature (Tmax and Tmin) during peanut crop growing season (January–May) of 2012 and 2013

Fig. 2 Monthly total rainfall and average monthly temperature (Tmax and Tmin) during rice crop growing season (June–October) of 2012 and 2013



Factor II (fertilization levels): (i) control (no fertilizer), (ii) 100: 50: 50 kg NPK ha^{-1}, (iii) 140: 50: 50 kg NPK ha^{-1}, (iv) 180: 50: 50 kg NPK ha^{-1}

Cultivar details:

Peanut: Peanut cultivar TMV-2 was Spanish, bunch type and non-dormant cultivar, developed at Tindivanum, Tamil Nadu, India. It was a medium duration cultivar (105 to 110 days to maturity). The yield potential of TMV-2 was 3 t ha^{-1} under irrigated conditions. Shelling percentage and oil content were 76.7% and 46.0%.

Rice: IR-36 is a photosensitive, lodging resistant, medium duration (110 to 120 days to maturity), and semi-dwarf cultivar highly resistant to a number of major insect pests and diseases. It was developed at the International Rice Research Institute, Philippines, in 1976. Potential yield of the cultivar was 6 t ha^{-1}.

2.3 Crop growth simulation model

The crop growth simulation model namely Decision Support System for Agrotechnology Transfer (DSSAT) was used for the simulation study. DSSAT is a software package integrating the effects of soil parameters, genetic coefficient, weather parameters, and other management options that allow users to simulate the yield by using experimental data. In this experiment, DSSAT v 4.5 CROPGRO-Peanut and CERES-Rice models were used to simulate the crop yield under climate variability scenario using both the field experiment data and future climate data.

2.4 Model calibration and validation

Model calibration was done by determining the genetic coefficients by minimizing the error between the observed and

Table 1 Genetic coefficients of CROPGRO-Peanut model for cultivar TMV 2

CSDL	PPSEN	EMG-FLW	FLW-FSD	FSD-PHM	WTPSD	SDPDVR	SDEDUR	PODDUR	XFRUIT	THRESH	SDPRO	SDLIP
11.84	0.00	17.40	17.50	64.26	0.440	1.78	26.00	15.00	0.920	78.00	0.270	0.510

Table 2 Evaluation for CROPGRO-peanut simulations for pod yield and aboveground biomass (ADM) at harvest during the calibration and validation

Year	Yield parameters	Obs.	Sim.	r^2	$RMSE_a$ (t ha^{-1})	$RMSE_n$ (%)
2012	*Calibration*					
	Pod yield (t ha^{-1})	2.03	2.07	0.77	0.5	23
	ADM (t ha^{-1})	5.9	5.76	0.76	1.1	18
2013	*Validation*					
	Pod yield (t ha^{-1})	2.03	2.28	0.73	1.2	61
	ADM (t ha^{-1})	4.56	5.39	0.91	3.6	78

simulated values for the particular cultivar. For both the models, the calibration was based on data from end-of-season sampling of yield and yield components of the 2012 field experiment. The genetic coefficients of both the cultivars were derived using the "trial-and-error" method (Hunt et al. 1993) of DSSAT v 4.5. Adjustment was performed to match the observed crop phenology and yield with the simulated values and to make the calibrated genetic coefficient lie within the predefined error limits for both cultivars. Following this method, all coefficients were optimized for further simulation. For calibration of peanut (TMV 2) information for phenological events (anthesis day, first pod day, first seed day), pod yield and aboveground dry matter were used. Similarly for rice (IR 36), the information of phenological phases (panicle initiation day; anthesis day and physiological maturity day) and yield were used.

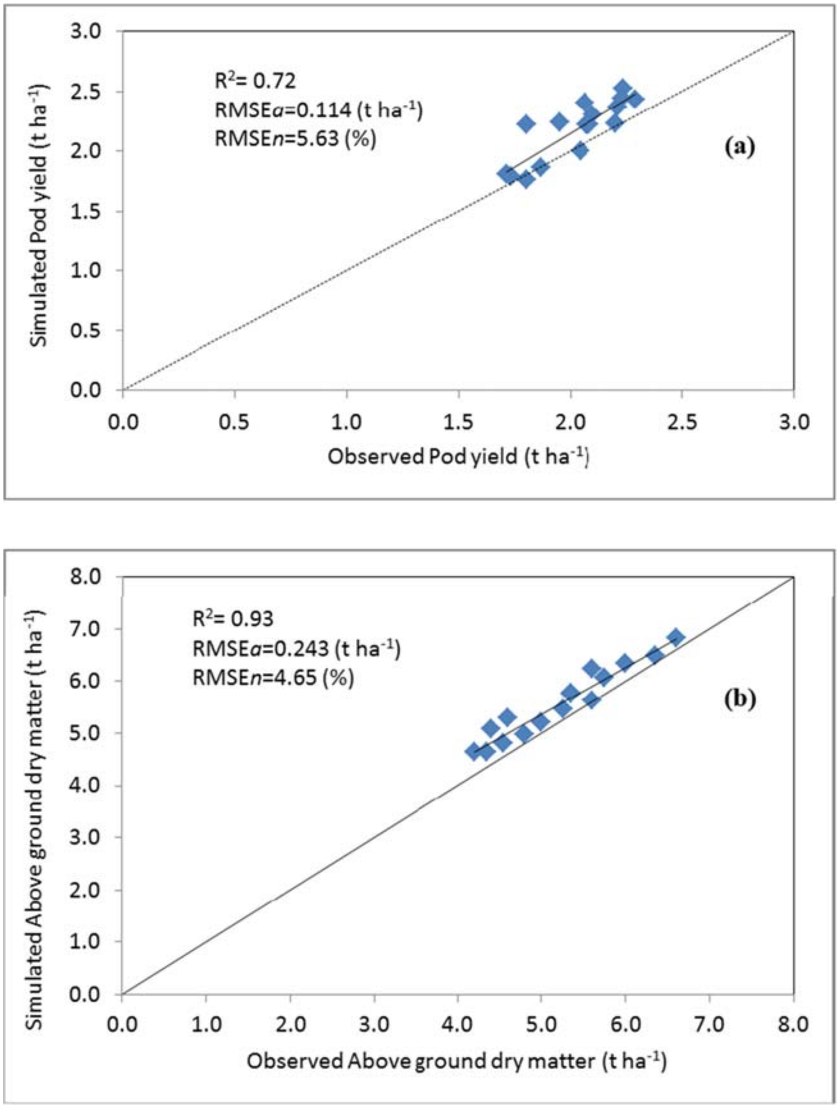


Fig. 3 Evaluation of CROPGRO-Peanut model for final Pod yield and above ground dry matter from 2012 and 2013 dataset

Table 3 Genetic coefficient of rice (IR-36)

P1	P2R	P5	P2O	G1	G2	G3	G4
450.0	50.0	450.0	11.7	65.0	0.0230	1.00	1.00

The model validation was based on the comparison of the statistical parameters of simulated data with that of the observed data. The performances of the CROPGRO-Peanut and CERES-Rice were evaluated using the dataset from the 2013 field experiments. This approach was considered as a true validation of the model, as the model parameters were not calibrated on the basis of the 2013 dataset.

2.5 Analysis of climate change on yield and biomass of peanut and rice

The future weather data of two Representative Concentration Pathways (RCP 4.5 and 8.5) generated using MarkSim@ DSSAT weather file generator (Jones and Thornton 2013) was used for predicting the crop yield for future climate variability scenarios for this location. The RCPs are used for making future climatic projections. The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0), and one scenario with very high GHG emissions (RCP8.5). For all RCP scenarios, at the end of twenty-first century, the global mean temperature is expected to increase over 1.5 °C compared to 1850 to 1900 except for RCP 2.6 and projected to have significant impact on food grain production of developing countries situated in tropical and sub-tropical latitude (IPCC 2013).

The CSIROMk3.6.0 is an Atmosphere-Ocean GCM. The weather data retrieved from the CSIRO-Mk3-6.0 (Collier et al., 2011) model for RCP 4.5 and 8.5 scenarios were used as input to CROPGRO-Peanut and CERES-Rice models for yield simulation at Kharagpur of Eastern India. The crop yield was simulated using future weather data for 2020, 2050, and 2080 under elevated temperature and increase in CO_2 concentration for the location. The change in the future predicted yield was compared with the baseline (1980–2013) yield. The CO_2 levels for base period (1980–2013), 2020, 2050, and 2080 were considered as 380, 420, 480, and 540 ppm, respectively.

Table 4 Simulated and observed phenology and growth of rice cultivar (IR 36) during the calibration (2012) period

Crop Parameter	IR 36	
	Simulated	Observed
Panicle initiation day	31	31
Anthesis day	59	59
Physiological maturity day	87	85
Yield (kg ha^{-1})	2325	3130 (± 569)

2.6 Assessment of best adaptation strategies

Various cropping sequences have been suggested at the farm level as effective adaptation strategy to nullify the effect of climate variability. Among the different adaptation practices, the most usual practices are change in date of planting, cropping sequence, and cultivating high-yielding cultivars which are resistant or tolerant to heat stress (Rosenzweig and Hillel 1998; Ogden and Innes 2008). In this study, the crop yield responses were determined under future climate change scenarios with all the possible combinations of planting dates and fertilization levels along with irrigation schedule as well as stochastic analysis of weather parameters. For peanut and rice, results of stochastic analysis of rainfall revealed the management strategies to be adopted during the future changing scenarios for the study area.

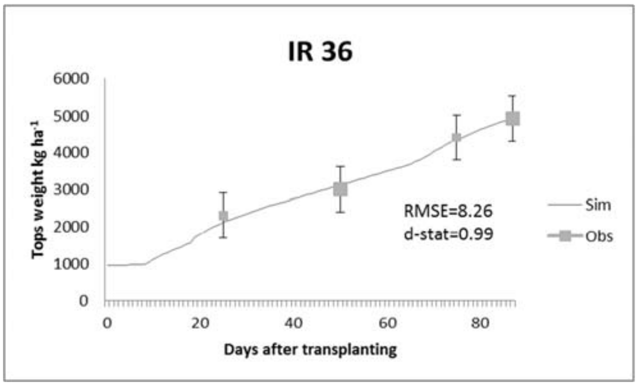


Fig. 4 Observed (Obs) and simulated (Sim) top weight of rice cultivar (IR 36) during the calibration year (2012) at Kharagpur using CERES-Rice model

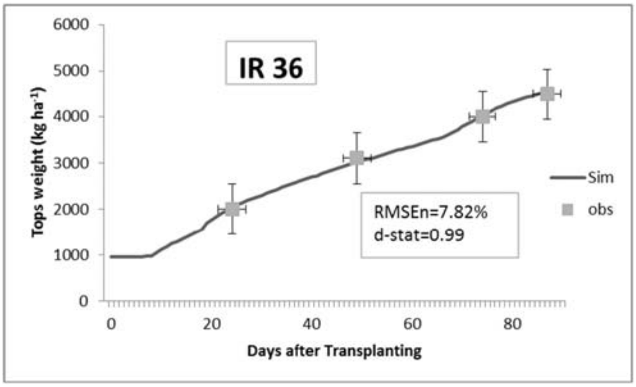


Fig. 5 Observed (Obs) and simulated (Sim) top weight of rice cultivar (IR 36) during the validation year (2013) at Kharagpur using CERES-Rice model

Table 5 Simulated and observed phenology and growth of rice cultivar (IR 36) during the validation (2013) period

Crop Parameter	IR 36	
	Simulated	Observed
Panicle initiation day	32	31
Anthesis day	61	60
Physiological maturity day	88	85
Yield (kg ha^{-1})	2020	2920 (±636)

3 Results and discussion

3.1 Calibration and validation of CERES-Rice and CROPGRO-Peanut models

3.1.1 Peanut

The CROPGRO-Peanut model was calibrated and validated for peanut cultivar "TMV-2" using data of the years 2012 and 2013, respectively. The calibration was performed by determining the genetic coefficients of the peanut (TMV-2) as presented in Table 1. The results presented in Table 2 reveal that RMSEa (t ha^{-1}) values with respect to pod yield (t ha^{-1}) and ADM (t ha^{-1}) were low during calibration and reasonably low during the validation period. On the other hand, the RMSEn (%) value for the same yield parameters was on the lower side during calibration and not quite high during the validation

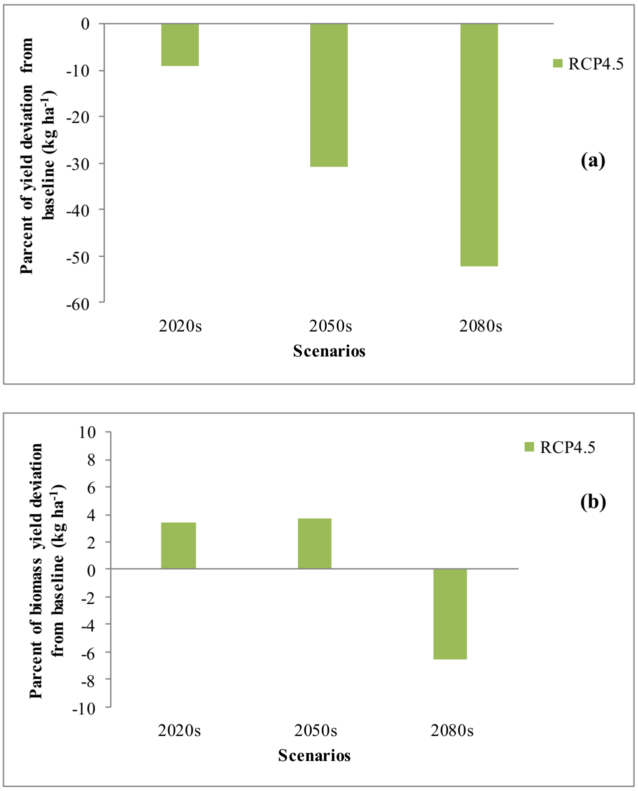


Fig. 7 Average temperature received during rice crop period under different climate change scenarios and planting dates at Kharagpur location

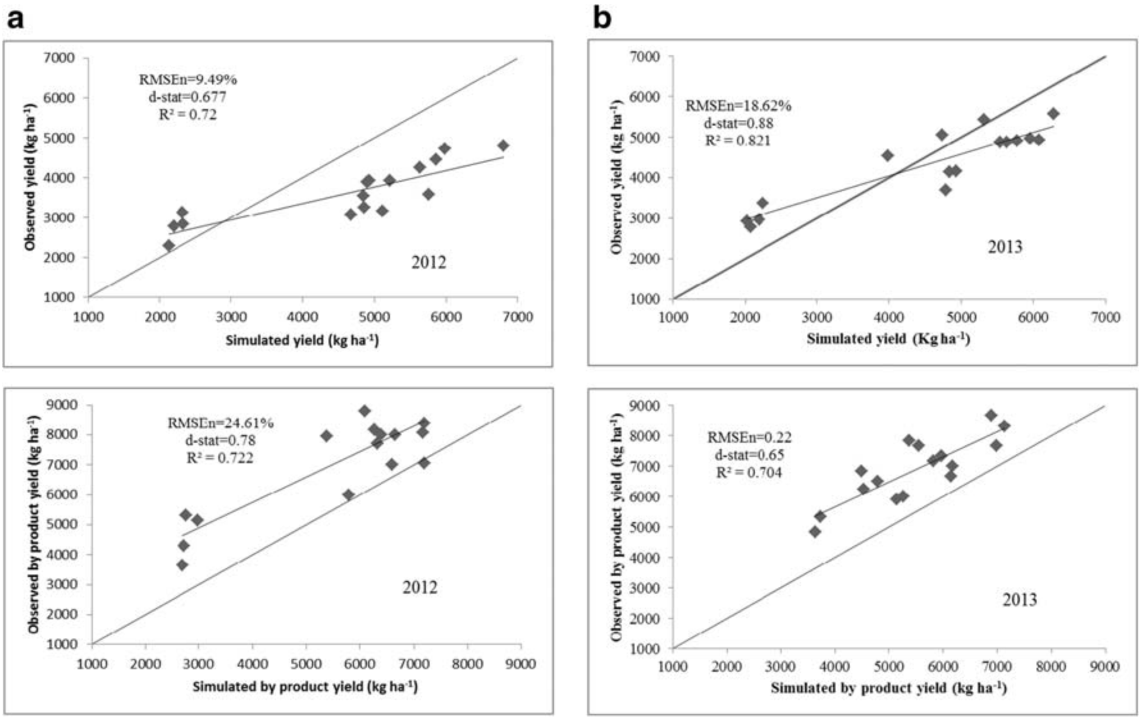


Fig. 6 **a** Simulated verses observed yield and by product yield (kg ha^{-1}) of rice during calibration (2012) period. **b** Simulated verses observed yield and by product yield (kg ha^{-1}) of rice for validation (2013) period

period. The relatively high value of R^2 indicates uniform distribution of data points around the linear line. The model shows quite satisfactory results for pod yield and ADM during calibration and validation period. The comparison between simulated and measured total pod yield and aboveground dry matter with respect to all calibration and validation data are presented in Fig. 3a, b. The $RMSE_a$ was 0.114 t ha^{-1} and $RMSE_n$ was 5.633% for pod yields and $RMSE_a$ of 0.243 t ha^{-1} and $RMSE_n$ 4.655% for aboveground dry matter. These results reveal that the model is able to reasonably simulate pod yield and final biomass for different sowing date and fertilizer combinations reasonably well with low $RMSE_a$ and $RMSE_n$ and $R^2 > 0.7$.

3.1.2 Rice

Unlike the CROPGRO-Peanut model, CERES-Rice model was calibrated and validated for the rice cultivar (IR-36) using the 2-year experiment data. Calibration of rice model was performed for determining the genetic coefficient of the rice cultivar as presented in Table 3. During the calibration period, the RMSE*n* and d-stat values of the simulated and observed top weight were 8.26% and 0.99 (Fig. 4). The observed and simulated values for panicle initiation, anthesis days, and maturity days were in close agreement (± 2 days), and difference between observed and simulated yield value was 8% (Table 4). During validation, there was close match between simulated and observed top weight of IR 36 (RMSE*n* = 7.82% and d-stat = 0.99) cultivar (Fig. 5). The simulated anthesis and maturity days differed from their observed value up to ± 3 days, and the difference between simulated and observed yield was within 9% (Table 5). Figure 6 a and b show comparison between the simulated and measured yield (kg ha^{-1}) and by product yield (kg ha^{-1}) during 2012 and 2013. The $RMSE_n$ of yield were 9.49% and 18.62% and d-stat values were 0.67 and 0.88, during 2012 and 2013,

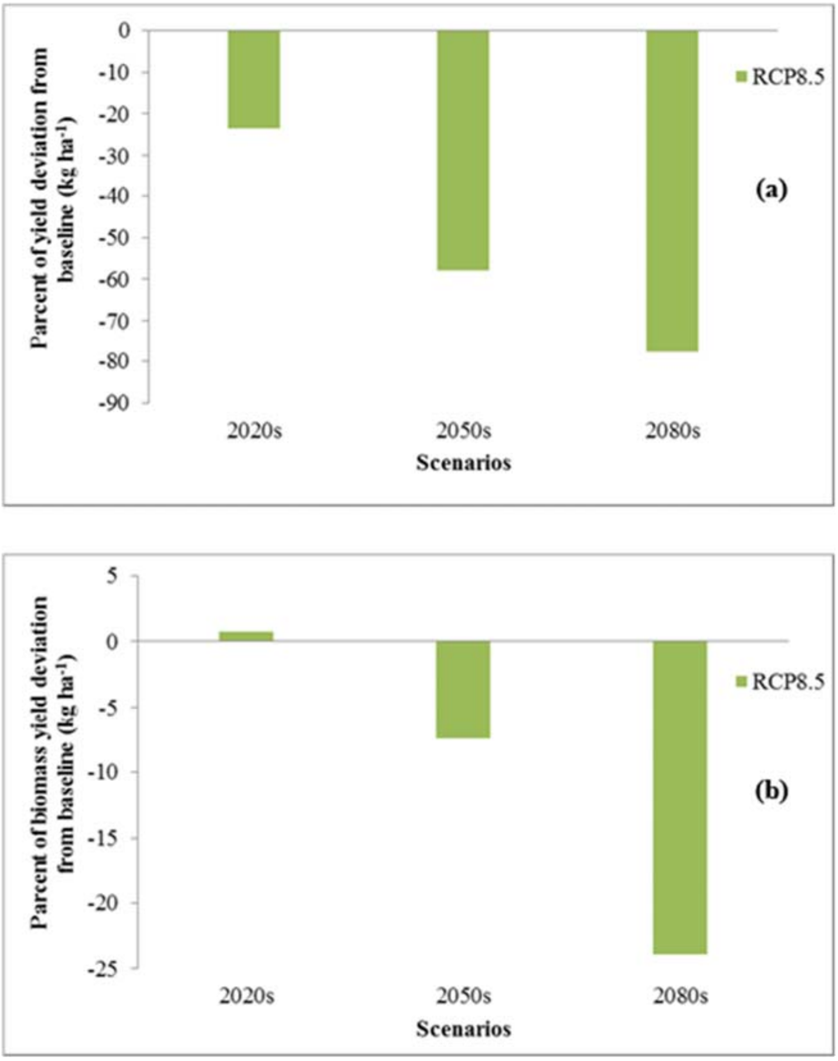


Fig. 8 Percent of deviation in peanut yield (kg ha^{-1}) and total biomass yield during different scenarios from baseline yield under RCP 8.5 with increase in temperature

respectively. The results showed that the model was able to simulate grain yield reasonably well for different sowing dates and fertilizer combinations with $R^2 > 0.7$. Similarly for total biomass, also the $RMSE_n$ were 24.61% and 0.22% and d-stat values were 0.78 and 0.65, during the cropping years. In this case, the R^2 values were more than 0.7, which reveals that the model is able to simulate total biomass reasonably well during the cropping season.

The RMSE value is used to test the agreement between simulated and observed data. A low RMSE value is always desirable. In contrast, the $RMSE_n$ value measures the relative difference between simulated and observed values (Wallach and Goffinet 1987). A simulation is considered excellent if the $RMSE_n$ value is < 10%: good if $20 < RMSE_n > 10$, and fair if $30 < RMSE_n > 20$ (Boote et al. 1988). This result shows that the model performed well in simulating crop yield and total biomass yield with a wide range of sowing date and fertilizer combinations.

3.2 Impact of climate variability on grain yield and total biomass in peanut and rice

3.2.1 Effect of rising temperature on pod yield and biomass yield of peanut

Peanut (var. TMV-2) yield was simulated for base period weather (1980–2013) and future periods of 2020s, 2050s, and 2080s under RCP 4.5 and 8.5 scenarios (CSIROMk3.6.0 model) for the location. In the base period, maximum peanut yield was simulated during the base period, whereas lowest yield simulated during 2080s at Kharagpur. The yield of the peanut declined from the base period (1980–2013) to 2020s, 2050s, and 2080s under RCP 4.5 and 8.5 scenarios of climate change (Figs. 7 and 8). Under RCP 4.5 scenario, the change in yield of peanut from baseline period was −9.04%, −30.98, and −52.24%, with the increase in temperature (Fig. 7a). Under RCP 8.5 scenario, the percentage of change in peanut yield from the baseline period was −23.52%, −57.95%, and −77.67% (Fig. 8a). However, under

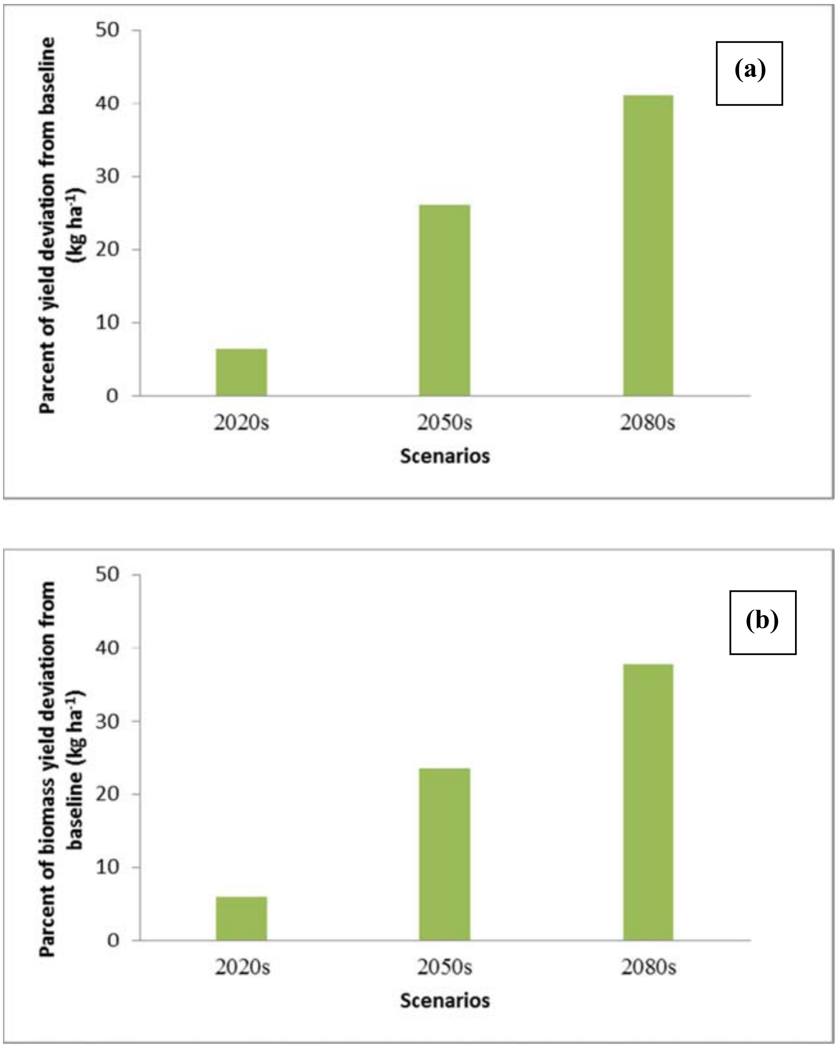


Fig. 9 Percentage of deviation in future peanut pod yield (kg ha^{-1}) and biomass yield (kg ha^{-1}) from baseline yield with changes in CO_2 concentrations

RCP 4.5, the percentage of change in biomass yield increased during 2020s and 2050, but decreases simultaneously during 2080, from the baseline yield (Fig. 7b). During the RCP 8.5, percentage of change in biomass yield was slightly increased during 2020, but then it decreased by − 6 to − 25% during 2050 and 2080 scenario, respectively (Fig. 8b).

During the simulation study, the average temperature during reproductive growth of peanut was found to be 29.8 °C during base period, which was higher by 2.1, 3.1, and 3.9 °C for 2020, 2050, and 2080 scenarios, respectively. Optimum temperature (22 to 24 °C) for reproductive growth becomes higher (25 and 30 °C) during vegetative growth of peanut, then it can lead to significant yield loss in peanut (Prasad et al. 2003). The results of the above study revealed that rising temperature showed negative effect on the growth and developmental phases of crop and brings the flowering to begin much early. Simultaneously, the temperature increase may cause pollen sterility and poor pollen growth resulting in reduction of yield during reproductive growth stage. Moreover, higher temperature reduces the duration of reproductive phase and thus prevents the pod from reaching their actual size (Halder et al., 2015a).

3.2.2 Effect of increasing CO_2 concentration on pod and biomass yield of peanut

The results presented in Fig. 9a, b reveals that the pod yield increased gradually from the baseline yield with the elevation in CO_2 concentration and delay in sowing dates during 2020, 2050, and 2080 scenario. The increase in pod yield was highest 41.24% during 2080 scenario followed by 26.00% during 2050 and 6.35% during 2020 scenario. With the elevated CO_2 concentration during 2020, 2050, and 2080, the biomass yield also increases from the baseline period (Fig. 9a, b). The increase of biomass yield from 5.90%, 23.43%, and 37.67% was obtained during 2020, 2050, and 2080 scenarios, respectively. The increased concentration of CO_2 affects the growth and yield of peanut by increasing the rate of photosynthesis and reducing stomatal conductance. As a result of that more carbon and biomass, accumulation occurs

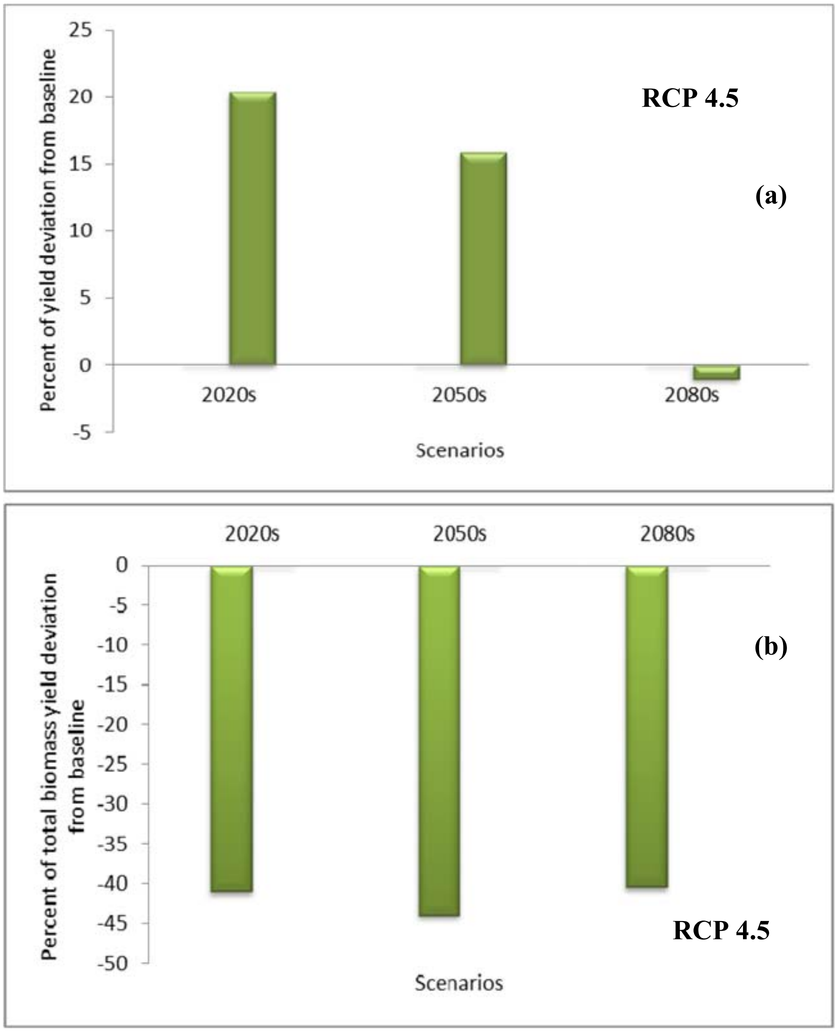


Fig. 10 Percent of deviation in rice yield (kg ha^{-1}) and total biomass yield during different scenarios from baseline yield under RCP 4.5 with increase in temperature

and simultaneously, reduction in stomatal conductance leads to less transpiration and low soil moisture depletion (Halder et al., 2015b). Rajwade et al. (2015) reported higher aboveground biomass at 2080 scenario. Similar results were reported by Bannayan et al. (2009), which revealed that the above ground biomass/total biomass production in peanut increases with increase in CO_2 level independent of temperature regime.

3.2.3 Effect of temperature on grain yield and total biomass in rice

The impact of temperature variability on yield of rice showed that the yield increased considerably for future scenarios (2020s, 2050s, and 2080s) given by IPCC RCP 4.5 and 8.5 in the study area (Figs. 10a and 11a). The yield projections using the simulation model showed that the grain yield will increase in a decreasing rate during 2020 and 2050 and subsequently during 2080s and gradual decrease in total biomass yield during 2020, 2050, and 2080 scenarios during the RCP 4.5. The decline in yield for rice was 1.01% during 2080, whereas in case of total biomass yield, the decreases were 41.01%, 44.02%, and 40.43% for 2020, 2050, and 2080 scenarios, respectively (Fig. 10a). Similarly, under RCP 8.5, it was found that the yield of rice increased gradually whereas the total biomass yield declined in the future scenarios (Fig. 11a). The percent of yield increases was 20.24%, 15.89%, and 19.14% and the percent of decrease of the total biomass yield was 40.92%, 44.02%, and 41.67% during 2020, 2050, and 2080 scenarios, respectively. Rice is highly sensitive to increase in temperature. The simulation results showed that the crop yields under the rising temperature were affected severely under both the RCPs (RCP 4.5 and RCP 8.5).

The rice yield was noted to increase significantly from the baseline yield varying from 15.89 to 20.38% during 2020 to 2080 scenarios. However, the decrease in total biomass yield under RCP 4.5 and 8.5 was the highest during 2050 (Figs. 10b

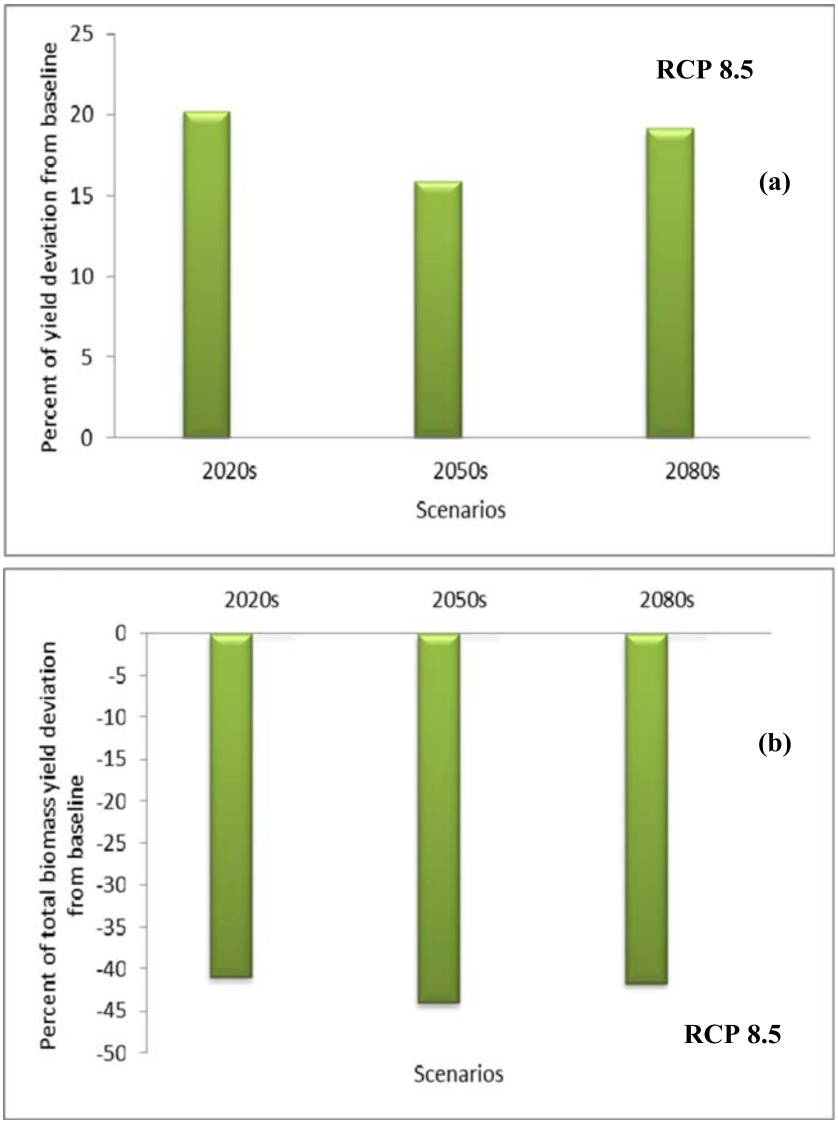


Fig. 11 Percent of deviation in rice yield (kg ha^{-1}) and total biomass yield during different scenarios from baseline yield under RCP 8.5 with increase in temperature

and 11b). The impacts of elevated CO_2 and temperature on irrigated rice yield was studied in eastern India by Krishnan et al. (2007), using ORYZAI and InfoCrop-rice models. The result of the study shows that increased CO_2 concentration can increase the rice yield, as higher temperature causes sterility of rice spikelet. Rice grain yield would decline by 10% for each 1 °C increase in the minimum temperature above 32 °C, as increase in minimum temperature increases respiration losses during the vegetative phase (Pathak et al. 2003; Peng et al. 1994, 2004) and simultaneously reduces the duration of grain filling stage and cell size during the maturity stage (Morita et al. 2005).

In 2020, the yield of rice will be reduced by 7 to 10% as compared to 2050 and 2080, where the reduction will be 11 to 15% and 13 to 21%, respectively (Ramachandran et al. 2017). Their results also showed that C3 and C4 crop yield will be decreased under the RCP 4.5 scenario. This would affect the local food security as well as livelihood security. Therefore, appropriate planning for sustainable crop production and livelihood security is essential. Simultaneously, appropriate adaptations and policy making are necessary for obtaining sustainable crop productivity in the future scenarios.

3.2.4 Effect of CO_2 concentration on grain yield and total biomass in rice

Results represented in Fig. 12 show that the rice yield would gradually increase (34 to 35%) with the increase in CO_2 concentration from 420 to 530 ppm and 650 ppm against the baseline yield under different scenarios namely 2020, 2050, and 2080. An increase in CO_2 concentration usually increases photosynthesis in crops, especially C3 crops. In spite of this, the increase in temperature and variability of rainfall would affect food production considerably. On the other hand, the total biomass yield would decrease by 37 to 39% with the elevation of CO_2 concentration viz. 420 ppm, 530 ppm, and 650 ppm during the future climate variability scenarios (Fig. 12). However, the total

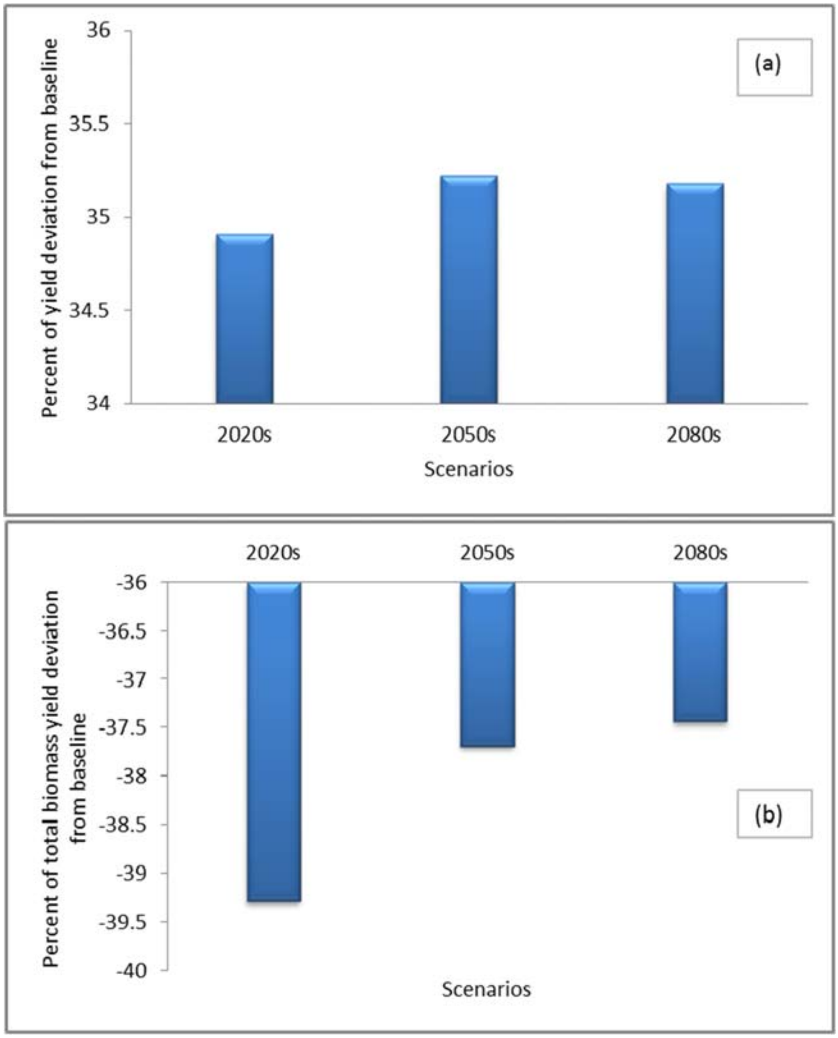
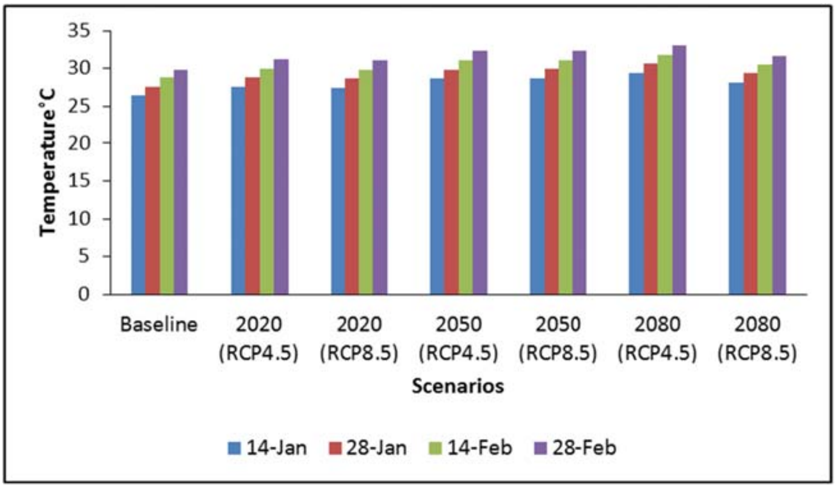


Fig. 12 Percentage of deviation in future rice yield (kg ha^{-1}) total biomass yield (kg ha^{-1}) from baseline yield with changes in CO_2 concentrations

Fig. 13 Average temperature during peanut growing period under different climate change scenarios and planting dates at Kharagpur



biomass yield would deviate maximum during 2020 with the CO_2 concentration of 420 ppm and gradually decrease with the increase of CO_2 concentration up to 650 ppm from the baseline byproduct yield. The yields of major field crops could be increased by 10 ± 20% with an increase in CO_2 concentration to 550 ppm. The yields of wheat, soybean, mustard, groundnut, and potato may get reduced by 3 ± 7% with the 1 °C increase in temperature (Aggarwal, 2008). An increase in temperature reduces the water availability (Gosain et al. 2011) and would be crucial for Indian agriculture. The global warming is mainly caused due to the increase in CO_2 concentration, which may decrease stomatal conductance and improve the water use efficiency through reducing transpiration (Morison and Gifford, 1983) and reduction of the photorespiration, which promote photosynthetic capacity, and thus increase the dry matter production. This would help for the biomass production in C3 plants (Imai, 1988; Sakaigaichi et al. 2004). It was seen that the crop productivity increases with rising temperature; however, increase in temperature beyond the optimal range reduces the productivity. High temperatures during flowering cause sterile spikelet and reduce the yield (Kim et al. 1996a,b). In India, crop production would decline by 10–40% with increase in temperature by 2080–2100 (Aggarwal, 2008). On the other hand, increased CO_2 concentration can increase the rice yield with more sterile spikelet of rice at higher temperature (Krishnan et al. (2007).

3.3 Adaptation strategies to climate variability

Appropriate management strategies are needs to be adapted not only to minimize the negative effect of climate variability, but also to sustain the development of agricultural production under changing scenario. The simple adaptation strategies namely advancing or delay in planting time, appropriate fertilization of major and secondary plant nutrients, and selection of high-yielding or heat-tolerant cultivars etc. would mitigate the potential impact of climate variability (Attri and Rathore, 2003).

Fig. 14 Amount of rainfall recorded and predicted during peanut growing period under different climate change scenarios and planting dates at Kharagpur (Total rainy days during baseline: 44, 2020s: 17; 2050s: 19; 2080s: 19)

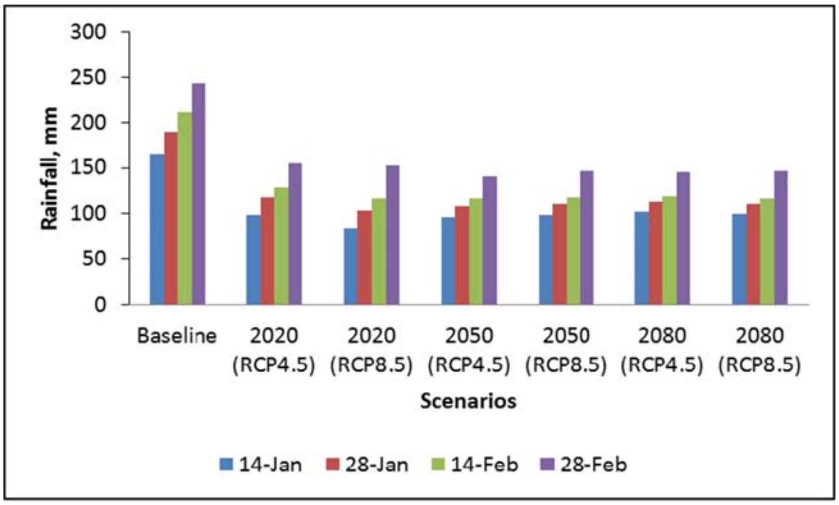
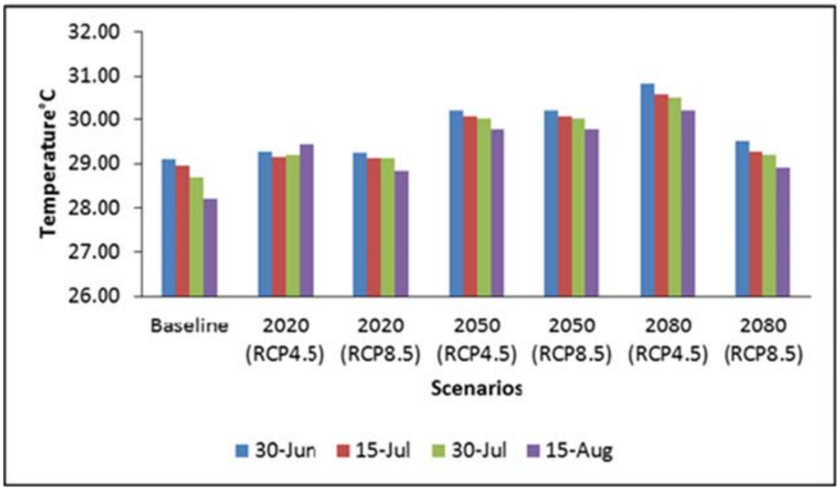


Fig. 15 Average temperature during rice growing period under different climate change scenarios and planting dates at Kharagpur

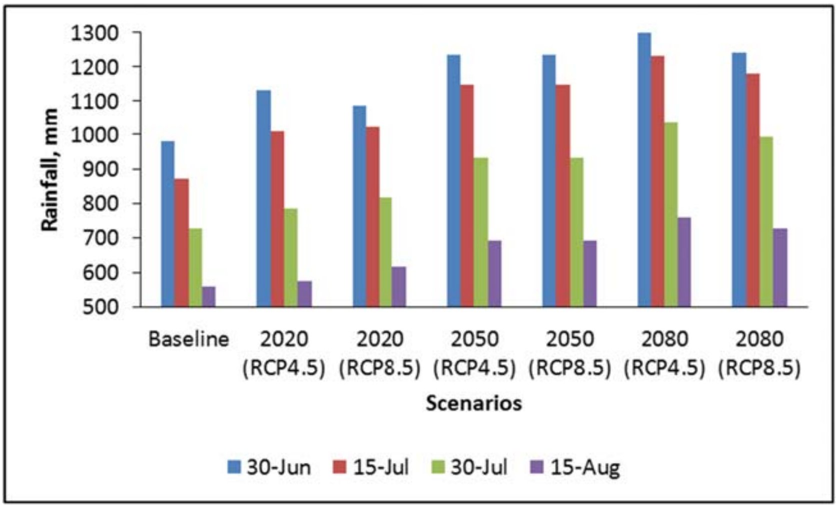


In addition to these, changes in the cropping sequence, irrigation, and agriculture land use can be adopted as alternative option.

In the present study, the changing of planting or sowing date as well as appropriate water management is being considered for peanut and rice crop for this region as an adaptation measure to combat the variability conditions of future climate scenarios. For peanut crop, the temperature in the range of 28–30 °C is optimum for plant development (Prasad et al. 2009) along with well-distributed rainfall of at least 500–600 mm during the crop-growing season, accompanied by an abundance of sunshine and relatively warm temperature provides favorable climate for peanut cultivation. From Fig. 13, it can be depicted that for all the sowing dates, the available temperature is with the range of optimum temperature during the baseline period as well as in future scenarios. But, when we consider the rainfall, it can be revealed from Fig. 14 that during the baseline and future climate scenarios, the rainfall was recorded below the required amount. However, peanut can be grown in regions receiving higher (800 mm) or lower (350 mm) rainfall. Therefore, irrigation scheduling must be done to meet up the water requirement of the crop throughout the growing period. Irrigation requirement for light textured soil is 600–700 mm of water (about 10 irrigations) and medium- to heavy-textured soil 500–600 mm (6–7 irrigation). In this study, the experimental site has light-textured sandy loamy soil which requires more water for good crop growth and higher yield. But the rainfall analysis shows that lesser amount of rainfall will be available during the future scenarios. Therefore, it can be concluded that under limited water condition, irrigation scheduling must be done considering the 50% maximum allowable depletion (MAD) of available soil water for peanut crop to achieve the maximum yield (Halder and Panda, 2014).

The study result shows that the average temperature during the baseline and in future scenarios is within the range at the time of rice growing period (Fig. 15). The recorded and predicted rainfall during the growing period shows that rainfall is decreasing with delay in planting dates (Fig. 16). Among the four planting dates, 15 August planting date shows very less

Fig. 16 Amount of rainfall recorded and predicted during rice growing period under different climate change scenarios and planting dates at Kharagpur (Total rainy days during baseline: 113, 2020s: 109; 2050s: 114; 2080s: 114)



rainfall during the baseline period as well as future scenarios. Planting on or after 15 August may expose the crop to shorter photoperiod during the grain filling stage which will ultimately effects the grain yield. In our study, the analysis of probability of withdrawal of rainfall shows high chances of withdrawal during the 45–46 SMW coinciding with the grain filling stage with 15 August planting. In the case of rice, the optimum temperature required is 20–35 °C (Yoshida 1981) with 1200–1400 mm of rainfall (Rajwade et al., 2015). Therefore, planting on or after 15 August may cause potential yield loss. However, the consecutive wet week analysis of our study shows that during the 25th to 39th SMW, the probability of getting different magnitude of rainfall is $> 50\%$. So, crop planted between 30 June and 30 July will get the required amount of rainfall during the critical growth stage. Thus, from our study, it is revealed that harvesting of excess runoff water is needed for supplemental irrigation in future dry period (Halder et al. 2016).

4 Conclusion

Variability in the yield of peanut and rice crop is due to change in weather parameters. The crop yield is expected to get affected under future climate scenarios with rising temperature and CO_2 concentration as well as availability of rainfall. The stochastic analysis reveals that irrigation scheduling must be done under limited water condition considering 50% maximum allowable depletion (MAD) of available soil water for peanut crop to achieve maximum yield. However, analysis of rainfall data during rice growing season suggests that harvesting of excess runoff water is needed for supplemental irrigation during future scenario to provide required amount of water during critical growth stages. The peanut pod yield will decline (−) 9.04 to (−) 77.67% from the base period with the increase in temperature. However, the effect of future climate variability was favorable for peanut biomass yield. Elevated CO_2 concentration will gradually increase in the pod yield and biomass yield for peanut crop. Grain yield of rice will be increased by 15.89 to 20.24% during the future scenarios from base period, whereas the total biomass yield will be decreased by 40.92 to 44.02% with elevated temperature during future scenarios. Though the grain yield increases gradually, the rice biomass yield would reduce in future climate variability scenario as revealed from the model simulation. Study also shows that early planting increases peanut and rice crop yield under future climate scenarios due to availability of favorable temperature during critical growth phases (flowering to maturity) and help them to escape from vulnerable rising temperature or shortfall of precipitation. Hence, appropriate agronomic management strategy in terms of advanced planting of peanut and rice is expected to combat the adverse effect of climate variability on growth and yield of both the crops.

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