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Simulating impacts of climate changes on rice yields

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Background

- Global concern about the adverse effects of changing climate on agricultural productivity is raising. Simulation analysis by using different models has shown that increasing CO_2 concentration in the atmosphere has a positive effect on crop biomass production, but its net effect on rice yield also depends on the rising of the temperature.

- Thus an assessment of the potential impacts of increasing CO_2 levels and temperature on rice productivity is essential.

Materials and Methods

- This study was under taken to assess the impact of climate change on rice yield using ORYZA2000 model.
- The model was validated with the experimental data in NUIST in 2011. The input data including soil condition and weather data were also taken from the experiment.
- ORYZA2000 can be modified with new values of selected parameters in the file named “RERUN.DAT”.

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TMCTB=0.,-1.9713,
      366.,-1.9713
CO2=412.0678
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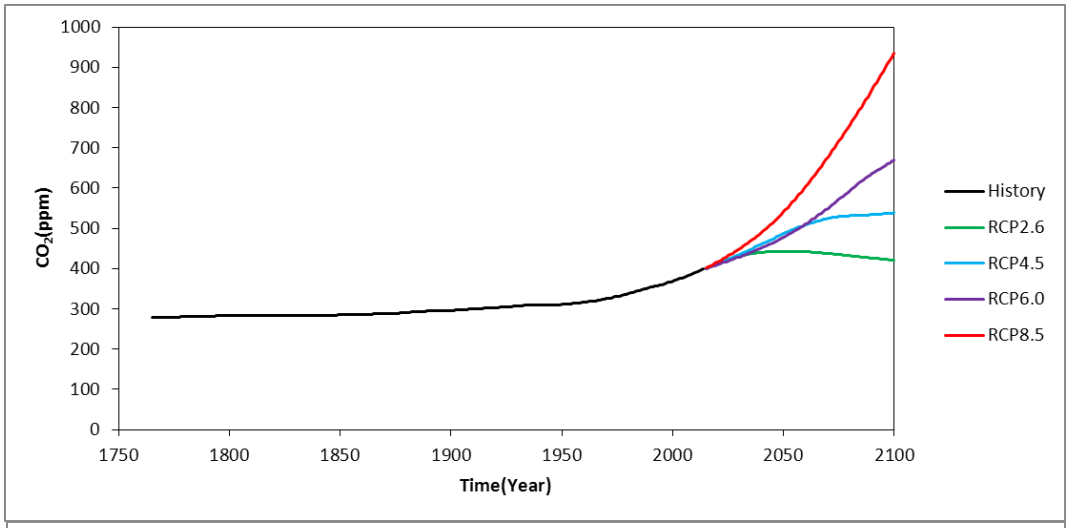
Materials and Methods

- The Representative Concentration Pathway (RCP) scenarios for temperature and CO_2 emissions from Coupled Model Intercomparison Project 5 (CMIP5).

- By using the model and raising the temperature to 35 ℃, 38 ℃ and 41 ℃ for 3, 5 and 7 consecutive days from booting to flowering stages, a simulation of high temperature impact on rice yield was carried out.

Results

a.



b.

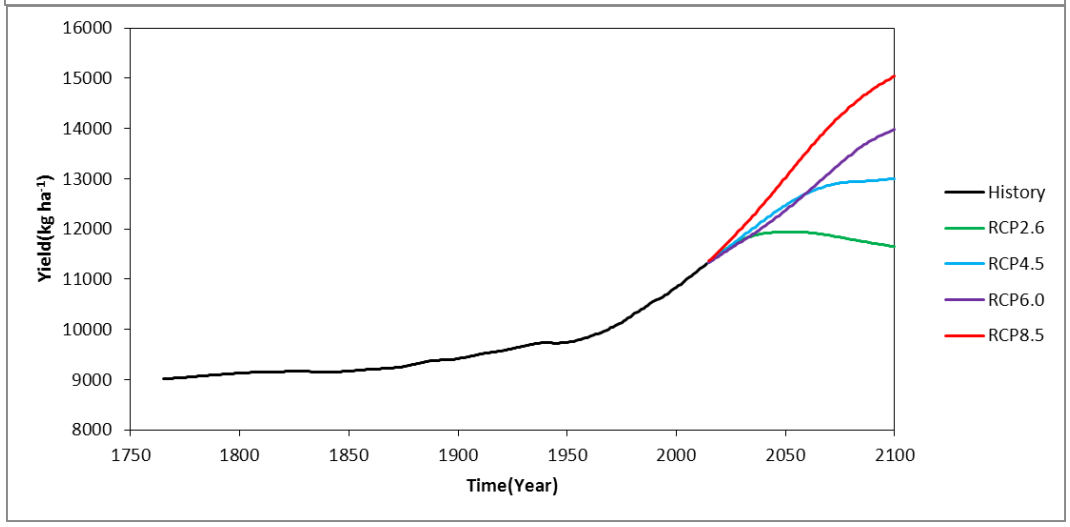


Figure 1. CO_2 concentration (a) and simulating yield in different CO_2 concentration (b) .

Results

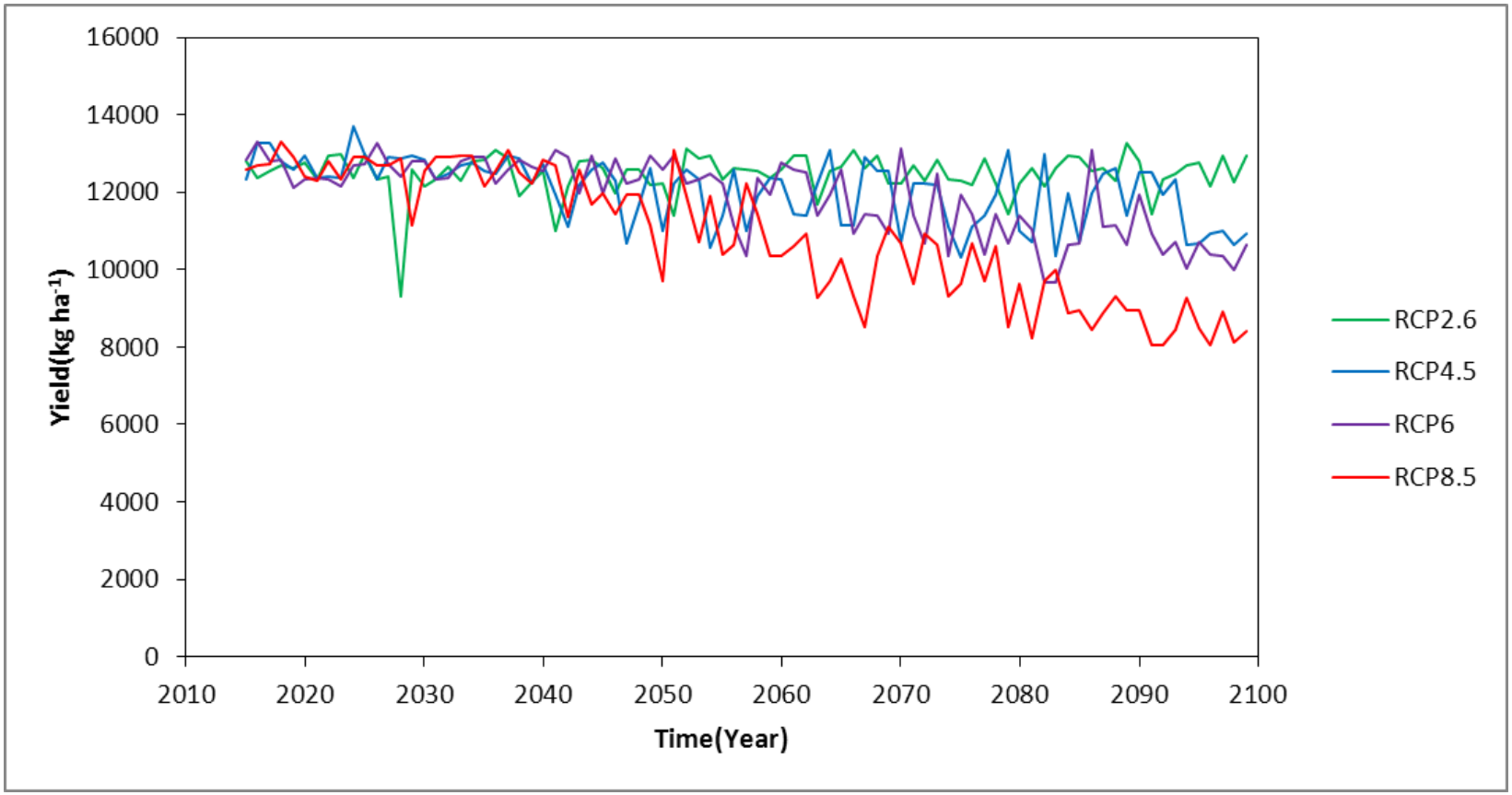
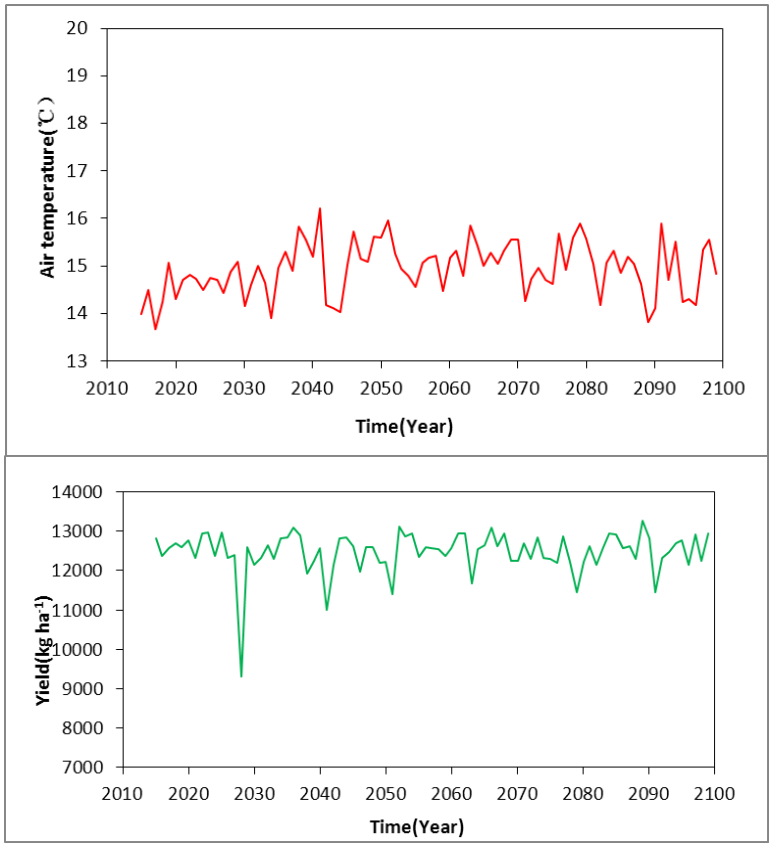


Figure 2. Simulating yield in different temperature scenarios.

Results

a.



b.

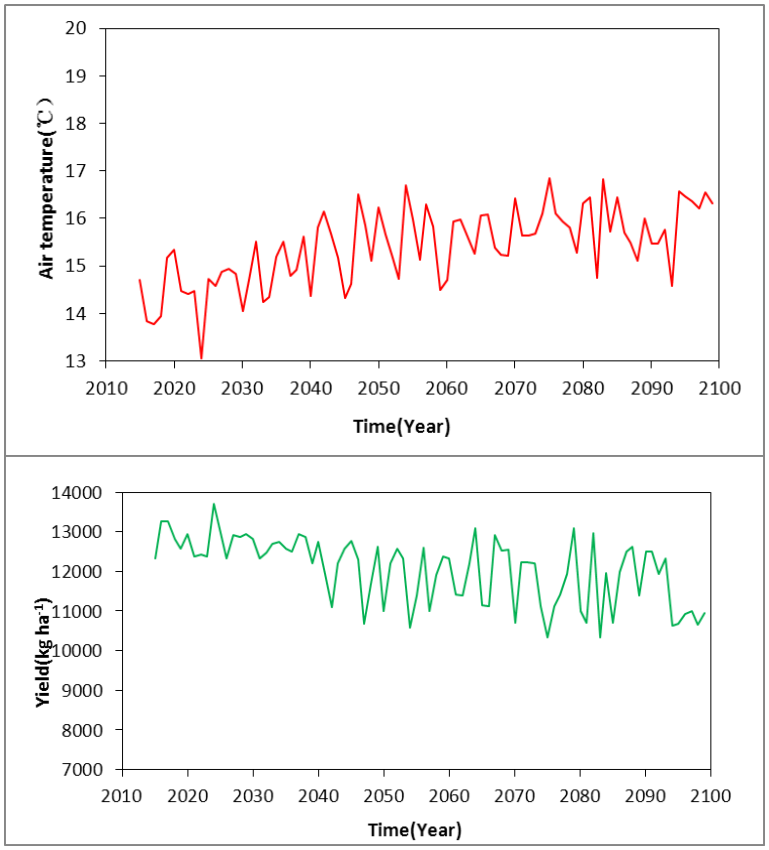
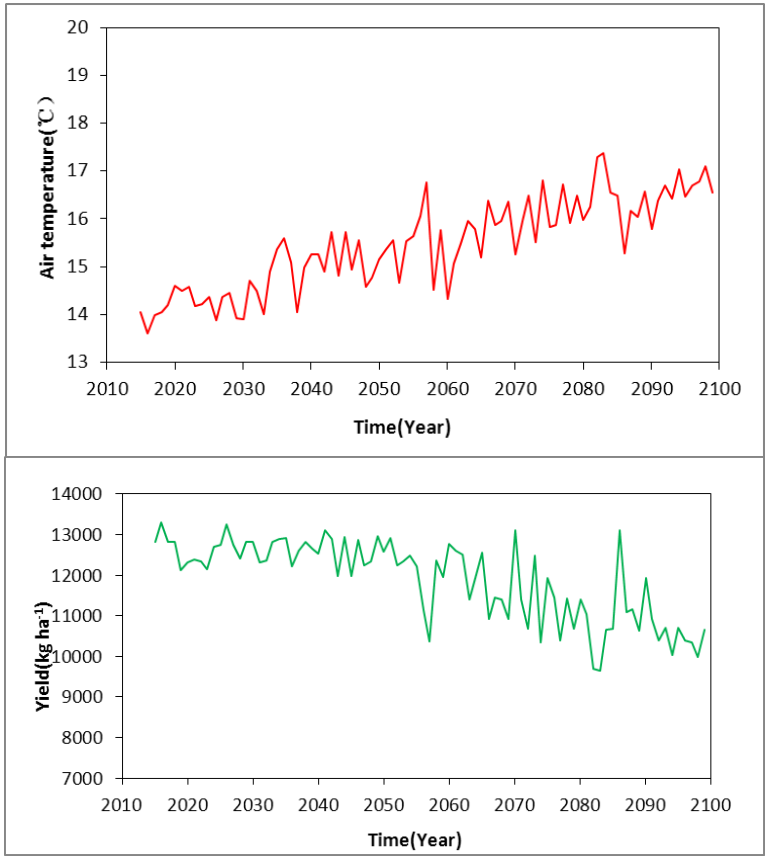


Figure 3. Temperature (red) and simulating yield (green) in RCP2.6 (a) and RCP4.5 (b).

Results

a.



b.

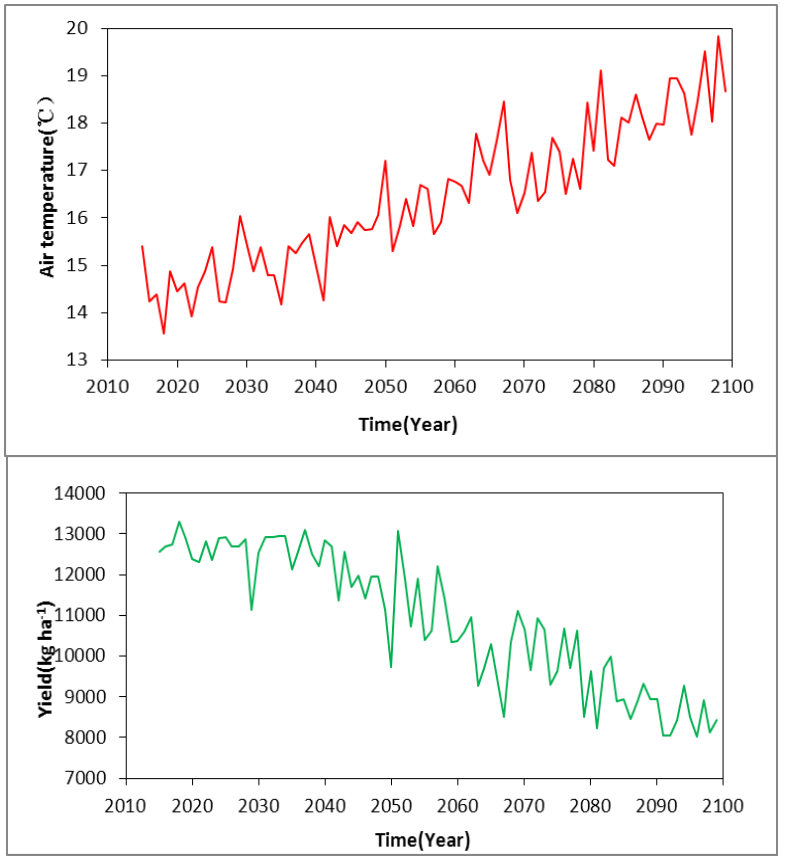


Figure 4. Temperature (red) and simulating yield (green) in RCP6.0 (a) and RCP8.5 (b).

Results

Table 1. Simulating yield change relative to yield in 2011.

Time(Year)	RCP2.6	RCP4.5	RCP6	RCP8.5
2020	15.84%	17.34%	11.76%	12.46%
2030	10.25%	16.41%	16.28%	13.83%
2040	13.99%	15.59%	13.69%	16.60%
2050	10.84%	-0.23%	14.15%	-11.80%
2060	14.06%	11.88%	15.77%	-5.96%
2070	11.07%	-2.80%	18.95%	-3.26%
2080	11.00%	-0.17%	3.38%	-12.54%
2090	16.28%	13.43%	8.31%	-18.80%

Results

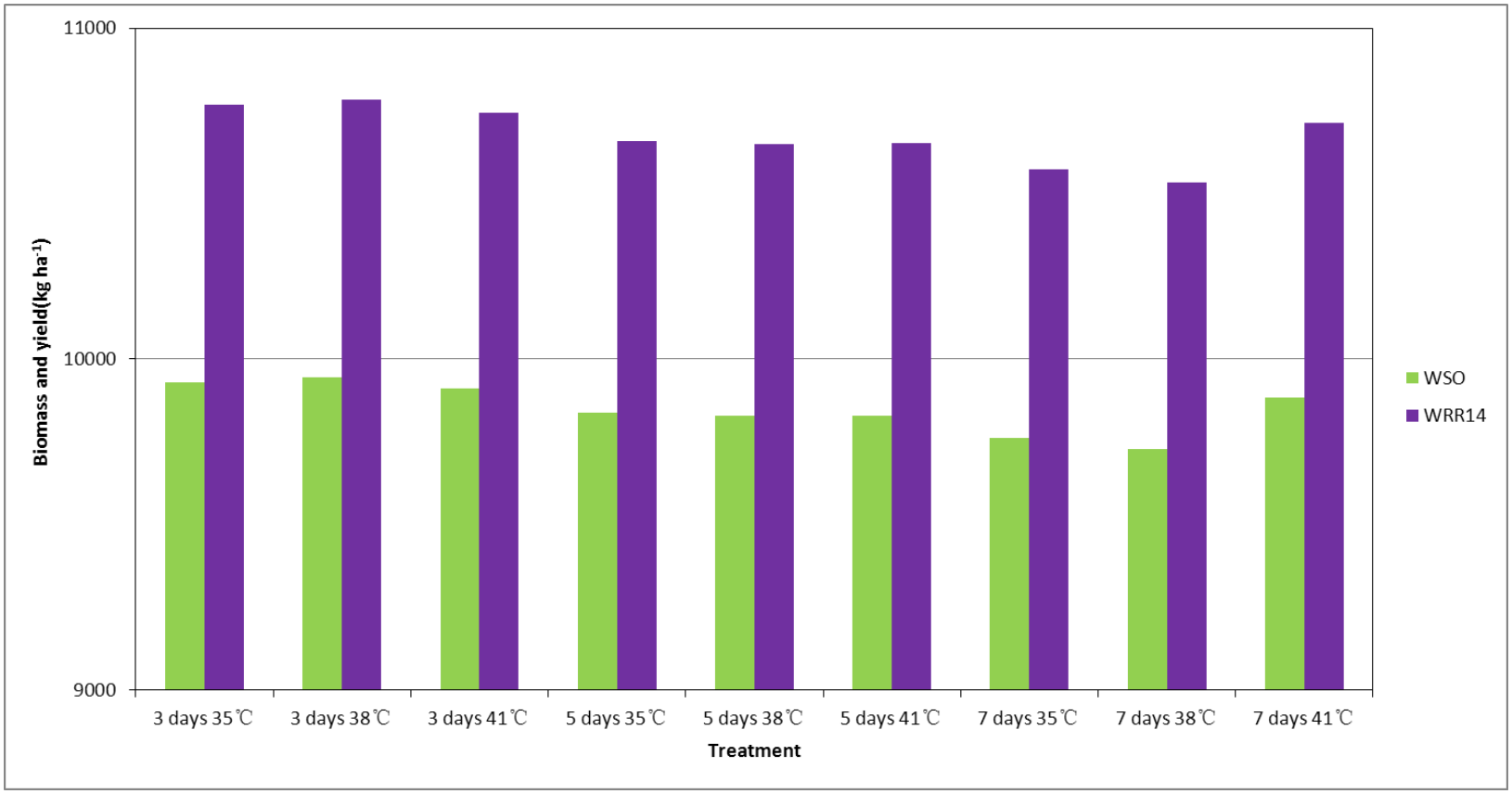


Figure 5. Simulation of high temperature impact on rice yield.

Results

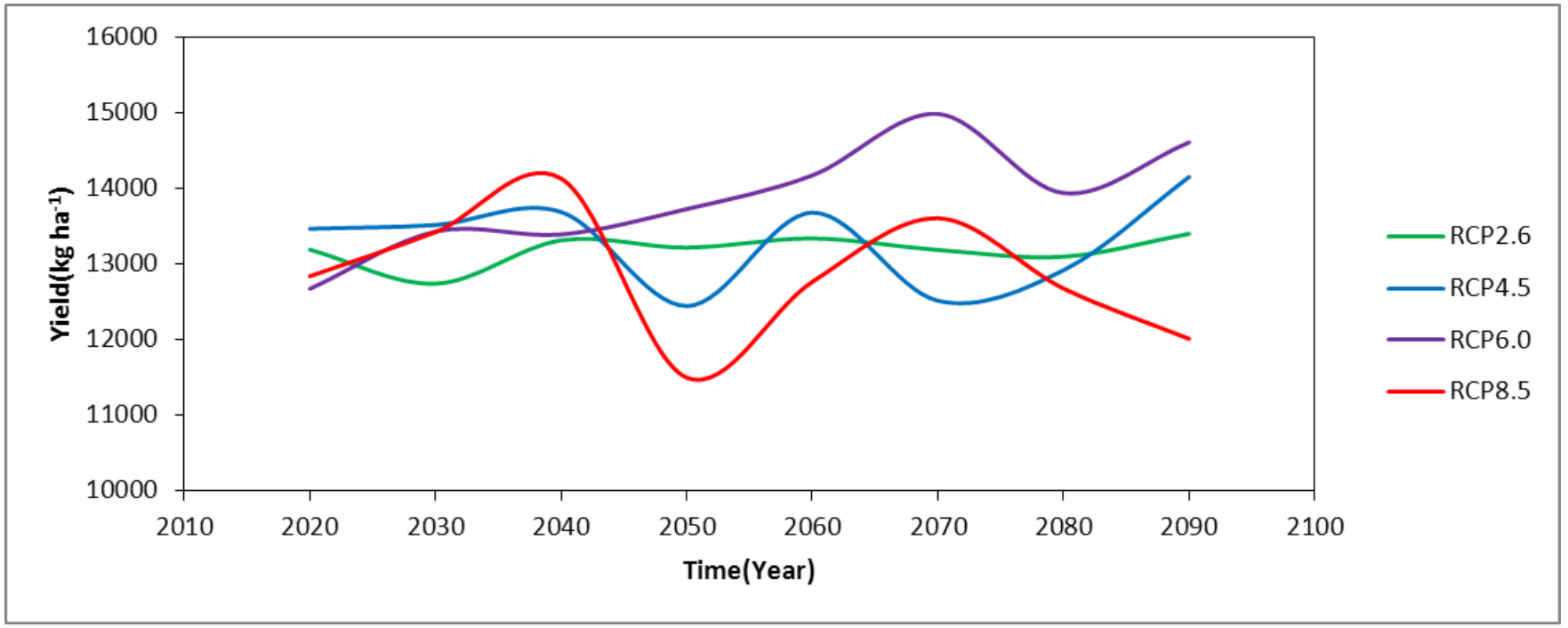


Figure 6. Simulating impacts of both CO_2 and temperature.

Results

Table 2. Simulating yield change of both CO_2 and temperature.

Time	RCP2.6	RCP4.5	RCP6.0	RCP8.5
2020	18.03%	20.50%	13.40%	14.89%
2030	14.01%	20.95%	20.17%	20.12%
2040	19.14%	22.49%	19.83%	26.45%
2050	18.28%	11.37%	22.84%	2.90%
2060	19.36%	22.42%	26.81%	14.22%
2070	18.01%	11.99%	34.09%	21.75%
2080	17.20%	15.59%	24.74%	13.44%
2090	19.91%	26.63%	30.73%	7.49%

Sensitivity test of temperature

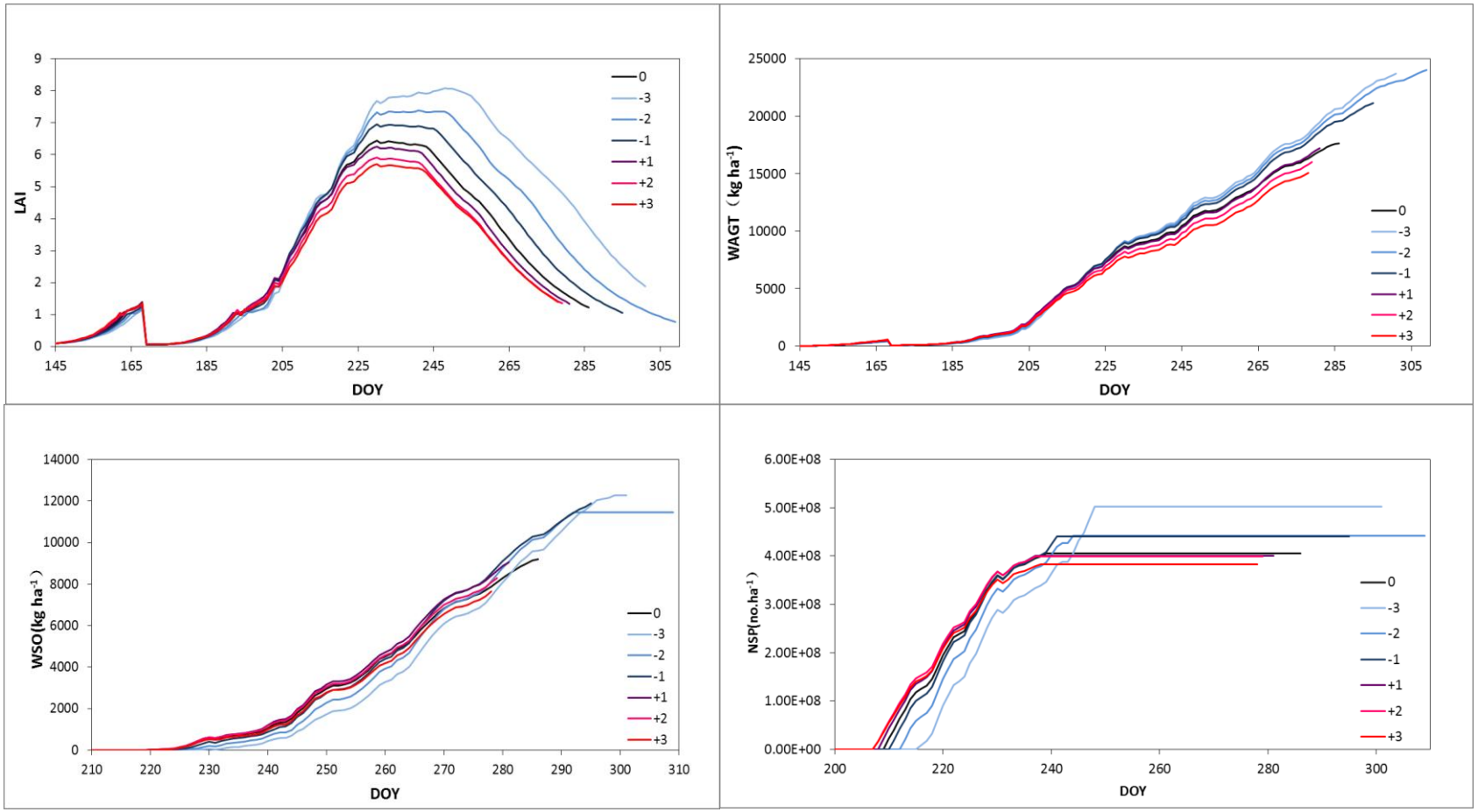


Figure 7. Temperature impacts on leaf area index, total aboveground dry matter, dry weight of storage organs and number of spikelets.

Sensitivity test of temperature

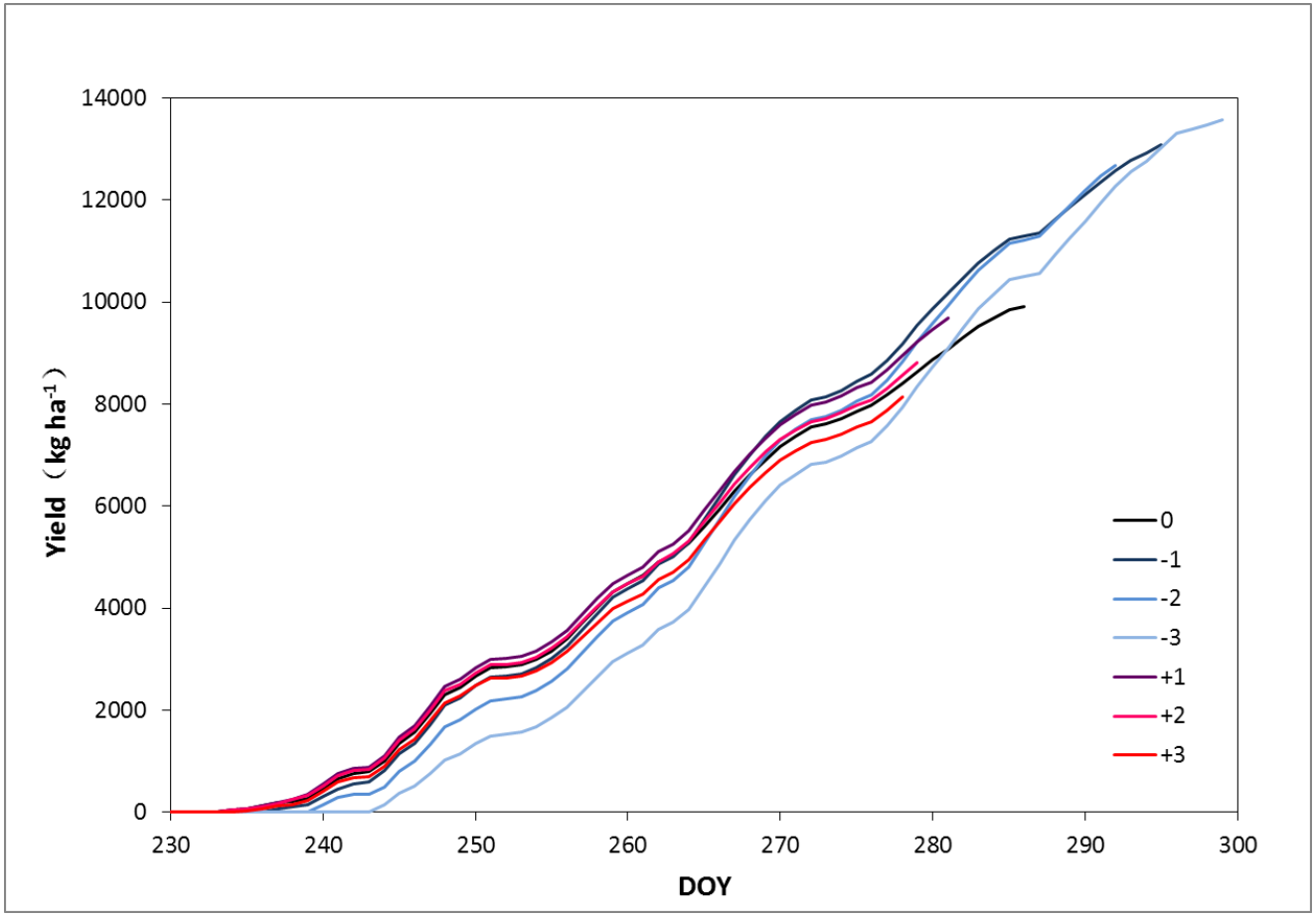


Figure 8. Temperature impacts on final yield.

Conclusions and discussion

- Increasing atmospheric CO_2 concentration has beneficial effects on rice production without change in temperature. Therefore, simulating yield in RCP8.5 is the highest.

- Because the CO_2 concentration doesn't reach the CO_2 saturation point. And higher CO_2 concentration can restrict the respiration of rice.

- But its net effect on rice yield also depends on the rising of the temperature.

Conclusions and discussion

- Generally, higher temperature has negative effects on yield. The total biomass and final yield showed decreasing trend when temperature was raised to 35 ℃, 38 ℃ and 41 ℃ for 3, 5 and 7 consecutive days.
- The increasing temperature at flowering inhibits swelling of the pollen grains which is the driving force behind anther dehiscence and therefore high temperature would induce spikelet sterility and increase in instability of the rice yield.
- Simulating impacts of both CO_2 and temperature indicated that RCP6.0 have most positive impact on rice yield. But it is not convincing enough using the data at the interval of 10 years.

Conclusions and discussion

- In sensitivity test, leaf area index, total aboveground dry matter, dry weight of storage organs and number of spikelets all decreased with increasing temperature.

- From booting stage, the difference of yield factor among different temperature showed increasing trend.

- For final yield, lower temperature induce longer growth period and higher yield. Increasing temperature decreased the yield and shorten the growth period.

Next work

- Test the sensitivity of weather data.
- Try to modify the diffuse radiation, find simulated radiation data in CMIP5 or other climate model, and simulate impacts of radiation on rice yield.
- To enrich my research, it is necessary to find another model which simulates rice or wheat.

Thank you