

Estimation of maize yield incorporating the synergistic effect of climatic and land use change: A case study of Jilin, China

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Text A1.

The improvement in agricultural mechanization (*machine*, *machine*²) and county-fixed effects (*county*) explain 40.3% of the county-level yield variance, which reflects the mean and the rapid improvement pace of crop have presented uneven spatial distribution since 2000. *T*, *P*, and their square terms explain 3.3% of the county-level production variance. Sunshine hours (*SH*) has an insignificant coefficient of determination, and is excluded in the final model (**Equation A1**). **Table A1** shows the model coefficient and significance test.

$$\log(yield) = 0.000128 * machine^2 - 0.0055 * machine + 1.598 * T - 0.043 * T^2 + 0.006394 * P - 0.0000262 * P^2 - 6.234 \quad (A1)$$

Considering the error value, the model can be written as:

$$\log(y_{county,year}) = \log(\hat{y}_{county,year}) + \log(\epsilon_{county,year}) \quad (A2)$$

The hat symbol (^) indicates the estimated value of yield production. Assume that the error is independent of the estimated value $\log(\epsilon)$. All terms in the above equation are logarithmic. We first take the exponents on both sides of (**Equation A2**) to calculate the yield per hectare.

$$y = e^{\log(\hat{y})} e^{\log(\epsilon)} \quad (A3)$$

It is crucial to consider the yield error when comparing the yield variance between 2011-2030 and 2031-2050. We can calculate the variance of the final production, substituting the variance values of the residuals at all levels (Attached **Table A2**):

$$Var(y) = (E[\log(\hat{y})])^2 \times Var(\log(\epsilon)) + (E[\log(\epsilon)])^2 \times Var(\log(\hat{y})) + Var(\log(\hat{y})) \times Var(\log(\epsilon)) \quad (A4)$$

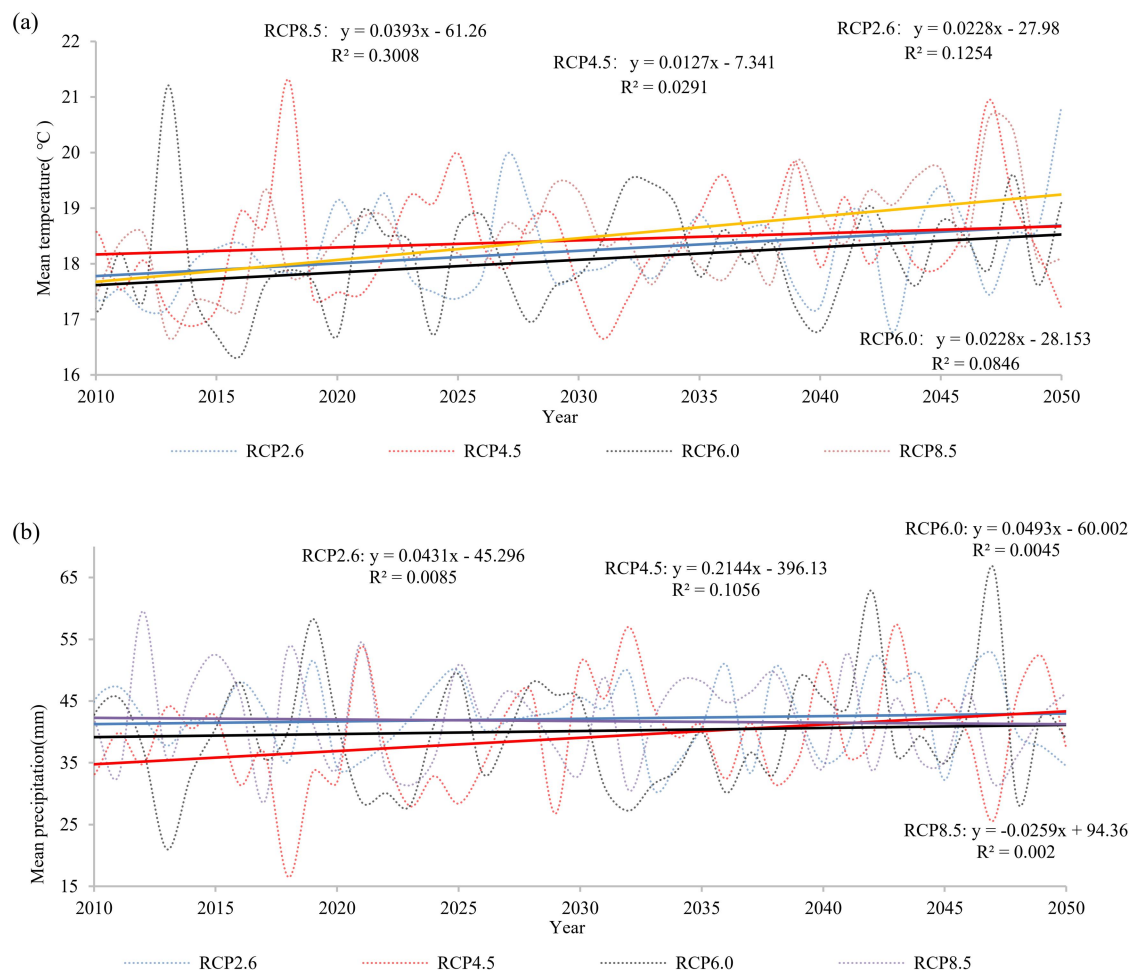


Figure A1. (a)Average temperature in the study area from May to September under RCPs; (b) Average precipitation in the study area from May to September under RCPs.

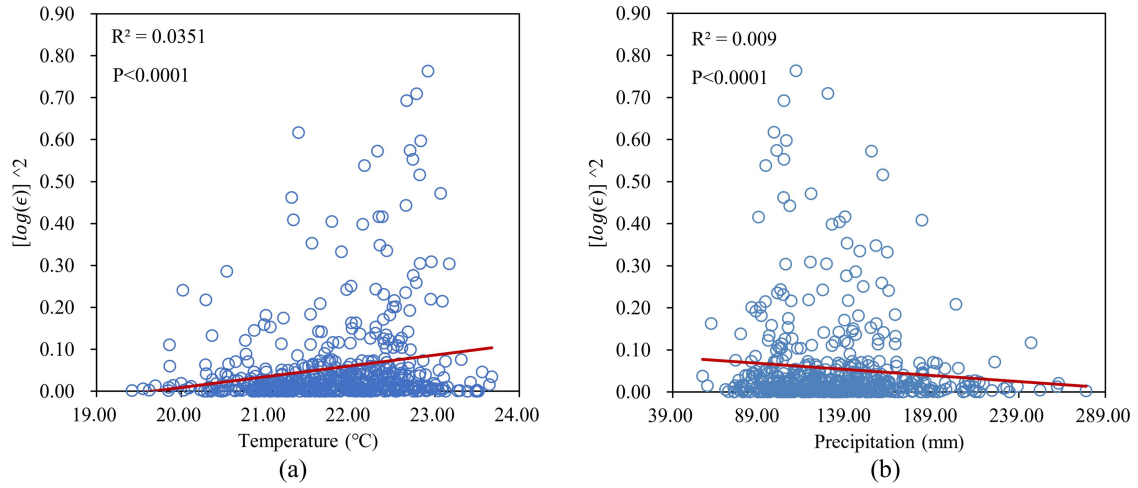


Figure A2. Least-squares regression diagram of the square of the production residuals and the average T and P during the training period.

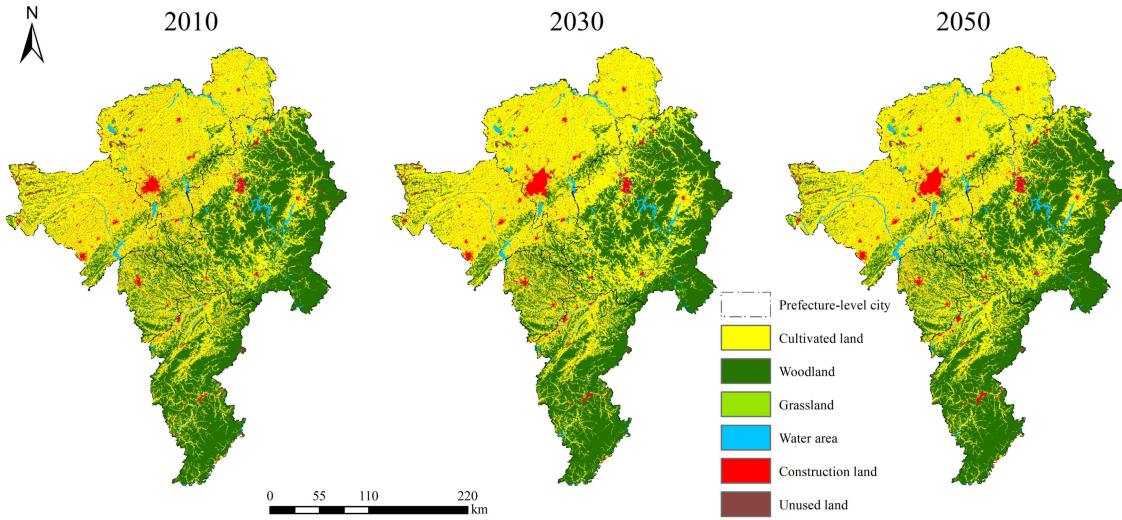


Figure A3. Land use maps in 2010, 2030 and 2050.

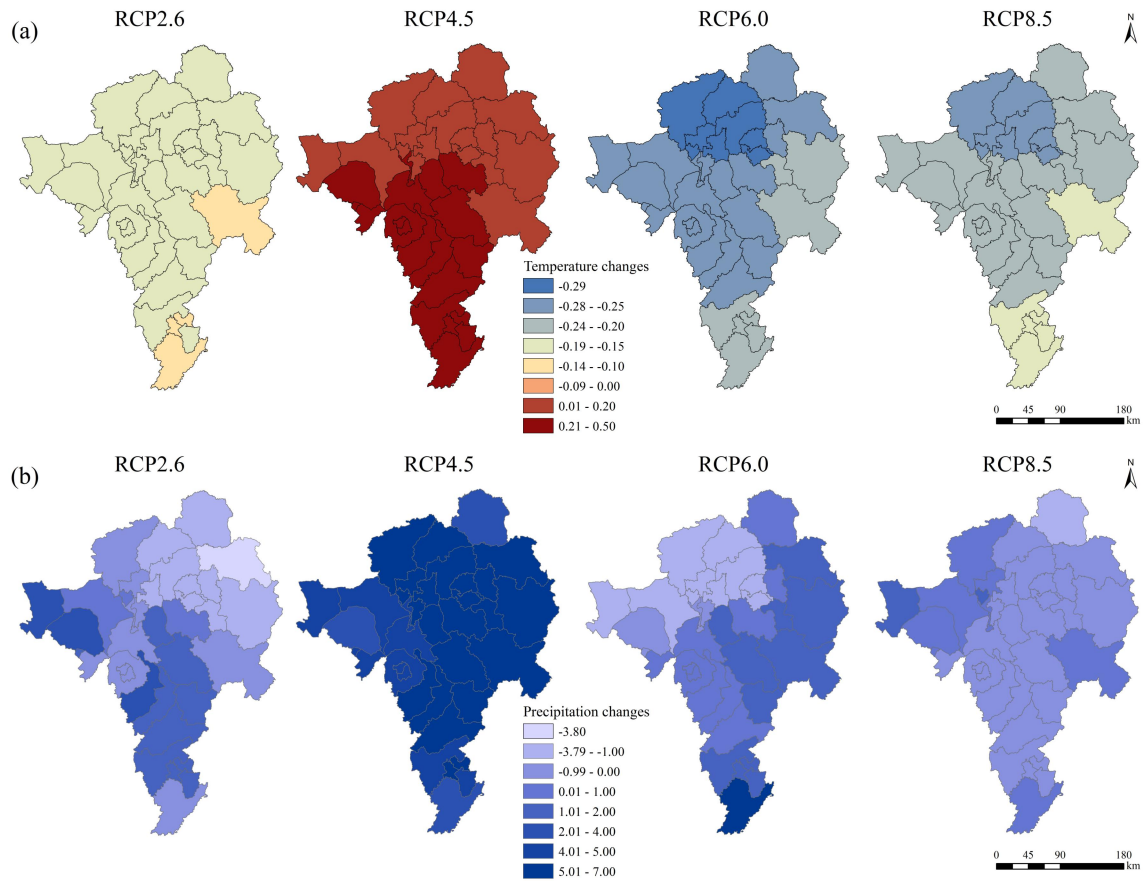


Figure A4. (a) Temperature variation by county from 2011-2030 to 2031-2050; (b) Precipitation varies by county from 2011-2030 to 2031-2050.

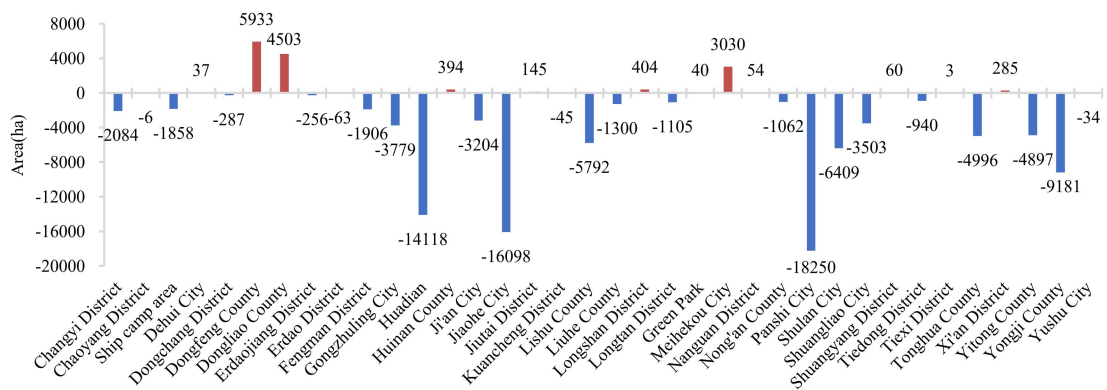


Figure A5. Changes in cultivated land areas at county level from 2030 to 2050.

Table A1*Regression coefficients.*

Model	Unstandardized coefficient		t	Sig.
	B	Standard error		
(constant)	-6.226	7.759	-0.802	0.423
<i>T</i>	1.598	0.788	2.029	0.043
<i>T</i> ²	-0.043	0.020	-2.163	0.031
<i>P</i>	0.006	0.003	2.254	0.025
<i>P</i> ²	-2.622E-05	0.000	-2.146	0.032
<i>machine</i>	-0.006	0.001	-4.633	0.000
<i>machine</i> ²	1.284E-04	0.000	3.153	0.002
<i>SH</i>	2.750E-04	8.02 E-04	0.342	0.732
Area=Dongfeng County	0.243	0.104	2.329	0.020
Area=Dongchang District	0.265	0.135	1.971	0.049
Area=Dongliao County	0.251	0.105	2.392	0.017
Area = Fengman District	0.095	0.115	0.821	0.412
Area=Jiutai City	0.035	0.104	0.342	0.733
Area = Erdao District	-0.409	0.102	-4.025	0.000
Area = Erdaojiang District	0.148	0.134	1.105	0.269
Area=Yitong County	0.267	0.102	2.623	0.009
Area=Gongzhuling City	0.652	0.105	6.212	0.000
Area=Nong'an County	0.431	0.105	4.085	0.000
Area = Nanguan District	-0.019	0.109	-0.173	0.863
Area=Shuangyang District	0.316	0.108	2.920	0.004
Area = Kuancheng District	-0.400	0.102	-3.920	0.000
Area=Dehui City	0.298	0.106	2.813	0.005
Area=Changyi District	0.092	0.103	0.888	0.375
Area=Chaoyang District	-0.106	0.113	-0.942	0.346
Area = Liuhe County	0.255	0.112	2.263	0.024
Area = Huadian City	-0.020	0.121	-0.167	0.867
Area=Meihekou City	0.087	0.104	0.834	0.405
Area = Lishu County	0.724	0.105	6.916	0.000
Area = Elm City	0.313	0.104	3.019	0.003
Area=Yongji County	0.028	0.103	0.268	0.788
Area=Panshi City	0.106	0.103	1.024	0.306
Area = Green Park	0.055	0.119	0.461	0.645

Area = Shulan City	0.200	0.111	1.810	0.071
Area = Ship Camp Area	0.063	0.105	0.599	0.549
Area = Jiaohe City	0.102	0.116	0.877	0.381
Area = Xi'an District	-0.042	0.103	-0.412	0.680
Area=Huinan County	0.351	0.112	3.130	0.002
Area=Tonghua County	-0.051	0.110	-0.460	0.646
Area=Tiedong District	0.236	0.107	2.200	0.028
Area = Tiexi District	0.449	0.185	2.427	0.016
Area = Ji'an City	-0.098	0.109	-0.894	0.372
Area = Longshan District	-0.055	0.102	-0.538	0.591
Area=Longtan District	0.091	0.105	0.868	0.386

Note: B and Beta are regression coefficients; Sig. is the P-value, which represents the significance in the hypothesis test.

Table A2*Variance of county residual error.*

region	$Var(\log(\epsilon))$	region	$Var(\log(\epsilon))$
Changyi District	0.025572075	Liuhe County	0.044541441
Chaoyang District	0.195618882	Yongsan District	0.088251022
Ship Camp Area	0.014275893	Longtan District	0.019158748
Dehui	0.033632781	Green Park	0.249584034
Dongchang District	0.014318566	Meihekou	0.009294256
Dongfeng County	0.026302486	Nanguan District	0.14462959
Dongliao County	0.049171297	Nong'an County	0.011689685
Erdaojiang District	0.031237137	rock city	0.01400162
Erdao District	0.431996676	Shulan	0.01074008
plump area	0.048536536	Shuangliao	0.038542727
Gongzhuling	0.010237088	Shuangyang District	0.072074432
Huadian	0.026221195	Tiedong District	0.039590128
Huinan County	0.070030835	Tiexi District	0.079287917
Ji'an	0.023745877	Tonghua County	0.011766734
Jiaohe	0.046481507	Xi'an District	0.344605244
Jiutai District	0.0508169	Yitong County	0.071153589
Kuancheng District	0.28749462	Yongji County	0.043845527
Lishu County	0.030609236	Elm City	0.012829379