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Effects Of Climate Change On Maize Yield (*Zea Mays L.*) In Hebei Province Of China

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Abstract

Maize is one of major crop in Hebei province in northeast China which is under threat for yield instability due to climate change effects. Previous studies argued on the significance of the impact of climate change on maize yield variability. We used weather data from 2000 to 2010 then we simulated predictive maize yields under regional PRECIS A2 and B2 scenario using Maize Production Emulation System (MPES). Our results projected that, the LAI , for the same field there is different LAI and ET Significant upward trend in the growth of maize during the average temperature rise high amplitude were 0.07°C/year and 0.067 °C reached to the significant level with $P \leq 5\%$ *r=0.64**, r=0.58** . The maize yield change up to 20% change is expected due to rain increase amount, but this change will fail down by 2050s and even serious around 2070s in most simulated sites in Hebei province.*

Keywords: Climate Change, Maize Yield, Regional Scale, PRECIS scenario, Hebei Province China.

1. Introduction

Maize (*Zea mays L.*) is one of the most important feed crops in China and it is also one of the main crops in Huang-Hai-Plain (HHP) china including Hebei province. For example HHP, known as the “bread basket” of China (World Bank, 2002), has only 7.7% of national water resources, yet it produces 39.2% of national grain supply and 32.4% of gross domestic product (Tian, 2006). Thus, the ability to meet future demand may hinge on proper assessment of medium- and long-term agricultural vulnerability to climate change and the measures taken to adapt accordingly (Lin, 1996).

The decline of the productivity in this area continues to be a major concern to policy makers due to its impact on food security (Liu, et al. 2012). At national and regional scale, differences in climate projections often have larger influence on changes in crop yields. How significant these changes in climate affect maize yield and food security?

Previous studies showed different views on the significance of the impact of climate change on maize yield. Fulu Tao et al. (2009) demonstrated that for all maize cultivation grids across Henan province China, the maize yield changes based on super ensemble simulations with 60% probability maize yield s could decrease by 8.4% by 2020 and 13.3% by 2050 under A1F1 scenario and 18.1% under B1 scenario.

Allison et al. 2006 showed in the study of climate change impacts on agriculture in Huang-Hai Plain (HHP) that, the specific development under scenario A2 or B2 did not significantly alter the sequestration crop potential of the region but future precipitation increases simulated would prove beneficial to both crop yields and soil organic matter.

Chi-Chung Chen et al. (1999) investigated on the yield variability influenced by climate change has an interesting positive impact, so this might have been achieved at the expense of increased yields risk confirming work by Anderson and Hazel. More rainfall causes maize yield level to rise, while decreasing yield variance. Temperature has the reverse effect on maize yield levels and variance.

Some other results have shown by Meng Wang et al., (2011) that, using uncertainties of the future climate change projection, the maize yield in Jilin province China is highly likely to decline in western and central regions of the province but increases in the east part. The average maize yield in west and central regions is projected to decrease 15% or more by 2050 and around 30% in 2070 under A2 and B2 scenarios respectively. David B. Lobell and Marshall B. Burke (2010) used CERES to show that with +2°C increase on temperature, the maize yield loss is between 11.4% and 12.7%.

However, Liming Ye et al, (2012) carried out some research on the same area. Their results predict that food crop yield will increase from+3% to 11% under A2 and +4% under B2 scenarios by 2030 and 2050 respectively. The maize yield in northeast China is projected to respond negatively to climate change the 2015 under SRES A2 scenario but overall, the maize yield is projected to increase at 0.2-0.3% per year at national scale during period 2011-2040 under A2 scenario and the yield change of 10% in 2040 under B2. Their demonstrated that their results showed largely positive effects of climate change on crop yield in China. This could be the hope for the maize yield increase.

Zhijuan Liu et al. (2012) have presented that within Northeast China (NEC) maize yields were, on average, only 51% of the potential yields including a large exploitable gap, which provides an opportunity to significantly increase production by effective irrigation, fertilization and planting density. However in the past 30 years, the time from sowing to maturity has increased, including that farmers adapted new hybrids varieties. The adoption of longer season hybrids would contribute to the yield increases. This show that the new varieties role in the adaption to the climate change in term to expect maize yield increase.

Some other studies on climate change impact on maize yield at national or regional scale showed very interesting results. Chi-Chung Chen et al. (1999) ; Bruce A. McCarl and David E. (1999); Allison et al.(2006); Fulu Tao et al., (2009); David B. Lobell and Marshall B. Burke; Meng Wang et al. (2011) affirm in their result that there is significant worries about maize yields. All these, using different methods and different IPCC scenarios describe the maize yield loss due to the climate change effects.

At the other side, some other research argues on this idea. For example Liming Ye et al. (2012) used Food Security Index (FSI) to demonstrate that their results show largely positive effect of climate change on crop yield in China. ZhiJuan Liu et al. (2012) show that climate change is no longer a worry by using the good farm management (new varieties, planting density etc.).

The argument between two sides is a challenge because of uncertainty of the climate change issues. We propose to examine this problem using MPES simulation model to simulate the impact of the change in rain and temperature under regional PRECIS A2 and B2 scenarios. It is an additional view to the existing results.

This research examines the impact of climate change on maize yield in Hebei province China. We use Maize Production Emulation System (MPES) model, Li Shijuan and Yeping Zhu (2008) to simulate maize yield variability under regional climate change scale then compare the result to the observed maize yield.

The objectives of this work are focusing on the evaluation of the performance of the MPES for simulating maize growth, development and yield under climate change conditions with the climate drivers (Temperature, Rain); the identification of the impact of the local climate change on the maize yield variability; the prediction of the future maize yield under PRECIS A2 and B2 climate scenarios and the display of different thematic map using GIS.

2. Material and Methods

2.1 Study area

In this study, 9 simulation sets in different 9 counties (*Quzhou; shenzhou; xinji; ningjin; zhengding; qingxian; dahe; luanxian and huailai*) from 2000 to 2010 located in 7 different cities(*Handan; Hengshui; Shijiazhuang; Xingtai; Cangzhou; Tangshan and Zhangjiakou*) of Hebei province China(36° 01'to 42° 37' North and113°31 to 119°53East), Figure.1. Hebei province has a continental monsoon climate, with cold, dry winters, and hot, humid summers. Temperatures average −16 to −3 °C in January and 20 to 27 °C in July; the annual precipitation ranges from 400 to 800 mm, concentrated heavily in summer. The main annual temperature is between11-13°C.

2.2 MPES model description

The MPES model is a computer software system serving field experiment and simulation of the intelligent agriculture laboratory of the Chinese academy of agricultural sciences. MPES is issued from the CERES-maize model adapted on the cropping situation in Northern China, Li Shijuan and Zhu Yeping (2007). MPES integrated many technologies such as system theory, simulation; artificial intelligent; visualization and network technology, Yan Ding-Chun et al., (2007).

This MPES model can provide plant management mean and decision making information after processing computer simulation. Basic parameter database consists of the information about location, fertilizer type and management, irrigation management, cultivation variety, phenology data, soil texture and soil parameter, among which phenology data; also the water content before sowing, and organic matter percent, volume weight, NH4-N, NO3-N and PH of every soil layer, Li Shijuan and Zhu Yeping (2008). This model can simulate the effects of cultivars, sowing date and density, solar radiation, air temperature, rainfall, soil moisture, and nitrogen on crop growth, development and yield. Simulating the crop yield according to the weather drivers such as Temperature, Sun radiation and Precipitation, and then forecasting the maximum yield is one of the important functions of MPES, Yeping Zhu and Zhang Jian Bin (2001).

2.3 Data collection

In this study, 9 meteorological stations in Hebei province china were selected from the weather stations operated by the National Meteorological Networks of China Meteorological Administration. 9 simulation sites across Hebei province were selected based on 10 years (2000-2010) length data. In each simulation site, we used the nearest meteorological data where maize growth and yield observed information are available. Hence, we used 4 of the 10 stations were used in all the 9 sites for the model calibration and validation by utilizing available phenological and climate data Table 1.

The soil parameters and cultivars were obtained from database of the institute of soil fertilizer of Hebei province’s academy of agricultural sciences, Zhao Tong-ke et al., (2001). Soil nutrient in 2007 with reference to the location in samples depth (0-100cm); bulk density 1.26-1.4g/cm3); PH (5.8-8.83); NH4+_N and N03-_N, organic matter (OM). The cultivar using in this work are the *zhenda958* and *nongda108* the maize varieties adapted to the Hebei Province’s environment, Table 2. The monthly mean sun radiation was from NASA website http://power.larc.nasa.gov/cgi-bin/cgiwrap/solar/agro.cgi?email=agroclim@larc.nasa.gov . The mean temperature range during the growing period is between 26.8°C and 23.7°C, the maximum temperature range is between 41.1°C and 39.2°C and the minimum temperature 15.9°C and 11.9° . The future climate scenario using in this work is PRECIS A2 and B2 scenario from Inter-governmental Panel of Climate Change (IPCC).This future climate is generated using WGEN based on 2000-2010 baseline Hebei Province weather data Figure2.

2.2 Research Method

A three-step approach has been developed in this research. First, we collected weather, soil, crop, and management data from 4 different meteorological stations of the China Meteorological Administration and the solar radiation from NASA as well as the historical observed maize yield from the Chinese statistical book year. Secondly we inputted weather data into the MPES model after checking its sensibility to weather drivers (Temperature (0%, ±20%), Rain (0%; ±20%)) and simulated the maize yield relative to each under the same soil parameters. After the simulation, we compared the maize yield simulated using correlation *r* and RMSE with the observed yield. Thirdly, we simulated the future yield according to the PRECIS A2 and B2 scenarios and the predictive maize yield relative to the predict climate display using GIS at provincial scale.

2.4.2 Data Analysis

This research used the Time-series to define to relation between the yield and climate factors relation (1) Nathaniel Beck (2006) and Lence (2009), which can be seen as (2) Saha, Schumway and Talpaz (1994). The difference between two yields at the same site at different period as shown in (3) as maximum likelihood error, Saha, Havenner and Talpaz (1997); David E. Schimmelpfennig et al., (1999).The Pearson correlation coefficient *r*; RMSE was calculated as shown in relation (4).

We analyzed the spatial and temporal maize yield change, evapotranspiration (ET) and leaf area index (LAI) using ANOVA for SAS version 8.0 and SigmaPlot version 11.0 as well as different results graphics under PRECIS A2 and B2 scenarios. And then the ArcGis software version 9.3 is used to show the different maps display of the results.

(1) $\text{Log } y_t = \beta_0+\beta_1 T_t + \beta_2 P_t + \varepsilon_t$ Where y_t, T_t, P_t represent respectively in year t yield, growing average temperature, and growing period total precipitation, $\beta_{0\text{-}2}$ represent model parameters to be fit and ε_t is an error, t=1……T .

The (1) can be written as below:

(2) $y_t = f(T_t, P_t)\exp\varepsilon_t$ Where y is a maize yield, f (a) represents an production function, and $\exp\varepsilon_t$ represents an error.

Suppose that the variable of interest, yi,t has a representation as a stochastic first-order auto-regressive process for region i and time period t, demonstrated by Im, Pesaran, and Shin(1997, 2003 and 2005) propose as a series of unit root test statistics in dynamic heterogeneous panels based on individual Dickey-Fuller, David E. Schimmelpfennig et al., (2007), regressions as equation (3) using the Maximum Likelihood Error

(3) $\Delta y_{i,t}=\alpha_i+\beta_i X_{i,t-1} +\varepsilon_{i,t}\ ; \quad i=1,\ldots\ldots,N\ ;\ t=1,\ldots.,T$

Where $\boldsymbol{\Delta y_{i,t} = y_{i,t} - y_{i,t-1}}$ is the variation of the yield simulated at i simulation site at year t, $X_{i,t}$ represents the weather factors (Temperature, Rain) β is the MPES model parameter and ε represents error. And the RSME calculations were obtained using the following relation. The root mean square error is defined by the relation (4).

$$(4)\quad RMSE = \sqrt{\frac{\sum_{i=1}^{n}(Y_{obs,i} - Y_{model,i})^2}{n}},$$

Where $\boldsymbol{Y_{obs,i}}$ and $\boldsymbol{Y_{model,i}}$ represent respectively the yield observed and simulated at site *i*.

3. Results and Discussion

3.1 MPES model calibration

Maize Production Emulation System (MPES) was used by Li Shijuan and Zhu Yeping in 2008, to show that using actual experiment data under deferent water conditions in 1996 and 1997 in Hebei province, we calibrated and validated Maize Production Emulation System based on cooperative models. Our results indicated the system has good prediction performance and strong applicability. The RMSE of yield and biomass predicted by system were 426.3kg/ha, 477.5kg/hm^2 and 1029.8 kg/ha, 1356.0 kg/ha respectively. The relative RMSE were 6.78%, 5.55% and 7.60%, 7.50%, all less than 10%.

The maize varieties using in this simulation are *nongda 108* and *zhengda958*. The initial parameters in the first simulation with 10% change the results show different with relative RMSE gap of 546.5Kg/ha in Luanxian and the smallest 42.72Kg/ha in Shenzhou . For different cultivars with new parameters including the grain per plant per hectare but the harvest time difference is no significant.

3.2. MPES sensibility to weather

The maize yield changes according to the high temperature and low temperature change and with an additional rain during the 2000-2010 growth periods. The LAI indicated that, for the same field there is different LAI and ET Significant upward trend in the growth of maize during the average temperature rise high amplitude were 0.07°C/year and 0.067 °C reached to the significant level with $P \leq 5\%$ (r=0.6421**, r=0.576**) the graphics show in different site across the study area in Figure3a.

3.3 Climate Change effects on maize yield

3.3.1 Rain impact under PRECIS A2 and B2 scenario

The annual rain in this study is between 627 and 461 mm per year, this amount is mostly during the maize growing season from late may to September. There is significant change in the maize growth due to the change in the rain as it's shown by We noticed with the change of 20% in rain, the yield change as well in all simulation sites. Figure3b.

3.3.2 Temperature impact under PRECIS A2 and B2 scenario

The temperature is around 40°C as a maximum and 39°C as a minimum in the different selected meteorological stations but during the growing period, the maximum is about 30°C to 35°C. With an additional degree on the usual temperature, the ET changed as shown by the figure. It shown that the change in the yields is no significant, about -5% to 2% change in yield in the grain per plant and the late harvest time in north part (Huailai, Luanxian) and early in the south (Qingxian, Quzhou, Shenzhou and Ningjin) and center (Xinji, Luquan and Zhengding) Figure3c.

3.3.3 Temperature and Rain impact under PRECIS A2 and B2 scenario

In all simulation sites, the combination of the change under A2 and B2, showed yield trends in 2020s, 2050s and 2070s.There is serious decrease in yield in the 2070s scenario due to high additional rain (17%) and Temperature (4.5°C) for A2 scenario and the B2 scenario Table3. This trend will affect seriously the crop production thus the food security by the end of the century.

However there is no significant difference between the yield trends under A2 and B2 in most of the sites during 2020s.

4. Conclusion

The maize yield is in threat under PRECIS A2 and B2 scenarios. We noticed that the elevated in temperature contributed to the variation in the harvest period. There is not significant change in maize yield due to temperature. The rain is a key factor in the growing system. In fact there is serious change in the yield due rain variation in all simulation sites as shown in the results.

The argument on the impact of climate change on crop production whether the yield will increase or decrease depending on the position and the soil fertilizer uptake is no longer in debate. All information we have now notify clearly the crop will be in threat due to environmental change. To insure the under increasing maize production in Hebei Province Chine farmer should improve the sustainable management techniques focusing on cultivars improvement and the efficient fertilizer application otherwise water and soil degradation will speed up then the total agriculture's environment in danger.

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List of Figures and Tables

Experiment Site	Soil Depth (cm)	Bulk Density (g/cm3)	Water content(w/w)%	pH	NH4+_N (mg/kg)	NO3-_N (mg/kg)	OM (g/kg)	Soil Type	Maize varieties

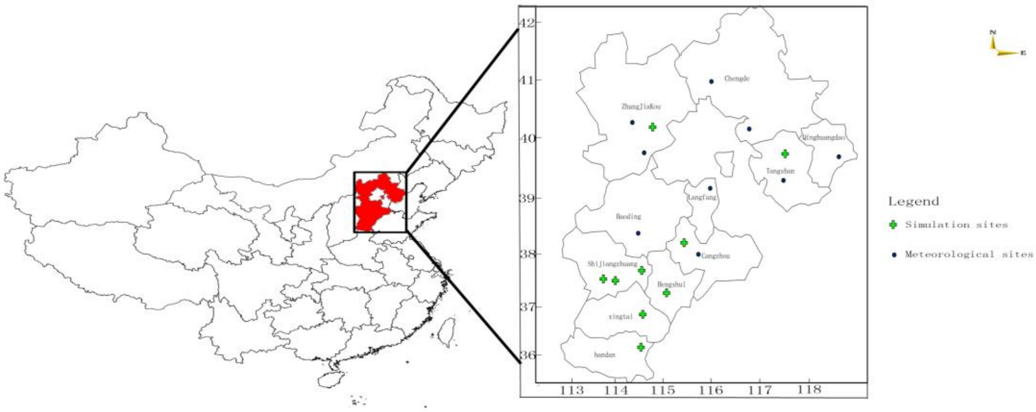


Figure1: Study Area (Hebei province with simulation sites)

Meteorological station ID and location	Total Solar Radiation MJ/m^2/year	Mean Temperature (°C)	Highest Temperature (°C)	Lowest Temperature (°C)	Annual rainfall (mm)	cultivar	Climate zone
54602 Baoding satation 38°27’N115°30’E *(Xinji, Dahe, zhengding)*	9403	26.8	41.1	-26.9	461.6	Zhengda 958	Continental Monsoon
54405 *Huailai station* 40°30’N115°40’E (huailai)	9048	23.7	39.2	-15.7	507.23	Nongda108	Continental Monsoon
54534 Tangshan station38°55’N117°31’E *(Luanxian)*	9203	25.7	39.6	-25.2	549	Zhengda 958	Continental Monsoon
54616 Cangzhou station 37°4’N115°6’E *(Qingxian,Quzhou,Shenzhou,ningjin)*	9960	26.5	40.5	-11.9	627	Zhengda 958	Continental Monsoon

Table1: Different nearest meteorological stations to the simulation sites

Quzhou County (in Handan region)	0-20	1.26	21.12	7.3	2.33	19.3	12.1	light loam	Zhengda 958
	20-40	1.31	19.52	7.3	3.35	16.2	10.6	light loam	
	40-60	1.31	18.51	7.6	2.67	15.6	7.83	heavy loam	
	60-80	1.4	22.32	7.6	2.32	12.3	5.6	middle loam	
	80-100	1.4	19.15	7.8	2.19	14.5	4.3	light loam	
Shenzhou County (in Hengshui region)	0-20	1.34	13.65	8.1	1.44	15.1	11.5	light loam	Zhengda 958
	20-40	1.34	12.05	8.1	2.36	12.4	11.5	light loam	
	40-60	1.41	16.36	8.1	2.62	10.5	10.3	middle loam	
	60-80	1.41	15.63	7.6	2.98	19.6	6.33	heavy loam	
	80-100	1.45	18.15	7.6	1.41	19.1	5.22	light loam	
Xinji City (in Shijiazhuang east region)	0-20	1.26	8.63	7.8	0.891	32.58	17	light loam	Zhengda 958
	20-40	1.26	9.16	7.8	0.884	23.82	11.4	light loam	
	40-60	1.31	11.25	7.6	1.025	15.31	9	middle loam	
	60-80	1.31	12.26	7.8	1.166	2.15	7.22	middle loam	
	80-100	1.4	14.61	8.1	0.899	6.43	5.22	middle loam	
Ningjin County (in Xingtai region)	0-20	1.31	12.11	7.1	1.122	15.34	13.1	light loam	Zhengda 958
	20-40	1.32	13.26	7.6	1.462	8.31	11.3	light loam	
	40-60	1.41	12.84	7.6	1.583	9.20	9.84	middle loam	
	60-80	1.33	18.21	7.5	2.056	3.97	8.11	middle loam	
	80-100	1.46	19.37	7.5	1.044	4.72	5.6	middle loam	

Zhengding County (in Shijiazhuang region)	0-20	1.35	18.55	7.23	1.056	20.39	16.55	light loam	Zhengda 958
	20-40	1.35	18.69	7.26	2.356	15.53	12.58	light loam	
	40-60	1.35	19.25	7.55	2.547	11.36	9.23	middle loam	
	60-80	1.33	21.33	7.25	2.261	11.53	5.12	middle loam	
	80-100	1.4	24.68	7.43	1.011	15.59	5.73	middle loam	
Qingxian County （ in Cangzhou region)	0-20	1.452255	14.48	8.83	1.418	23.64	20.1	light loam	Zhengda 958
	20-40	1.510926	14.67	8.48	1.548122	19.06	11.8	middle loam	
	40-60	1.592388	16.60	8.33	1.519129	9.93	10.9	middle loam	
	60-80	1.582327	18.89	8.38	1.176138	11.26	8.97	light loam	
	80-100	1.521559	17.13	8.42	0.519283	5.88	8.4	light loam	
Dahe (in Shijiazhuang west region)	0-20	1.45	14.925	8.6	0.911101	38.29	19.1	middle loam	Zhengda 958
	20-40	1.5	13.249	8.4	0.416318	30.93	8.94	heavy loam	
	40-60	1.51	13.400	8.3	0.331968	31.78	7.16	middle loam	
	60-80	1.46	14.605	8.4	0.382434	32.95	7.06	middle loam	
	80-100	1.49	14.886	8.2	0.293288	22.27	7.1	middle loam	
Luanxian County (in Tangshan region)	0-20	1.459006	4.32	5.8	3.157904	6.472	8.8	light loam	Zhengda 958
	20-40	1.594037	8.58	6.08	2.193278	13.98	5.58	sandy loam	
	40-60	1.56977	9.87	6.26	2.041851	13.21	3.63	middle loam	
	60-80	1.603483	11.40	6.37	1.727244	12.24	1.93	sandy loam	
	80-100	1.571273	11.88	6.2	1.833677	12.59	1.07	sandy	

				9				loam	
Huailai County (in Zhangjiakou region)	0-20	1.45	8.9	8.1	2.331	14.4	15.31	middle loam	Nongda 108
	20-40	1.46	7.8	8.2	3.233	14.6	12.14	middle loam	
	40-60	1.41	12.6	8.1	3.512	15.6	8.49	middle loam	
	60-80	1.51	14.3	7.6	2.561	15.6	9.24	heavy loam	
	80-100	1.33	11.5	7.7	1.843	18.1	6.29	middle loam	

Table2: Simulation sites and soil information

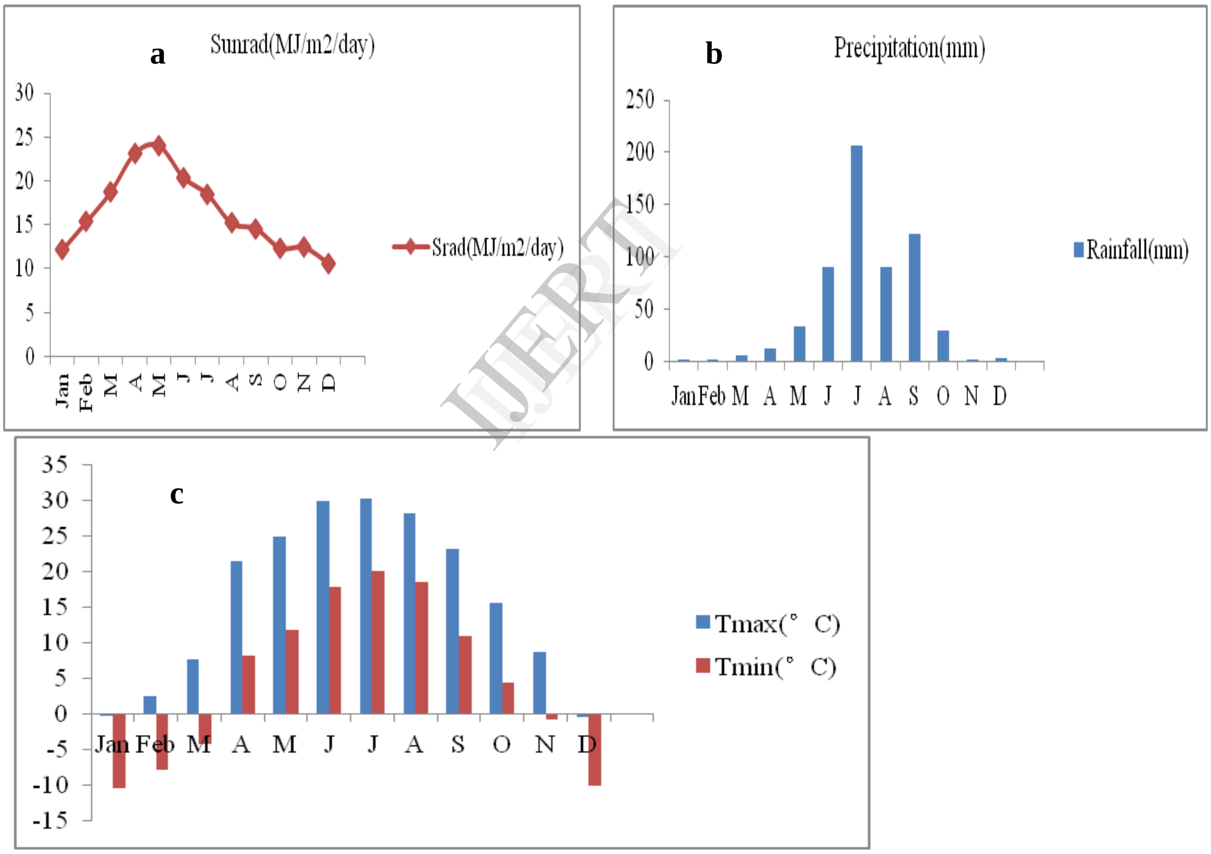
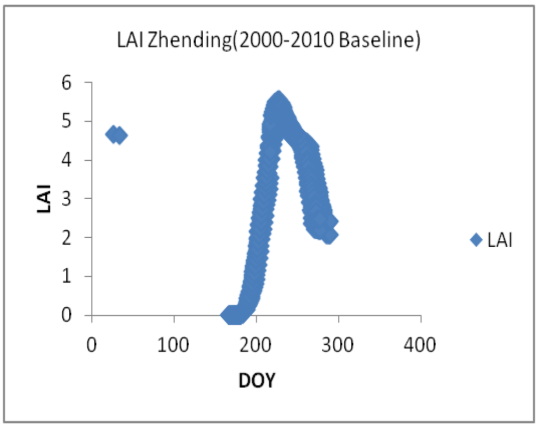
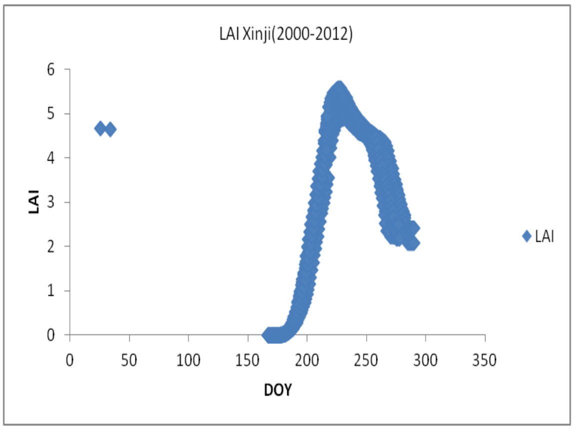
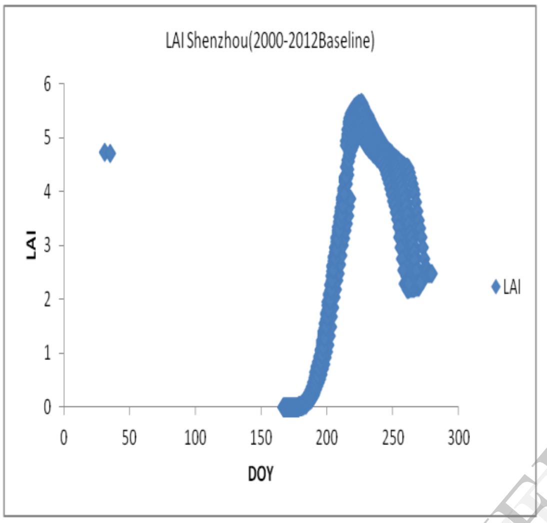
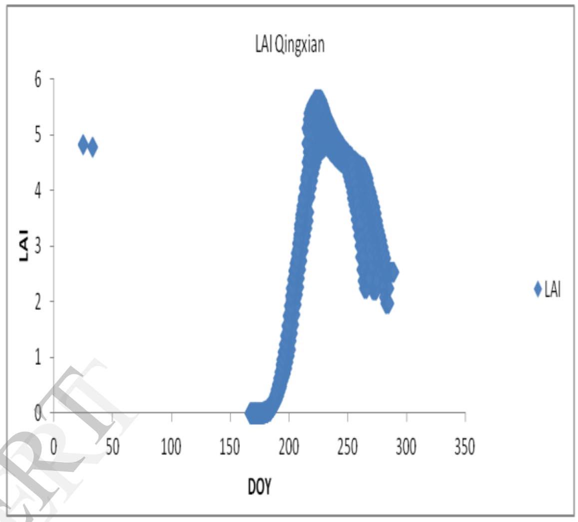


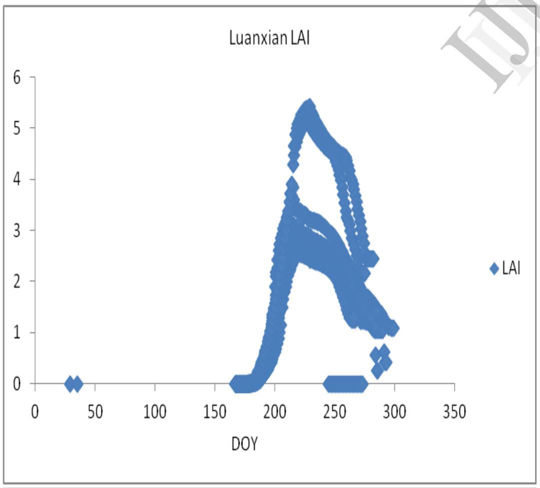
*Figure2: (**a**) the year sun radiation in Hebei Province (**b**) Yearly distribution of the Precipitation in Hebei Province (**c**) year temperature (Maximum and Minimum) in Hebei province (baseline 1980-2010)*

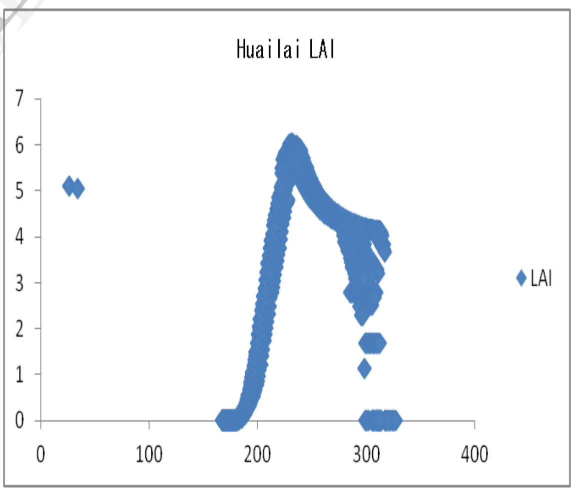

LAI Zhending(2000-2010 Baseline)
LAI
0
1
2
3
4
5
6
0
100
200
300
400
DOY
LAI

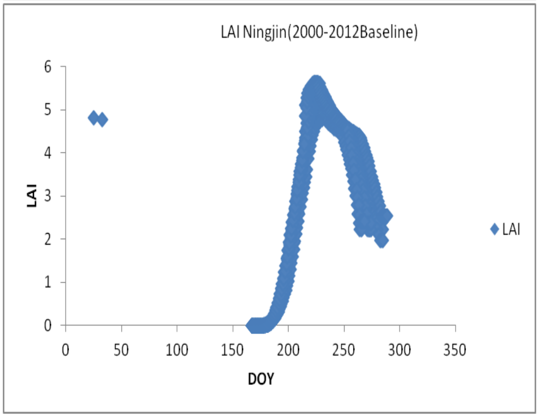

LAI Xinji(2000-2012)
LAI
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
DOY
LAI

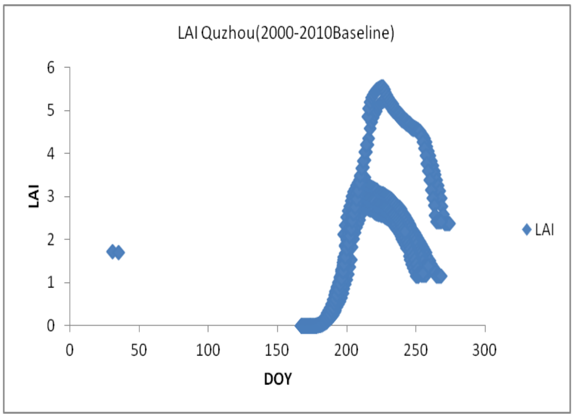

LAI Shenzhou(2000-2012Baseline)
LAI
0
1
2
3
4
5
6
0
50
100
150
200
250
300
DOY
LAI

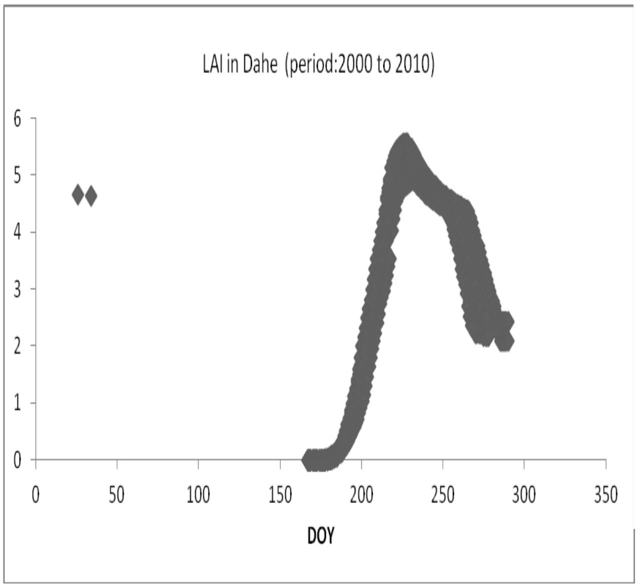

LAI Qingxian
LAI
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
DOY
LAI


Luanxian LAI
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
DOY
LAI


Huailai LAI
0
1
2
3
4
5
6
7
0
100
200
300
400
LAI


LAI Ningjin(2000-2012Baseline)
LAI
0
1
2
3
4
5
6
0
50
100
150
200
250
300
350
DOY
LAI


LAI Quzhou(2000-2010Baseline)
LAI
0
1
2
3
4
5
6
0
50
100
150
200
250
300
DOY
LAI



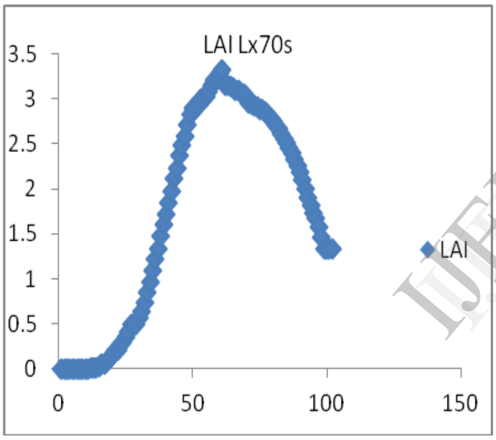
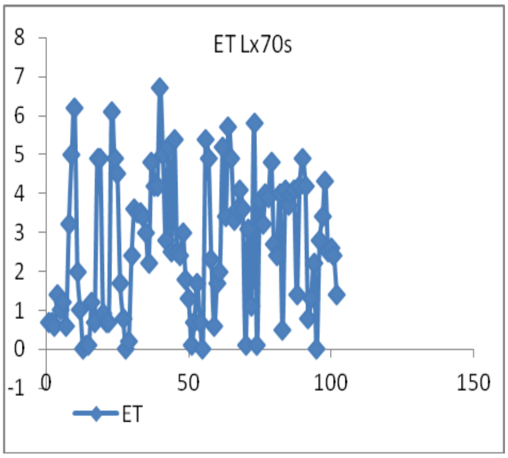
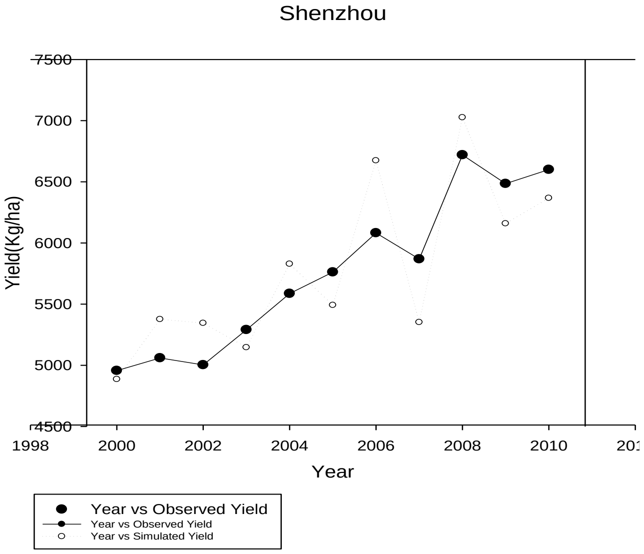


Figure3a LAI of different simulation sites

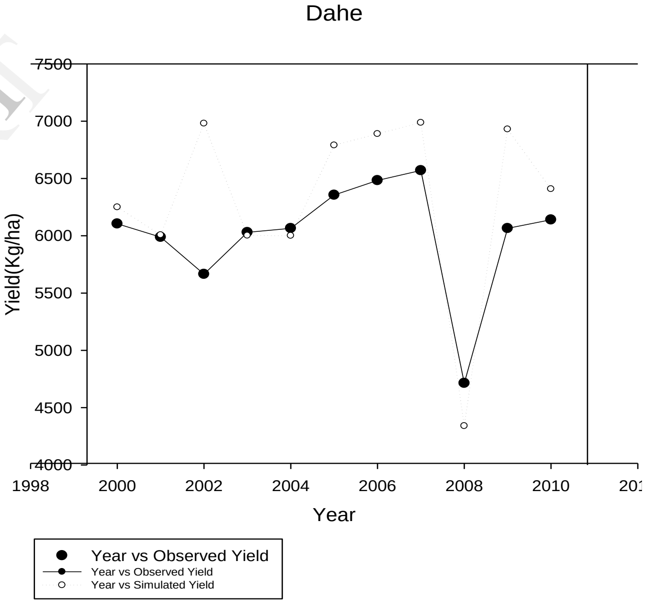


ET in Luanxian(Lx) baseline 2070s

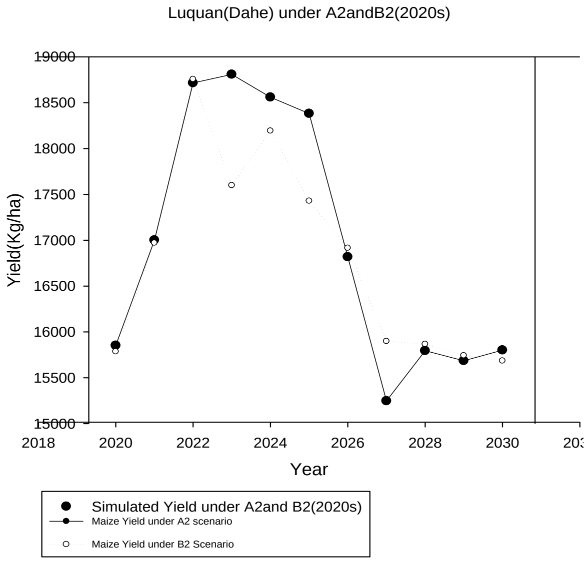


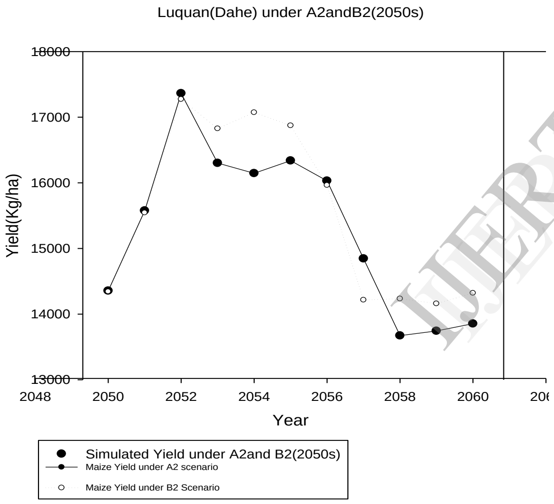
R² = 0.075

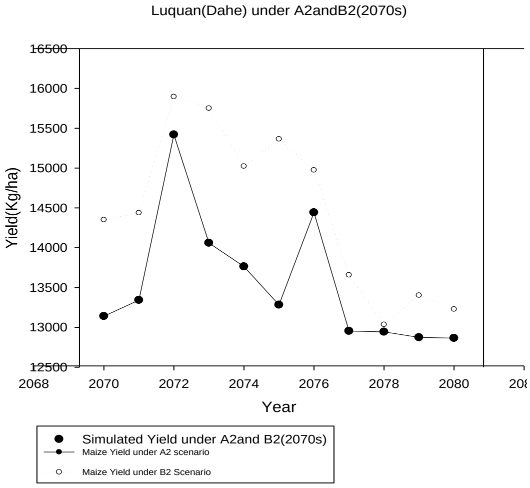
RMSE=193.35kg/ha

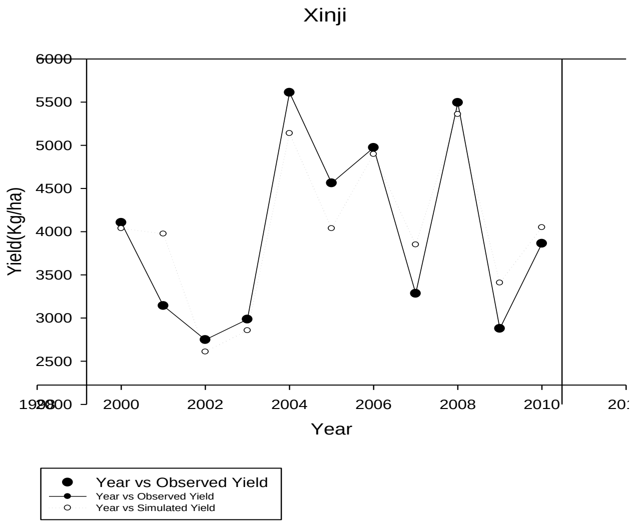


RMSE=1026.441kg/ha

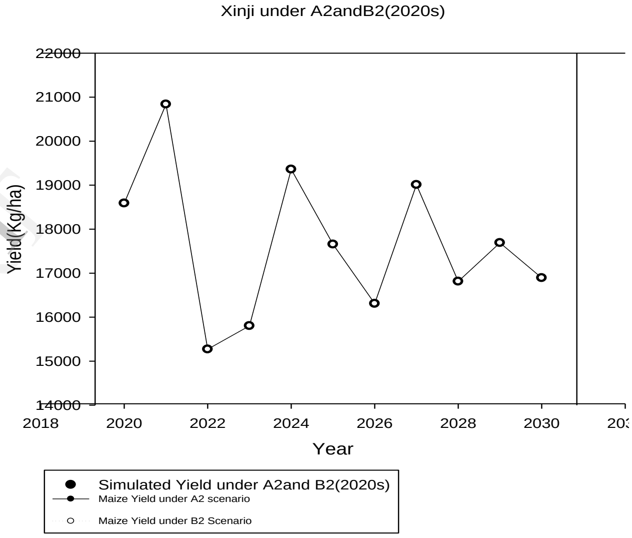


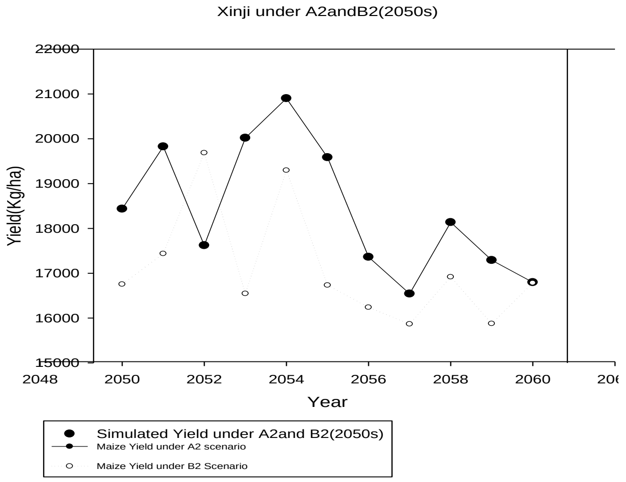


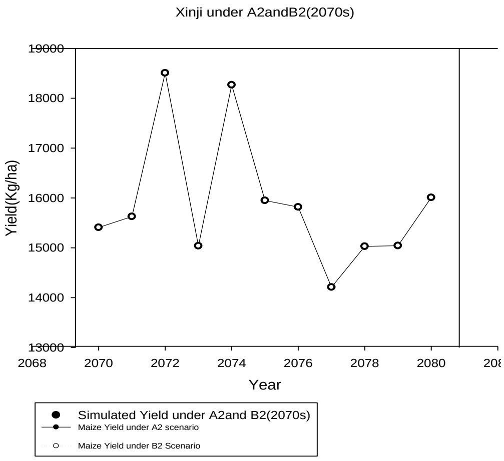


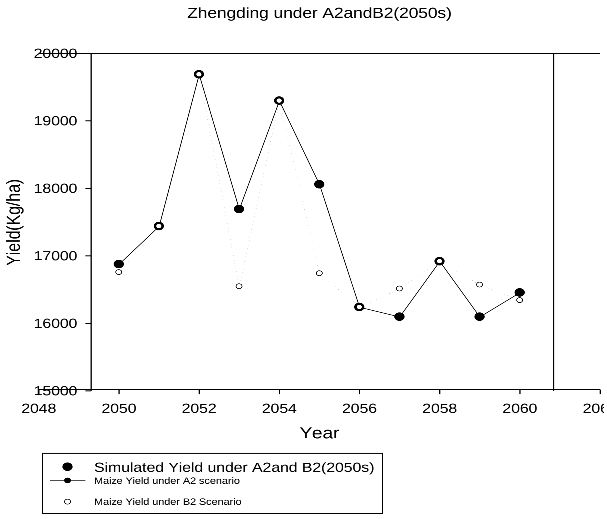


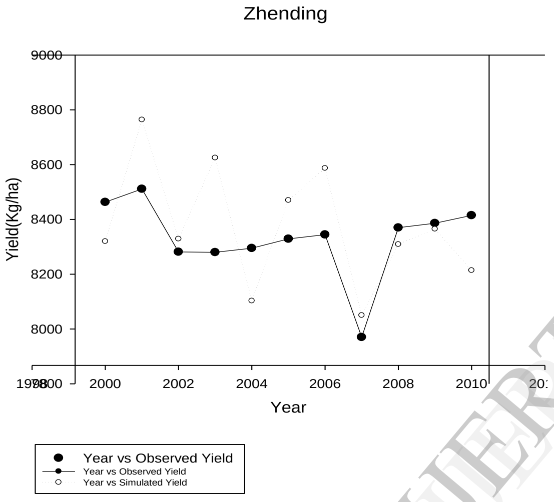
RMSE=193.35 kg/ha



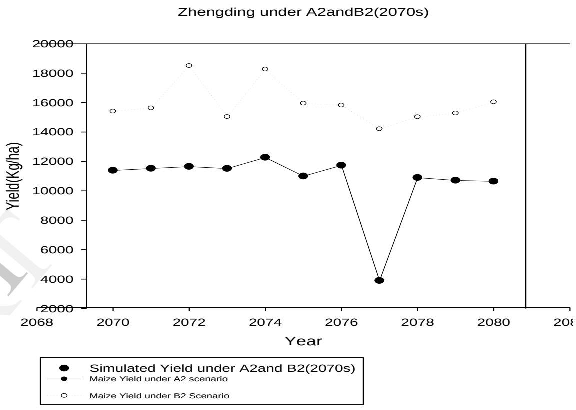


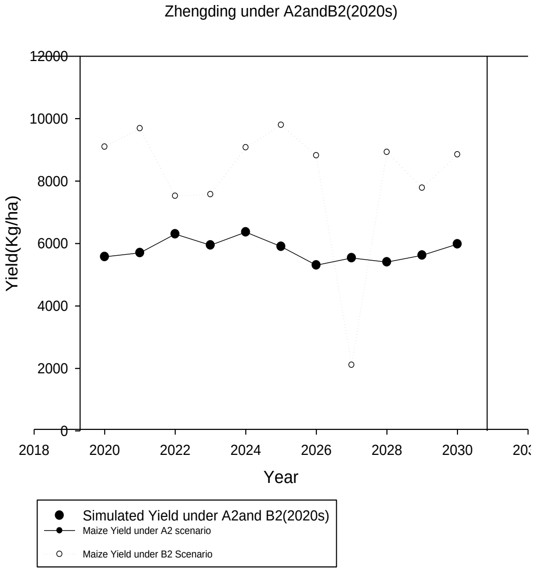


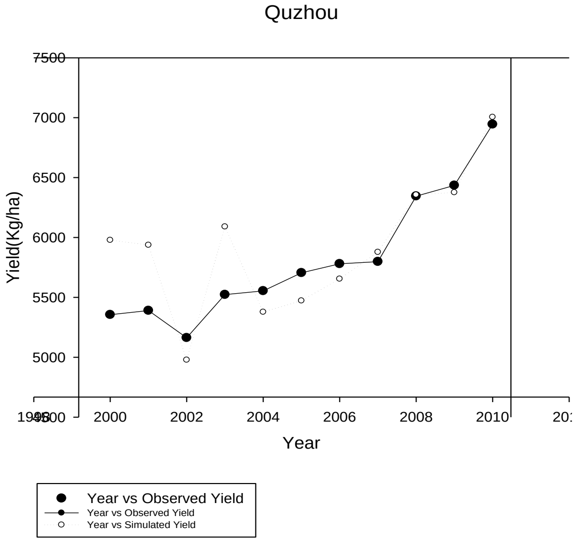




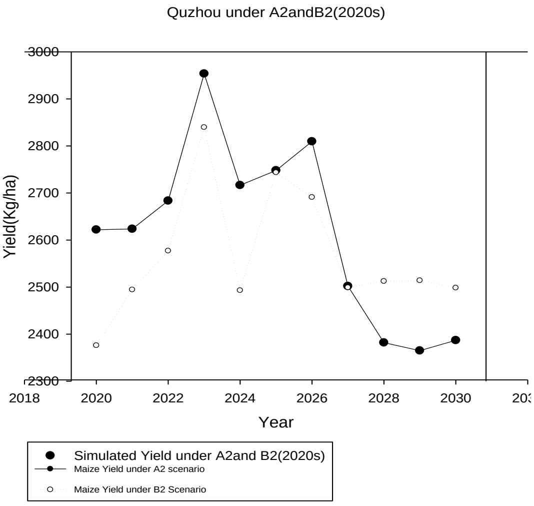
RMSE=147.98kg/ha

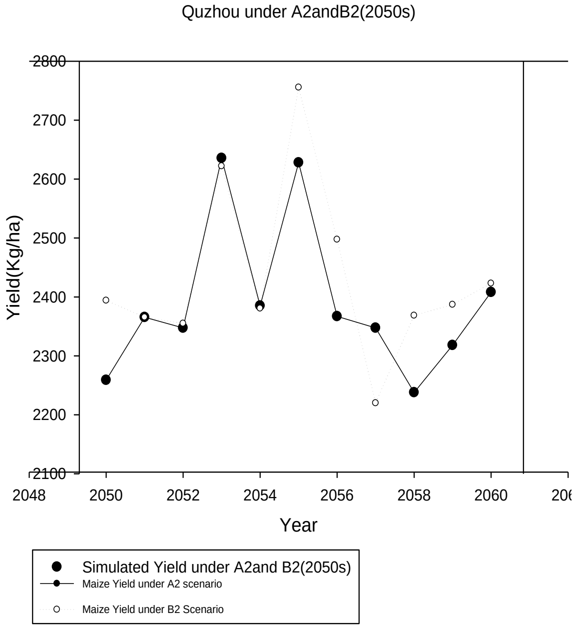


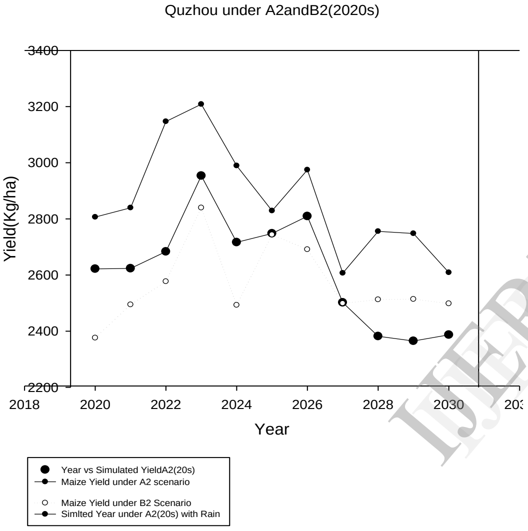


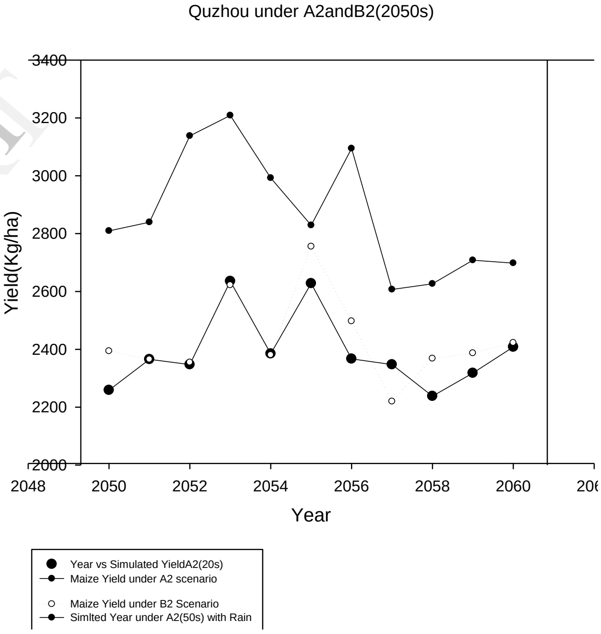


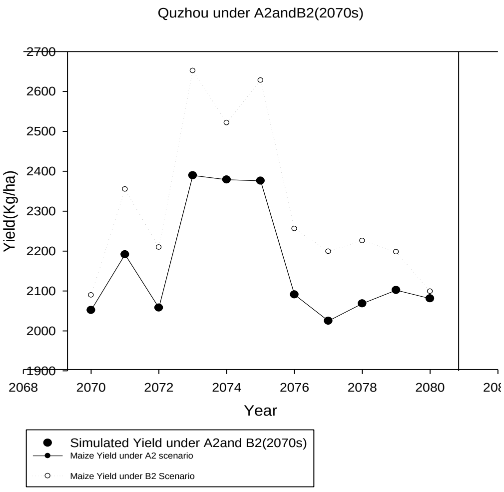
RMSE= 334.41kg/ha

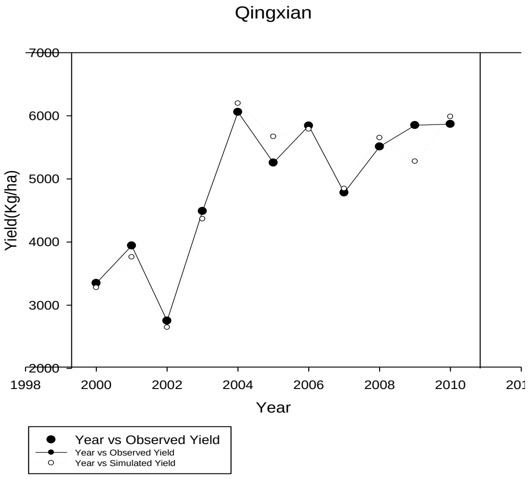

Quzhou under A2andB2(2020s)
Yield(Kg/ha)
3000
2900
2800
2700
2600
2500
2400
2300
2018
2020
2022
2024
2026
2028
2030
Year
Simulated Yield under A2and B2(2020s)
Maize Yield under A2 scenario
Maize Yield under B2 Scenario


Quzhou under A2andB2(2050s)
Yield(Kg/ha)
2800
2700
2600
2500
2400
2300
2200
2100
2048
2050
2052
2054
2056
2058
2060
Year
Simulated Yield under A2and B2(2050s)
Maize Yield under A2 scenario
Maize Yield under B2 Scenario

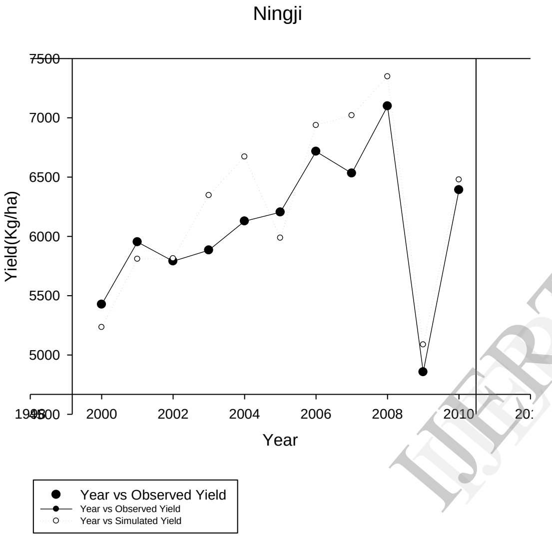

Quzhou under A2andB2(2020s)
Yield(Kg/ha)
3400
3200
3000
2800
2600
2400
2200
2018
2020
2022
2024
2026
2028
2030
Year
Year vs Simulated YieldA2(20s)
Maize Yield under A2 scenario
Maize Yield under B2 Scenario
Simlted Year under A2(20s) with Rain

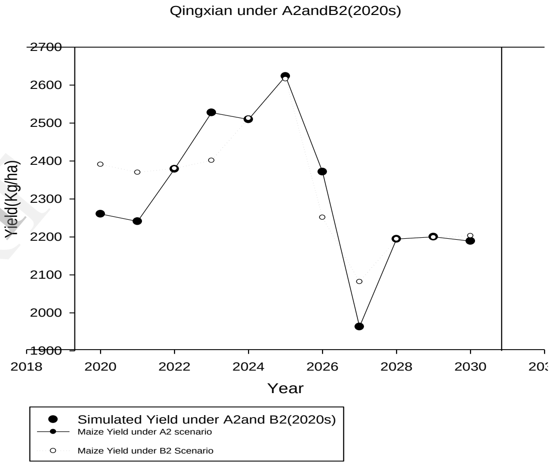

Quzhou under A2andB2(2050s)
Yield(Kg/ha)
3400
3200
3000
2800
2600
2400
2200
2000
2048
2050
2052
2054
2056
2058
2060
Year
Year vs Simulated YieldA2(20s)
Maize Yield under A2 scenario
Maize Yield under B2 Scenario
Simlted Year under A2(50s) with Rain



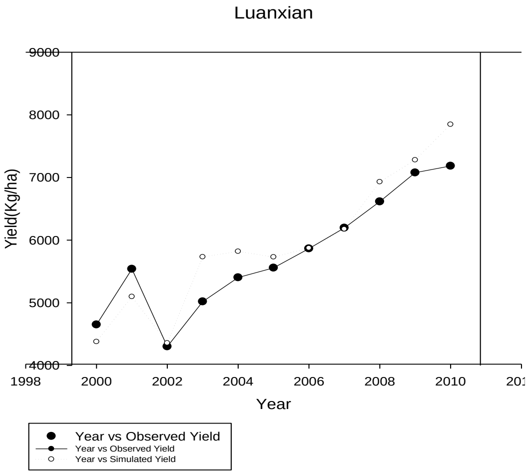


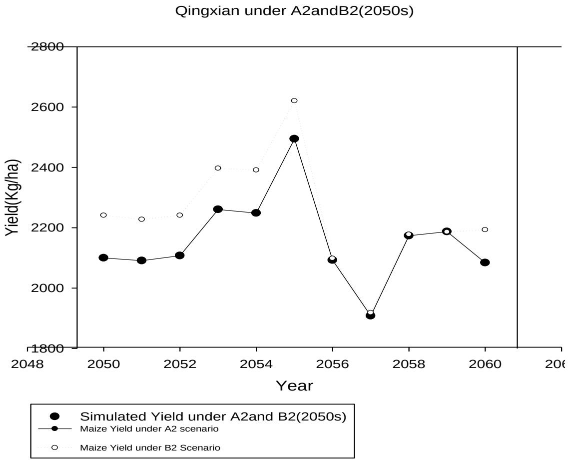
RMSE=68.59kg/ha



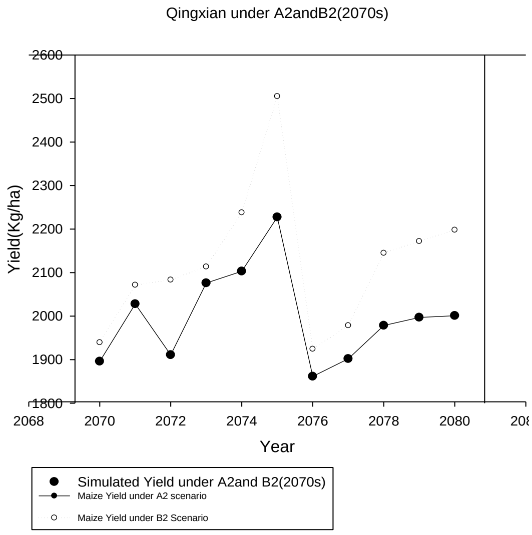


RMSE=527.57kg/ha

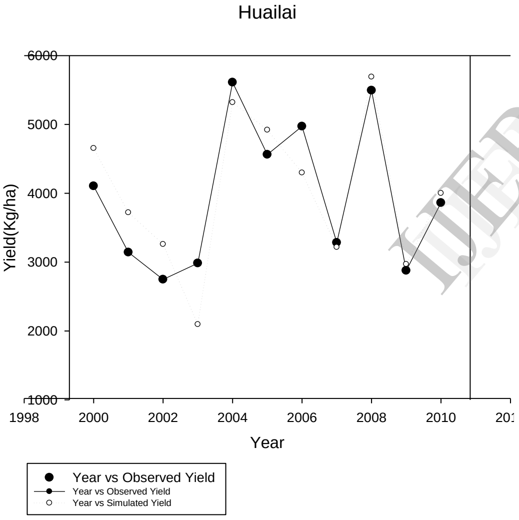




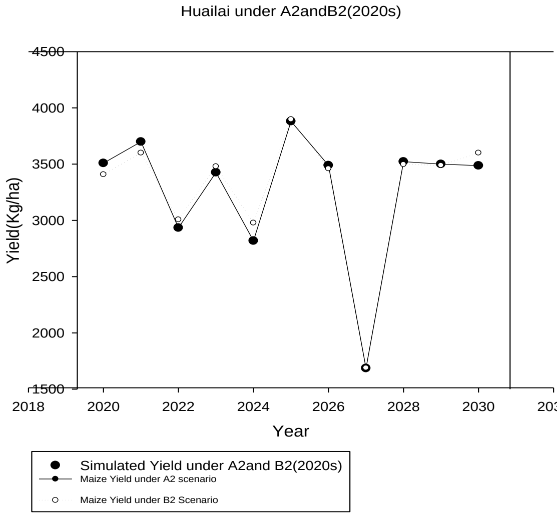
RMSE=546.54kg/ha

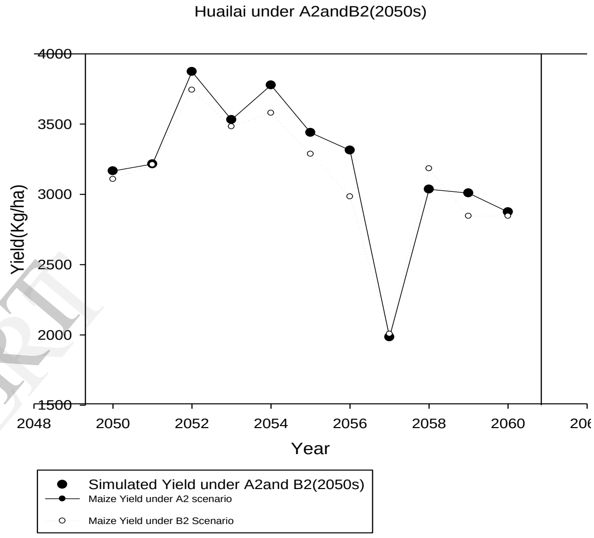


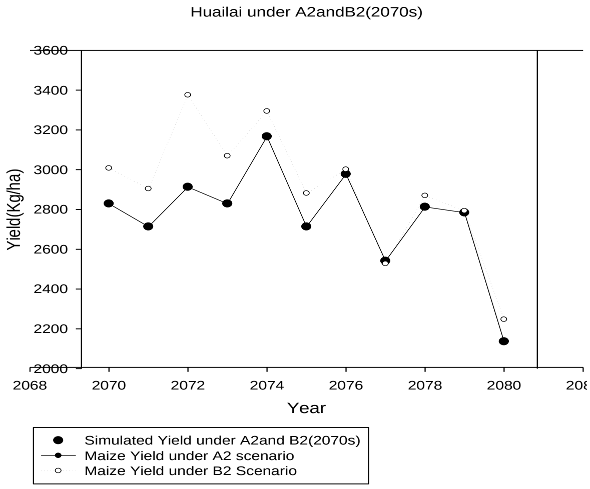
The RMSE in Qingxian for 20s; 50s and 70s respectively. RMSE= 181.2385kg/ha; RMSE= 128.4438kg/ha RMSE=488.4484kg/ha

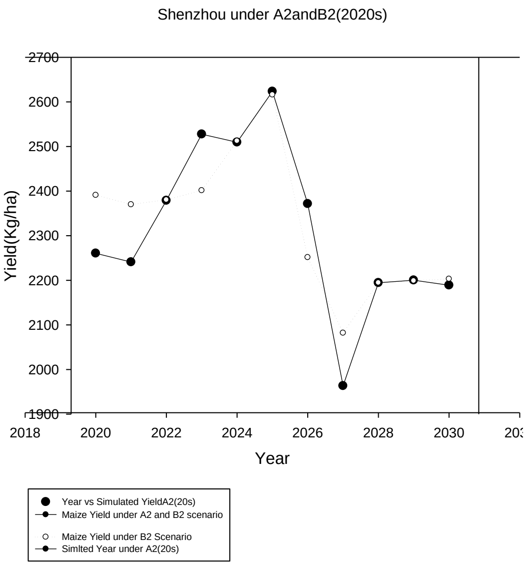


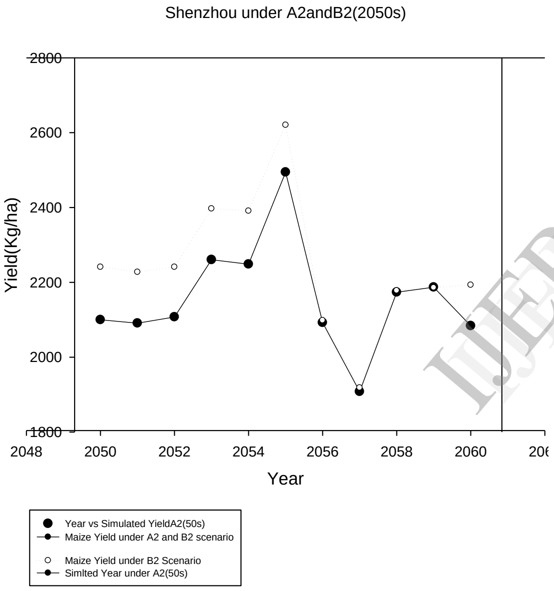
RMSE=152.4Kg/ha

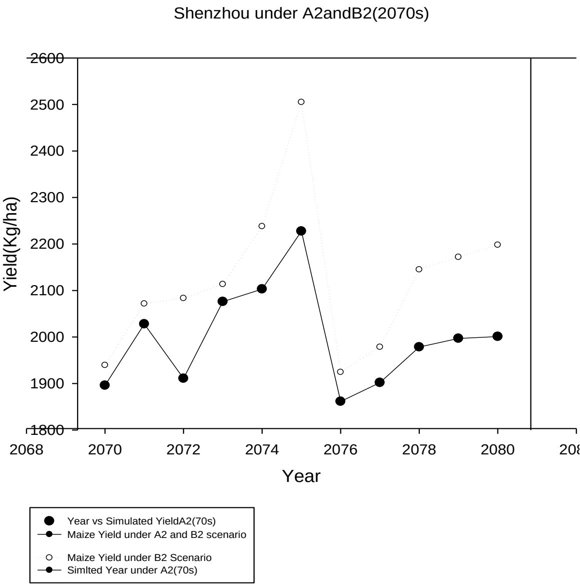




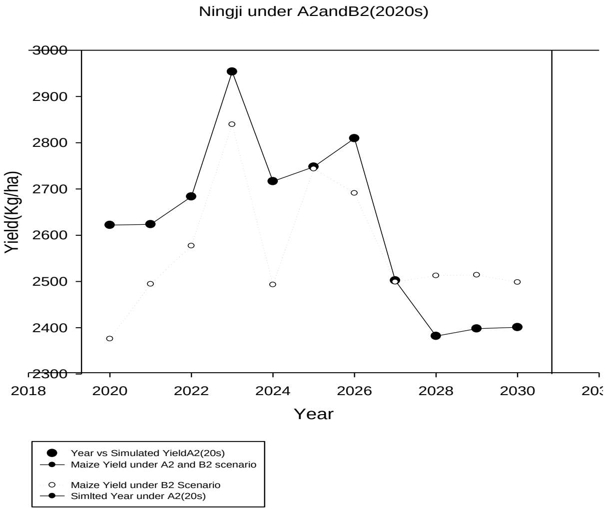


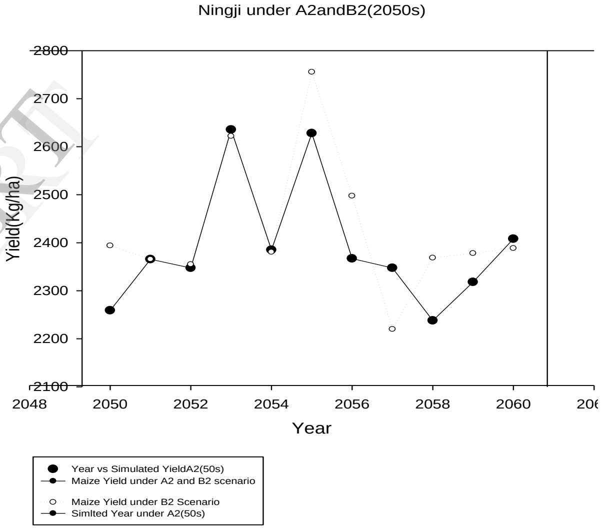


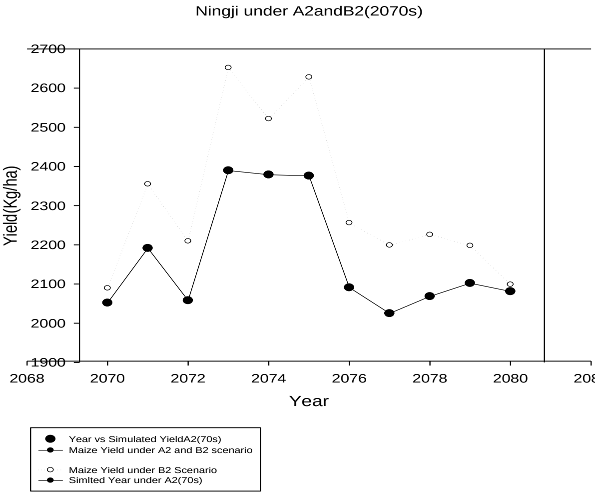




The RMSE in Shenzhou for 20s, 50s and 70s respectively are: RMSE=42.72416; RMSE=284.9282 and RMSE= 418.347

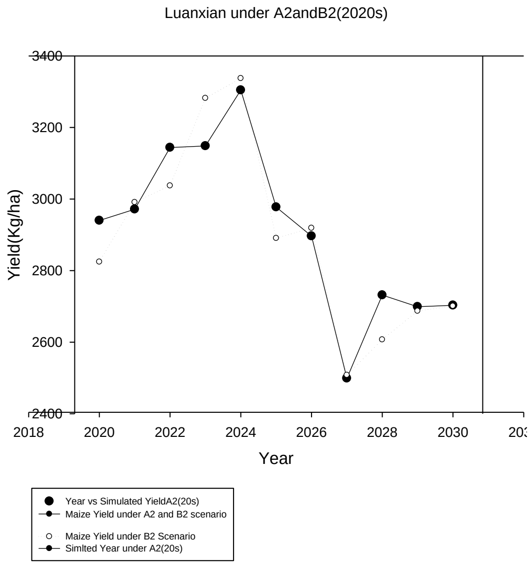


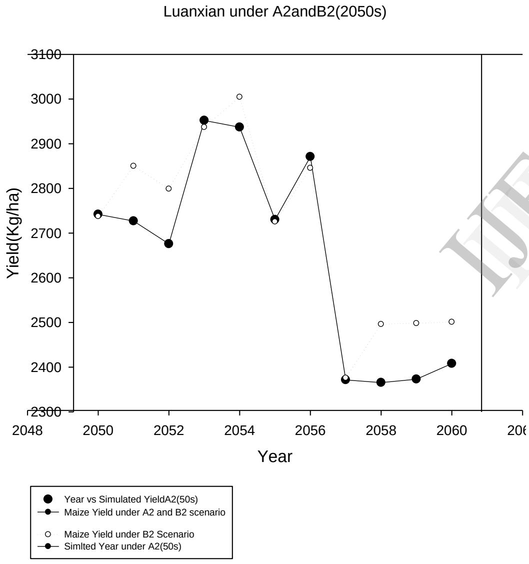


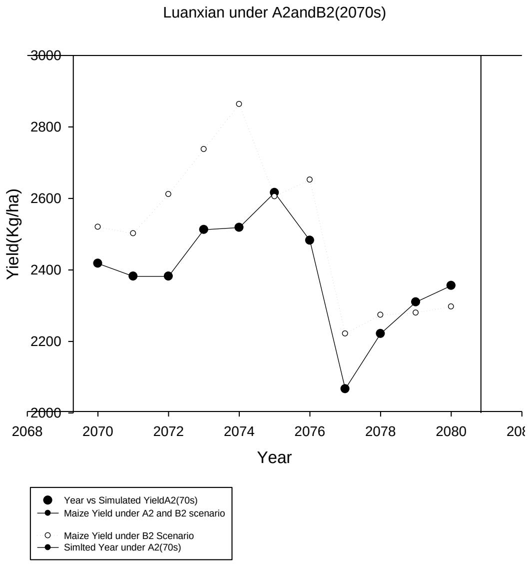


The RMSE in Ningji for 20s; 50s and 70s respectively.

RMSE= 181.2385; RMSE= 128.4438
RMSE= 488.4484







$R^2 = 0.0032$

The RMSE in Luanxian for 20s; 50s and 70s respectively: RMSE=46.88501; RMSE=284.0237; RMSE=468.5486

*Figure3 3**b** 3**c**: simulation yield and observed yield under PRECIS A2 and B2 scenario in different sites.*