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Maize Ecosystem Dataset including Management Measures and Surface Energy and Water Balance in the North China Plain

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Abstract: The change in farmland surface characteristics has important feedback on the regional climate by affecting the surface energy and water exchange at the land–atmosphere boundary layer. Based on the dynamics of maize phenology in North China Plain, this dataset provided three scenarios with different sowing dates and lengths of growth period: spring (early sowing date and normal length), summer (late sowing date and normal length), and potential (early sowing date and prolonged length of growth period) maize. The calibrated SiBcrop model was used to simulate the responses of surface energy and water flux in the three scenarios from 1980 to 2009. The results showed that the different scenarios had an important influence on the leaf area index, net radiation, latent heat, sensible heat, and canopy temperature. The differences in the sowing date, harvest date, and growth dynamics among scenarios were the key nodes in the changes in the surface energy budget. An early sowing date had a warming effect, and the prolonged length of the growth period exhibited no evident warming effect. The research results have a certain guiding significance for the adaptation and mitigation of climate change in farmland management.

Keywords: maize; phenology; surface energy partitioning; albedo

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Dataset Availability Statement:

The dataset supporting this paper was published and is accessible through the *Digital Journal of Global Change Data Repository* at: https://doi.org/10.3974/geodb.2021.11.07.V1 or https://cstr.escience.org.cn/CSTR:20146.11.2021.11.07.V1.

1 Introduction

Surfaces are an important source of energy, moisture, and gas in the climate system. Changes in surface characteristics have become an important feedback process for climate

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[2] Liu, F. S., Ge, Q. S., Tao, F. L., *et al*. Maize ecosystem dataset including surface energy and water budget in North China Plain (1980–2009) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2022. https://doi.org/10.3974/geodb.2021.11.07.V1. https://cstr.escience.org.cn/CSTR:20146.11.2021. 11.07.V1.

change by affecting the surface energy and water exchange at the land–atmosphere boundary layer[1]. The surface characteristics of farmland are strongly interfered with by anthropogenic activities and have become an important driver of regional climate[2]. Improving the simulation accuracy of the material and energy exchange process at the land–atmosphere boundary layer and quantitating the climate feedback of farmland management through surface energy and water processes are significant to adapting and mitigating climate change for agroecosystems.

2 Metadata of the Dataset

Table 1 shows the dataset name, author, geographical area, data size, data publishing and sharing service platform, data sharing policy, and other information of the dataset[2].

3 Development methods

With the North China Plain as the research area, stations with complete phenological and meteorological records from 1981 to 2009 were selected to carry out the study. Ten sites, including Miyun, Baodi, Huanghua, Tangshan, Weifang, Xinxiang, Zhengzhou, Shangqiu, Zhumadian, and Nanyang, were available (Table 1). Guantao Station in Hebei Province and Yucheng Station in Shandong Province had good maize growth and flux observation data, which were used for the calibration and verification of the SiBcrop model to improve the simulation accuracy of maize phenological period, leaf area index, latent heat, sensible heat, canopy temperature, and other processes (Table 2). The data from Yucheng Station were measured in 2004–2005 and came from the Chinese flux observation and research network[1]. The measured time of the eddy-correlated data of Guantao Station was from 2009 to 2010 from the National Tibetan Plateau Data Center[2]. The multi-year average temperature of the above stations fluctuated between 11.86–14.33 ℃, and the annual precipitation fluctuated between 617.96–1,060.3 mm; the soil type is sandy loam[1]; these values represent the natural growth conditions and agriculture production level in North China Plain.

The three maize scenarios, including different sowing dates and lengths of growth periods, were established (Table 3). The sowing date in the spring maize scenario was the median sowing date of spring maize at the selected site, that is, day of year 136 (DOY136), and the growing degree day reached 2,730 ℃ d; The sowing date in the summer maize scenario was the median sowing date of summer maize at the selected site (DOY162), and the growing degree day reached 2,730 ℃ d. The sowing date in the potential maize scenario was the median sowing period of spring maize at the selected site (DOY136); the harvest date was the median harvest period of summer maize. The average growing degree day of 10 stations was 3,036 ℃ d based on the dates of sowing and harvest. The other parameters in the model remain unchanged.

A calibrated SiBcrop model[1] was used to simulate the responses of surface energy and water balance under different maize scenarios. The simulation time was from 1980 to 2009, and the simulation step was half an hour. During the simulation, the initial boundary conditions, meteorological data, soil types, and other conditions were kept constant. The difference between spring and summer maize scenarios reflected the effect of changes in the sowing date, the difference between spring and potential maize scenarios reflected the influence of growth period length, and the difference between summer and potential maize

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1 China flux observation and research network. http://www.cnern.org.cn/.

2 National Qinghai-Tibet Plateau Science Data Center. http://data.tpdc.ac.cn.

reflected the combined effect of sowing date and length of the growth period.

Table 1 Metadata summary of Maize ecosystem dataset including management measures and surfaceenergy and water balance in the North China Plain

Items	Description
Dataset full name	Maize ecosystem dataset including management measures and surface energy and water balance in the North China Plain
Dataset short name	MaizeNorthChina_1980-2009
Authors	Liu, F. S., Fujian Agriculture and Forestry University, liufs.11b@igsnrr.ac.cn Ge, Q. S., Institute of Geographic Sciences and Resources, Chinese Academy of Sciences, geqs@igsnrr.ac.cn Tao, F. L., Institute of Geographic Science and Resource, Chinese Academy of Science, taofl@igsnrr.ac.cn Cai, Y. X., Fujian Agriculture and Forestry University, 275196219@qq.com Bu, J. C., Fujian Agriculture and Forestry University, 2450594360@qq.com Bai, N. N., Fujian Agriculture and Forestry University, 2450594360@qq.com
Geographical area	North China Plain Year 1980–2009
Data format	.xlsx
Data size	64.6 MB (62.1MB after compression)
Data files	The dataset includes the following variables: site name, scenario, date, maize growth dynamics (including leaf area index, growing degree day, leaf biomass, sowing date, seedling date), surface energy budget (including sensible heat, latent heat, four components of short-wave radiation (visible, infrared, scatter, and direct radiation), downward longwave radiation, net radiation), canopy temperature, soil surface moisture and so on
Foundation	National Natural Science Foundation of China (41801020)
Data publisher	Global Change Research Data Publishing & Repository, http://www.geodoi.ac.cn
Address	No. 11A, Datun Road, Chaoyang District, Beijing 100101, China
Data sharing policy	***Data*** from the Global Change Research Data Publishing & Repository includes metadata, datasets (in the *Digital Journal of Global Change Data Repository*), and publications (in the *Journal of Global Change Data* & *Discovery*). ***Data*** sharing policy includes: (1) ***Data*** are openly available and can be free downloaded via the Internet; (2) End users are encouraged to use ***Data*** subject to citation; (3) Users, who are by definition also value-added service providers, are welcome to redistribute ***Data*** subject to written permission from the GCdataPR Editorial Office and the issuance of a ***Data*** redistribution license; and (4) If ***Data*** are used to compile new datasets, the ‘ten per cent principal’ should be followed such that ***Data*** records utilized should not surpass 10% of the new dataset contents, while sources should be clearly noted in suitable places in the new dataset[3]
Communication and searchable system	DOI, CSTR, Crossref, DCI, CSCD, CNKI, SciEngine, WDS/ISC, GEOSS

Table 2 Basic site information

Site name	Latitude (N)	Longitude (E)	Altitude above sea level (m)	Temperature (℃)	Precipitation (mm)	Data
Huanghua	38.37	117.35	7.3	12.92	589.48	Meteorology, phenology
Tangshan	39.67	118.15	28.6	11.85	636.56	Meteorology, phenology
Nanyang	33.03	112.58	130.7	15.16	897.9	Meteorology, phenology
Shangqiu	34.45	115.67	51	14.37	770.15	Meteorology, phenology
Xinxiang	35.32	113.88	74	14.55	611.38	Meteorology, phenology
Zhumadian	33	114.02	83.3	15.16	1,079.31	Meteorology, phenology
Zhenzhou	34.72	113.65	111.3	14.76	708.83	Meteorology, phenology
Weifang	36.75	119.18	19.3	12.74	609.19	Meteorology, phenology
Baodi	39.73	117.28	6	11.77	608.09	Meteorology, phenology
Miyun	40.38	116.87	73.1	11.27	691.31	Meteorology, phenology
Yucheng	36.83	116.57	28	13.1	582	Meteorology, phenology, flux
Guantao	36.52	115.13	40	13.82	490.47	Meteorology, flux

Table 3 Simulation scenarios of maize

Simulation Scenarios	Parameters		Simulation time
	Sowing date	Growing degree day	
Spring maize	No earlier than DOY136	2,730 ℃ d	1980–2010
Summer maize	No earlier than DOY162	2,730 ℃ d	1980–2010
Potential maize	No earlier than DOY136	3,036 ℃ d	1980–2010

4 Data Results and validation

4.1 Dataset Composition

The dataset included the following: site name, scenario, date, maize growth dynamics (including leaf area index, growing degree day, leaf biomass, sowing date, and seedling date), surface energy budget (including sensible heat, latent heat, and four components of short-wave radiation (visible, infrared, scatter, and direct radiation), downward longwave radiation, net radiation), canopy temperature, and soil surface moisture.

4.2 Data Results

Certain differences were observed in the leaf area index between different scenarios, years, and stations (Figure 1). Between different scenarios, the spring maize had an earlier sowing date, a smaller peak of leaf area index, and an earlier harvest date. The potential maize had an earlier sowing date, the highest peak of leaf area index, and a later harvest date. The summer maize had a later sowing date, a middle peak of leaf area index, and a later harvest date. The leaf area index fluctuated significantly between different years. In most cases, the interannual fluctuations of the leaf area index between different scenarios were similar; that is, if the leaf area index is high in a certain year, then the leaf area index of all three scenarios is high. The difference in the leaf area index between stations is related to the spatial location. The stations located in the south have excellent hydrothermal conditions and generally have a higher leaf area index. According to the average leaf area index[3], the difference in the leaf area index between the three scenarios was in the range of −2.5 to 2.5. The relative magnitudes in the early stage of growth followed the order, potential maize > spring maize > summer maize, and gradually became summer maize > potential maize > spring maize in the later stage.

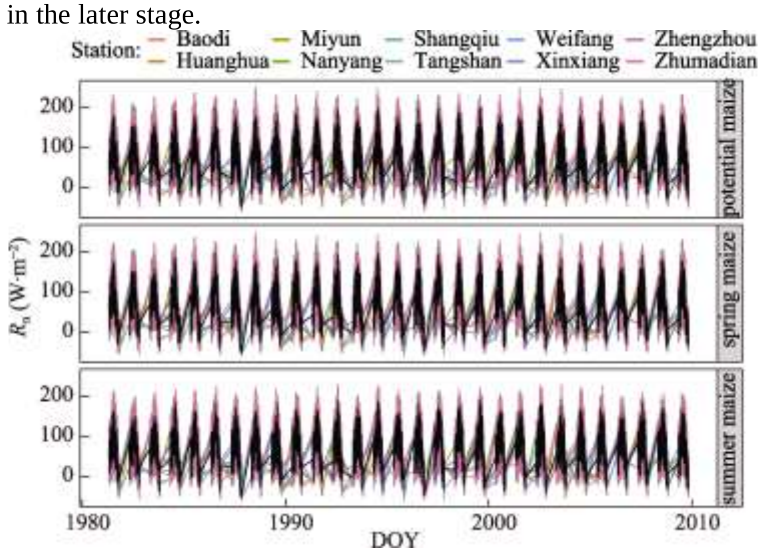

Figure 2 Seasonal dynamics of net radiation at different stations

The growth differences between different scenarios of each site were mainly exhibited in the late growth period, and the difference was small in the early stage of growth. For example, compared with the spring maize, the leaf area index of summer maize in the late growth period was higher, and stations located in the south had a larger difference. Compared with spring maize, the leaf area index of potential maize was higher, and stations located in the north had a larger difference. The leaf area index of potential maize in the northern station was generally higher than that of summer maize, and the leaf area index of potential maize in the southern site was lower than that of summer maize and became positive with the harvest of summer maize.

Net radiation showed evident seasonal dynamics (Figure 2). With the growth of maize, net radiation gradually increased, peaked at the peak growth of maize, and gradually declined. The peak of net radiation was 200 W m^{-2}, and the non-growth period was reduced to −50 W·m^{-2}. Large differences were observed in the net radiation between different years, and this finding was related to the leaf area index. However, the net radiation in some years (such as 1998 and 2004) with a high leaf area index was not the highest, and this finding was closely related to meteorological conditions. According to the average value of net radiation, the difference in net radiation between different scenarios can reach ±20 W m^{-2}, with early sowing and late harvesting scenarios having higher net radiation. During the growth period, scenarios with a high leaf area index captured more net radiation at about 10 W m^{-2}.

Changes in the latent heat flux were similar to net radiation (Figure 3). The peak of latent heat was 100–150 W m^{-2}. The difference in latent heat flux between scenarios was ±20 W m^{-2}. Certain results were evident in the two periods: the greater difference in the growth between different scenarios, the greater the difference in the latent heat. In addition, maize harvesting immediately significantly reduced the latent heat flux.

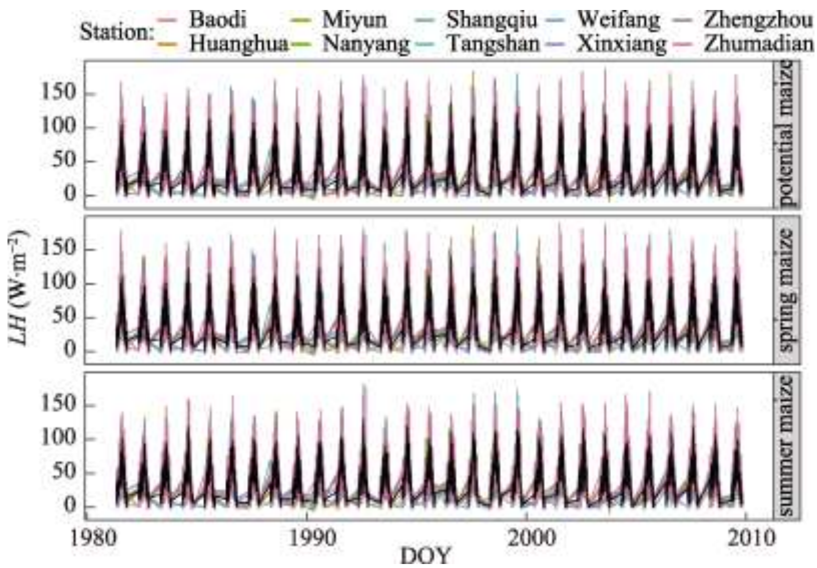

Figure 3 Seasonal dynamics of latent heat at different stations

The sensible heat flux fluctuated in the range of 0–50 W m^{-2}. Some sites have peaked at more than 100 W m^{-2} in certain years (Figure 4). Differences were noticed in the sensible heat flux between scenarios. The difference caused by various sowing dates was approximately 10 W m^{-2}, and the fluctuation caused by the difference in harvest date exceeded 15 W m^{-2}. The difference caused by different lengths of growth period was less than 5 W m^{-2}. The difference in the sensible heat flux between stations was similar to the change trends of net radiation and latent heat. Stations located in the south had higher net radiation and were allocated more to sensible and latent heat; the surface energy fluxes of northern stations were lower.

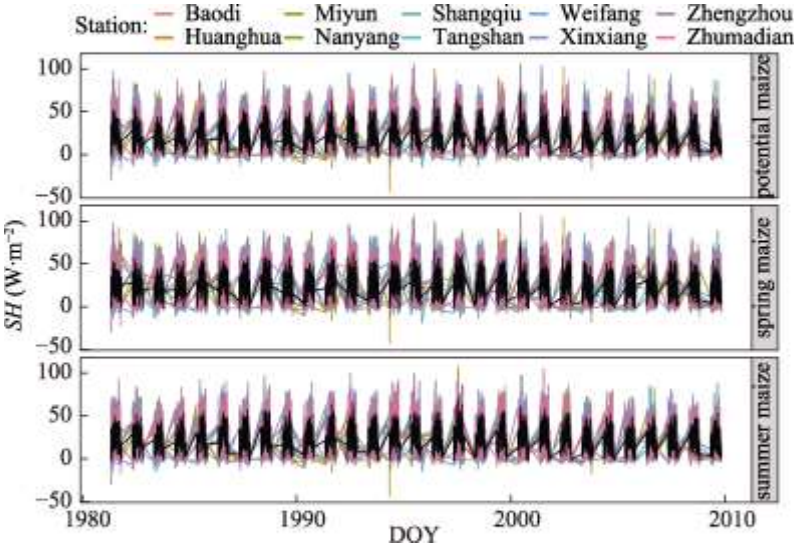

Figure 4 Seasonal dynamics of sensible heat flux at different stations

The fluctuation range of the canopy temperature in the maize growing season was 280–300 K. The canopy temperature difference between scenarios was ±0.5 ℃ (Figure 5). In different scenarios, the canopy temperatures at different nodes—the sowing date (early sowing, DOY145; abbreviated as D1; late sowing, DOY173; abbreviated as D2), peak transition time of leaf area index (DOY225, abbreviated as D3), harvest date (spring maize, DOY253, abbreviated as D4; summer maize, DOY279, abbreviated as D5; potential maize, DOY304, abbreviated as D6)—were compared; the sowing and harvest dates of maize are the key nodes for temperature differences[3]. The difference in canopy temperature between different scenarios varied with the change in the above key nodes. For example, the simulated values of spring and summer maize showed that from D1 to D2 and D3 to D5, the canopy temperature difference was positive, and the canopy temperature difference from D2 to D3 was negative. The difference between the simulated values of potential and spring maize was significantly negative from D4 to D5, and the canopy temperature difference was positive from D5 to D6. The difference between the simulated values of the potential and summer maize scene was similar to the spring-summer scenario. A positive difference was observed between D5 and D6, and the scenarios of spring and summer maize were obtained. No difference was observed in the canopy temperature between the two.

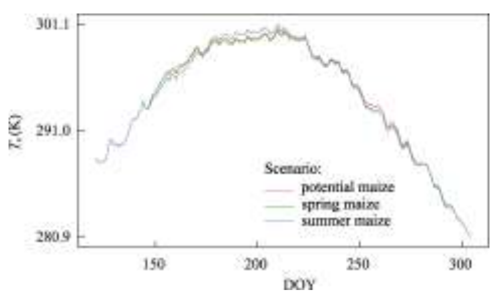

Figure 5 Different canopy temperatures between various simulation scenarios

4.3 Data Validation

Three statistical parameters were used to analyze the model's simulation errors in the leaf area index, latent heat, and apparent heat (Table 4). The model showed a good simulation of maize growth dynamics; the simulation accuracies of latent and sensible heat flux were poor.

The flux error varied from site to site. The sensible heat flux simulation accuracy of Yucheng Station was higher than that of Guantao Station, and the latent heat simulation accuracy of Guantao Station was higher than that of Yucheng Station. Certain differences were observed between the simulated and actual phenologies. On average, the simulated sowing date of spring maize was 7.4 days later than the actual, and the harvest date was 18.5 days later. The simulated sowing date of summer maize was 5.1 days later than the actual, and the harvest date was 17.5 days later.

Table 4 Simulation accuracy of SiBcrop model

Parameter	Yucheng Station			Guantao Station		
	R^2	RMSE	IOA	R^2	RMSE	IOA
LAI	0.93	0.49	0.96	–	–	–
LH	0.53	17.97 W m^{-2}	0.83	0.83	14.22 W m^{-2}	0.9
SH	0.6	14.82 W m^{-2}	0.77	0.47	9.7 W m^{-2}	0.75

Note: LAI, leaf area index; LH, latent heat flux; SH, sensible heat flux.

5 Discussion and conclusion

Changes in agriculture phenology in temperature areas usually show that the surface energy distribution-cooling effect exceeds the surface albedo-warming effect, resulting in the overall cooling influence. In the Agro-IBIS model, changes in the latent and sensible heat fluxes caused by the prolonged growth of maize were more than 47 and −20 W·m^{-2}[4], respectively. Early sowing increased (decreased) the latent (sensible) heat flux in June, and shortening from the maturity to the harvest date enhanced the net radiation in October[5]. Compared with maize monoculture, winter wheat harvesting in wheat–maize rotation system increases temperature and reduces humidity, which in turn affects atmospheric circulation and precipitation[1]. Under the background of climate change, the early sowing date and extended length of growth period are important changes in agroecosystems. This dataset shows the influence of the sowing date and the length of growth period on the surface energy budget. The magnitude of data was similar to the results of others, but it contained more information, which provides good guiding significance for the restructuring and management of the rotation system in North China Plain.

The surface process model showed a certain simulation error in the surface energy and water flux. In the SiB_2 model driven by remote sensing data, the simulation errors of latent and sensible heats in the winter wheat–summer maize rotation system in North China Plain were 35.6–40.8 and 32.6–69.8 W m^{-2}, respectively[6]. The simulation errors in the VIP model were 40.37 and 47.7 W m^{-2}[7]. Community Land Model was used to simulate the growth process of maize. The simulation errors of latent heat flux were 87.5 W m^{-2} (root mean square error (RMSE)), 0.71 (R^2), and 0.89 (IOA); the simulation errors of sensible heat flux were 67.5 W m^{-2} (RMSE), 0.4 (R^2), and 0.77 (IOA)[1]. The simulation error of this data was close to that of others, and provides the simulation accuracy of sowing and harvest dates, which has a good application value.

This dataset provided the surface energy and water balance under three maize scenarios based on the SiBcrop model simulation. Based on the phenological dynamics of maize under the background of climate change, two maize sowing dates and two growth periods in the North China Plain were constructed, and the effects of different scenarios on the material and energy exchange in the boundary layer were simulated using improved SiBcrop. The research results revealed different processes of surface energy and water balance between maize scenarios. The differences in maize growth processes interact with meteorological conditions. During the inter-sowing, growth, and inter-harvest periods, different effects were observed on factors, such as net radiation, latent heat, sensible heat, and canopy temperature. The earlier sowing date showed a certain warming potential, and the warming effect of the extended growth period was not evident. This climate feedback process is of reference value in guiding the mitigation of climate change in the North China Plain.

Author Contributions

Liu, F. S., Ge, Q. S., and Tao, F. L. made the overall design of data development; Cai, Y. X. and Bu, J. C. collected and processed meteorological data; Liu, F. S. and Tao, F. L. designed models and algorithms; Cai, Y. X., Bu, J. C., and Bai, N. N. did data verification; Liu, F. S. and Tao, F. L. wrote data papers.

Conflicts of Interest

The authors declare no conflicts of interest.

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