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Dataset of Spatio-Temporal Variation in Effective Accumulated Temperature, Heat Use Efficiency in Wheat-Maize Rotation System in Henan, China (1981–2014)

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Abstract: Studying heat use efficiency of wheat-maize rotation system and its promotion potential in Henan province is of vital importance to the adaptation of crop production in Henan province, North China Plain and even the globe to climate change. Firstly, authors collected the meteorological data (daily average temperature) and agro-meteorological data (actual sowing date, maturity date and yield of wheat and maize) at 17 study sites in Henan province from 1981 to 2014. Secondly, dataset of effective accumulated temperature, heat use efficiency (HUE) and its promotion potential in wheat, maize and wheat-maize rotation system were conducted by statistical methods including regression analysis and significance test with Matlab programming. Lastly, the study results at the site scale were interpolated to the regional scale with the method of Inverse Distance Weight. The data results showed that there was a high gap between potential and actual effective accumulated temperatures of wheat-maize rotation system in the north and east parts of Henan province, while HUE in the northern and eastern Henan province was higher than that in the southern and western Henan province. The gap between potential and actual effective accumulated temperatures and HUE of wheat-maize rotation system increased with periods. The spatial data includes 3 parts: (1) planting area of wheat-maize rotation system and distribution of 17 study sites in Henan province; (2) spatial distribution of effective accumulated temperature and HUE of wheat-maize rotation system; (3) spatial distribution of change in effective accumulated tempera-

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[2] Chang, Q., Wang, J., Yu, W. D., *et al*. Dataset of effective accumulated temperature, heat use efficiency and trend in the wheat-maize rotation system in Henan, China (1981–2014) [J/DB/OL]. *Digital Journal of Global Change Data Repository*, 2020. https://doi.org/10.3974/geodb.2020.05.15.V1.

ture and HUE of wheat-maize rotation system from 1981 to 2014. Tabular data was archived in 4 Excel tables. Table 1 includes effective accumulated temperature during the growth periods of wheat and maize of different varieties in the four regions of Henan province in 2 workbooks separately. Table 2 includes actual growth periods of wheat, maize and the rotation system and their lengths at 17 study sites of Henan province in 3 workbooks separately. Table 3 includes effective accumulated temperatures of wheat, maize and the rotation system and their changes at 17 study sites of Henan province in 3 workbooks separately. Table 4 includes HUE of wheat, maize and the rotation system and their changes at 17 study sites of Henan province in 3 workbooks separately. The dataset was archived in .xlsx, .shp and .tif formats in 56 files, with data size of 4.26 MB (compressed to 1.40 MB in one file).

Keywords: heat use efficiency; wheat-maize rotation system; Henan province; 1981–2014

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.2020.05.15.V1.

1 Introduction

North China Plain is one of the most important planting regions of wheat and maize[1] in which Henan province plays an important role[2]. It will be beneficial to make full use of light and heat resources and improve the coincidence of crop growth requirement and heat resources supply through wheat-maize rotation system[3–6]. Light and heat resources are rich in Henan province[7], but there is a big difference in the distribution characteristics of heat resources in different regions of Henan province due to the change of solar altitude and elevation. The spatio-temporal distribution and the promotion potential of heat use efficiency in wheat-maize rotation system are still unclear. Therefore, it is necessary to study the temporal and spatial distribution characteristics of potential and actual effective accumulated temperatures and heat use efficiency and evaluate quantitatively utilization degree and promotion potential of heat resource in wheat-maize rotation system based on statistical analysis in Henan province. It will be convenient and reasonable to regionally improve the heat use efficiency and tapping crop production potential according to local climate conditions in Henan province.

In this dataset[8], spatio-temporal distribution of potential and actual effective accumulated temperatures and their gap, heat use efficiency and its promotion potential in wheat-maize rotation system were collected by using the data of daily average temperature, actual growth periods and yields of wheat and maize from 1981 to 2014 at 17 study sites. Through the method of collation, calculation, statistics and regression analysis, we finally interpolate potential and actual effective accumulated temperatures, their gap and heat use efficiency of wheat-maize rotation system into the regional scale with inverse distance weight method. This dataset will provide references for the promotion of regional heat use efficiency, exploitation of crop production potential and adaptation to climate change.

2 Metadata of the Dataset

The metadata summary of the "Dataset of effective accumulated temperature, heat use efficiency and trend in the wheat-maize rotation system in Henan, China (1981–2014)"[8] including name, authors, geographical region, years, temporal resolution, data files, data publisher, and data sharing policy is shown in Table 1.

Table 1 Metadata summary of the "Dataset of effective accumulated temperature, heat use efficiency and trend in the wheat-maize rotation system in Henan, China (1981–2014)"

Items	Description
Dataset full name	Dataset of effective accumulated temperature, heat use efficiency and trend in the wheat-maize rotation system in Henan, China (1981–2014)
Dataset short name	AccuTemHUE_Wheat&Maize_Henan
Authors	Chang, Q., College of Resources and Environmental Sciences, China Agricultural University/Shanxi Meteorological Service Center, changqing707448911@163.com Wang, J., College of Resources and Environmental Sciences, China Agricultural University, wangj@cau.edu.cn Yu, W. D., China Meteorological Administrator/Henan Provincial Key Laboratory of Agrometeorological Safeguard and Applied Technique, ywd@hims.org.cn Zhang, N., Shanxi Meteorological Information Center, xxzxzhning@163.com Li, M. W., Shanxi Climate Center, lmw0706@163.com Meng, J., Shanxi Meteorological Service Center, ZSshaking@163.com Li, W. K., Shandong Provincial Meteorological Service Center, liwenke0112@163.com Huang, M. X., College of Resources and Environmental Sciences, China Agricultural University, 1959837491@qq.com
Geographical region	Henan (31°23′N–36°22′N, 110°21′E–116°39′E). 17 study sites: Tangyin, Puyang, Xinxiang, Qinyang and Fengqiu in Northern Henan; Sanmenxia, Lushi, Yichuan and Ruzhou in western Henan; Qixian, Shangqiu, Huangfanqu, Shenyang and Zhumadian in eastern Henan; Neixiang, Nanyang and Fangcheng in sourthern Henan
Year	1981–2014
Temporal resolution	1 Year
Data format	.tif, .shp, .m, .xlsx
Data size	1.4 MB (After compression)
Data files	Spatial data: (1) Area of wheat-maize rotation system and 17 study sites in Henan province; (2) Spatial and temporal distribution of effective accumulated temperature and heat use efficiency of wheat-maize rotation system from 1981 to 2014 Tabular data: (1) The effective accumulated temperature during the growth period of wheat and maize of different varieties in the northern, southern, eastern and western Henan; (2) The actual growth period and its length, effective accumulated temperature and its change rate, heat use efficiency and its trend of wheat, maize and the rotation system based on the 17 study sites
Foundations	Ministry of Science and Technology of P. R. China (2017YFD0300105, 2017YFD0300404); China Meteorological Administration (CCSF202018)
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[9]
Communication and searchable system	DOI, DCI, CSCD, WDS/ISC, GEOSS, China GEOSS, Crossref

3 Methods

Daily average temperature in 17 study sites from 1981 to 2014 in Henan province in this dataset[8] were from National Meteorological Information Center, China Meteorological

Administration, which is used to calculate the potential and actual effective accumulated temperatures and their gap. The actual growth period and yield of wheat and maize were obtained from agricultural meteorological observation stations of Henan province, which were used to calculate the actual effective accumulated temperature and heat use efficiency.

3.1 Algorithm Principle

There are large differences in spatio-temporal distribution of heat utilization degree of wheat-maize rotation system and its promotion potential due to the decreasing elevation from west to east and the uneven distribution of heat and light resources in Henan province. The algorithm principle of this dataset is to understand intuitively the overall distribution of heat resource and the utilization degree of crop on heat resources by studying the temporal and spatial distribution of potential and actual effective accumulated temperatures of wheat-maize rotation system in Henan province. We can master the promotion potential of heat use efficiency in this area by analyzing the gap between potential and actual effective accumulated temperatures of wheat-maize rotation system. In this case, it can provide a theoretical basis for optimal allocation of heat resources, exploitation of production potential and the promotion of heat resource utilization rate. This method mainly consists of three steps:

(1) Calculate the potential and actual effective accumulated temperatures, their gap and heat use efficiency.

(i) Potential effective accumulated temperature is defined as effective accumulated temperature during the potential growth period, which is calculated as

$TT_{W\_P} = \Sigma T_i$, where $T_i \geq 0$ °C, T_i is the daily average temperature from October of last year to May of the following year, TT_{W_P} is the potential effective accumulated temperature of wheat.

$TT_{M\_P} = \Sigma(T_i - 10)$, where $T_i \geq 10$ °C, T_i is the daily average temperature from June to September, TT_{M_P} is the potential effective accumulated temperature of maize.

$TT_P = TT_{W\_P} + TT_{M\_P}$, where TT_{W_P}, TT_{M_P} and TT_P are the potential effective accumulated temperatures of wheat, maize and the rotation system, respectively.

(ii) Actual effective accumulated temperature is defined as effective accumulated temperature during the actual growth period of wheat and maize, which is calculated as

$TT_{W\_A} = \Sigma T_i$, where $T_i \geq 0$ °C; T_i is the daily average temperature during the actual growth period of wheat (Figure 1), TT_{W_A} is actual effective accumulated temperature of wheat.

$TT_{M\_A} = \Sigma(T_i - 10)$, where $T_i \geq 10$ °C; T_i is the daily average temperature during the actual growth period of maize (Figure 1), TT_{M_A} is actual effective accumulated temperature of maize.

$TT_A = TT_{W\_A} + TT_{M\_A}$, where TT_{W_A}, TT_{M_A} and TT_A are actual effective accumulated temperatures of wheat, maize and the rotation system, respectively.

(iii) The gap between potential and actual accumulated temperatures is defined as potential effective accumulated temperature minus actual effective accumulated temperature. The gap between potential and actual accumulated temperatures of wheat, maize and the rotation system are calculated as follows:

$TT_W = TT_{W\_P} - TT_{W\_A}$, $TT_M = TT_{M\_P} - TT_{M\_A}$, $TT = TT_P - TT_A$, where TT_{W_P}, TT_{M_P}, TT_P, TT_{W_A}, TT_{M_A}, TT_A, TT_W, TT_M, TT are potential effective accumulated temperature, actual effective accumulated temperature of wheat, maize and the rotation system respectively and their gap .

(iv) Heat use efficiency of wheat, maize and the rotation system are calculated as follows: $HUE = \frac{Y}{\sum_{i=1}^{k} T_i}$, where *HUE* is heat use efficiency; *Y* is actual yield ($kg \cdot hm^{-2}$); T_i is the actual effective temperature on the *i*th day during the actual growth period (The actual effective temperature meets the following conditions: the daily average temperature during the actual growth period of wheat is greater than 0 °C and the daily average temperature during the actual growth period of maize is greater than 10 °C), *k* is the length of growth period; $\sum_{i=1}^{k} T_i$ is actual effective accumulated temperature.

(2) Temporal trends of potential and actual effective temperatures, their gap and heat use efficiency of wheat-maize rotation system are analyzed by the method of linear regression[10].

(3) The results in site scale were interpolated to region scale by the method of inverse distance weight interpolation[2] (IDW) to obtain spatial distribution characteristics and variation trends.

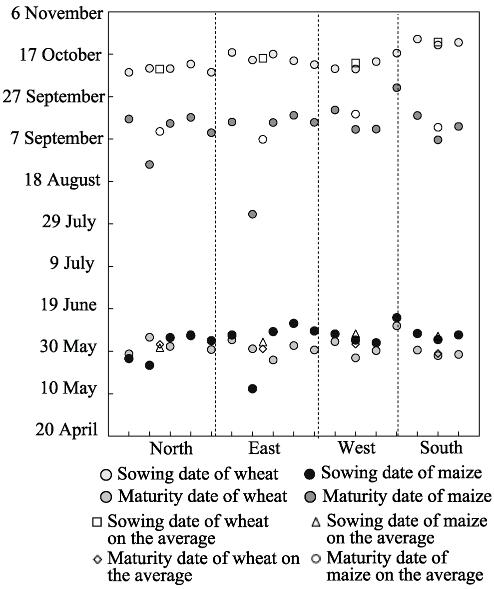

Figure 1 Actual growth periods and their average values of wheat and maize in 17 sites in the study area (Notes: Sowing date of maize was earlier than the maturity date of wheat at some sites in Henan province, which is related to the calculation method of taking the perennial average of sowing and harvesting dates and the planting method with intercropping of wheat and maize)

3.2 Technical Route

The development of this dataset included three steps: (1) spatial distribution of potential and actual effective temperatures, their gap and heat use efficiency of wheat-maize rotation system were obtained by data collection and sorting, calculation and analysis; (2) temporal variation characteristics of potential and actual effective temperatures, their gap and heat use efficiency of wheat-maize rotation system were obtained by linear regression and analysis; and (3) results at site scale were converted to spatial scale by the method of inverse distance weight interpolation (IDW).

4 Data Results and Validation

4.1 Data Composition

The dataset consists of 3 spatial data files and 1 tabular data file. Spatial data files includes: (1) planting region of wheat-maize rotation system and distribution of 17 study sites in Henan province; (2) spatial distribution of effective accumulated temperature and heat use efficiency of wheat-maize rotation system; (3) spatial distribution of the trend in effective accumulated temperature and heat use efficiency of wheat-maize rotation system from 1981 to 2014. Tabular data file consists of 4 data tables: (1) the effective accumulated temperature during the growth periods of wheat and maize of different varieties in the four regions; (2)

the actual growth periods of wheat, maize and the rotation system and their lengths based on the study sites; (3) effective accumulated temperature of wheat, maize and the rotation system and their trends based on study sites; (4) heat use efficiency of wheat, maize and the rotation system and their trends based on study sites.

4.2 Data Results

4.2.1 Actual Growth Periods of Wheat-Maize Rotation System and Their Interannual Change

The lengths of growth period of wheat-maize rotation system in different years ranged from 325–342 d with slight increase in northern Henan, increase–decrease–increase in eastern Henan, decrease in western Henan and decrease-increase in southern Henan (Figure 2). The spatial and temporal variations of the length of growth periods were caused by climate change, variety replacement of wheat and maize, and the change of sowing date in different regions.

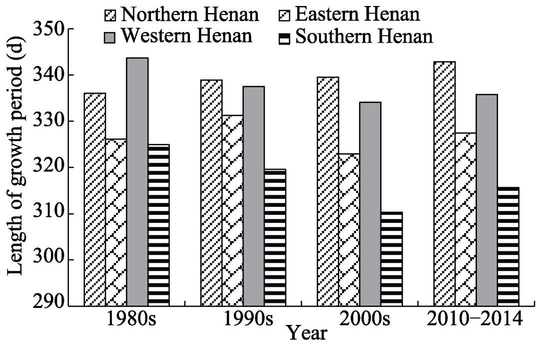

Figure 2 The length of growth period of wheat-maize rotation system in different regions and periods during 1981–2014 in Henan province

4.2.2 Temporal and Spatial Distribution

Potential and actual effective accumulated temperatures, their gap and heat use efficiency of wheat-maize rotation system were 3,815–4,560 °Cd (Figure 3a), 3,650–3,764 °Cd (Figure 3b), 154–827 °Cd (Figure 3c) and 1.5–3.5 kg·(°Cd·ha)$^{-1}$ (Figure 3d), respectively. The potential effective accumulated temperature in the south was higher than that in the north and it was higher in the middle of Henan province than that in the east and west parts of Henan province. The actual effective accumulated temperature was higher in the northwest and lower in the southeast. The gap between potential and actual effective accumulated temperatures reduced with the latitude, while the heat use efficiency was in the distribution characteristic of high-low-high from the northeast to the southwest. Potential and actual effective accumulated temperatures and their gap were lower in the northern and western Henan than other regions. The shortage of heat resources was one of the major factors that limiting the promotion of heat use efficiency. The potential and actual effective accumulated temperatures and their gap in the eastern part of western Henan were higher than other regions. The potential effective accumulated temperature was higher while the actual effective accumulated temperature was lower in southern and most part of eastern Henan than other regions. As a result, the gap between potential and actual effective accumulated temperatures was higher in the region than other regions. Therefore, heat use efficiency was lower in east part of western Henan, most parts of eastern Henan and southern Henan in spite of the abundance in thermal resources, which suggest large promotion potential of heat use efficiency in these regions.

Figure 4 showed the temporal distribution characteristics of potential and actual effective accumulated temperatures, their gap and heat use efficiency of wheat-maize rotation system. The potential effective accumulated temperature increased significantly except Fengqiu in northern Henan (Figure 4a) and the actual effective accumulated temperature increased significantly except Fangcheng in southern Henan (Figure 4b). Their gap decreased significantly at 2 sites, increased significantly at 6 sites and did not change significantly at other sites of Henan province (Figure 4c). Heat use efficiency increased significantly except Huangfanqu in eastern Henan and Yichuan in western Henan (Figure 4d). The results showed that the utilization degree of heat resource was improved significantly by the improvement of crop varieties, planting techniques and facilities under the background of climate warming, but there is still a great potential to improve heat use efficiency in most areas of Henan province, especially in southern and most parts of eastern Henan.

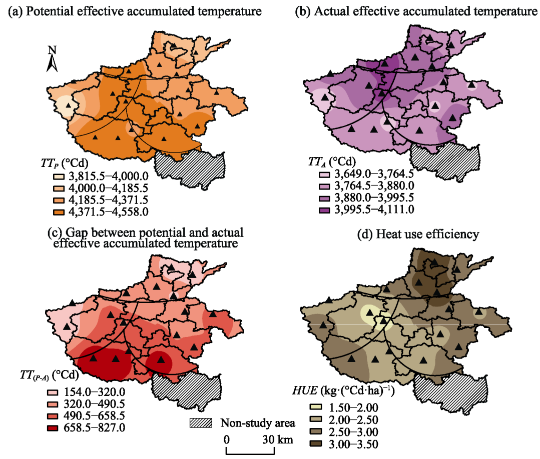

Figure 3 Spatial distribution of potential and actual effective accumulated temperatures, their gap and heat use efficiency of wheat-maize rotation system

4.3 Data Validation

Figure 5 showed the standard deviation and relative deviation of effective accumulated temperature and heat use efficiency of wheat and maize in four regions of Henan province from 1981 to 2014. Compared with existing relevant study results[3,11–12], the standard deviation of effective accumulated temperature of wheat was 34.02–162.95 °Cd, while the relative deviation was 2.14%–10.62%. The standard deviation of heat use efficiency of wheat was 0.001–0.28 kg·(°Cd·ha)$^{-1}$, while the relative deviation was 0.08%–18.46% (Figure 5a). The standard deviation of effective accumulated temperature of maize was 45.94–286.84 °Cd, while the relative deviation was 2.47%–15.64%. The standard deviation of heat use efficiency of maize was 0.18–0.40 kg·(°Cd·ha)$^{-1}$, while the relative deviation was 15.21%–24.29% (Figure 5b). The highest and lowest deviation of effective accumulated temperature of wheat was in southern and eastern Henan respectively, while the highest and lowest deviation of heat use efficiency was in southern and northern Henan respectively. The highest and lowest deviation of effective accumulated temperature of maize was in eastern and western Henan respectively, while the deviation of heat use efficiency was higher in northern and southern Henan than that in western and eastern Henan. The generation of deviation was related to the selected years, the distribution of sites and the measurement accuracy.

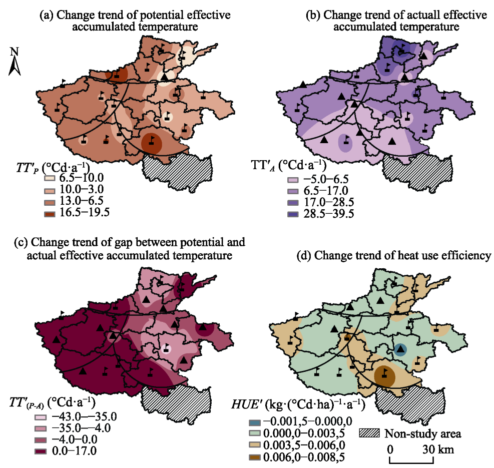

Figure 4 Spatial distribution of the change trend of potential and actual effective accumulated temperatures, their gap and heat use efficiency of wheat-maize rotation system

5 Discussion and Conclusion

The study systematically analyzed spatio-temporal distribution characteristics of heat resources and heat use efficiency of the wheat-maize rotation system, and quantitatively evaluated heat utilization rate of wheat and maize and its promotion potential based on the meteorological data of 17 study sites in Henan province from 1981 to 2014. It will provide an important support on the further improvement of heat use efficiency in this area. The study results showed that there were abundant heat resources in most areas of Henan province, especially in the eastern and southern Henan province. However, heat resources have not been fully used due to the short crop growth period. Therefore, the improvement of heat use efficiency in this area should be paid more attention in the future. This study will be a sound foundation for further research on heat use efficiency in Henan province and North China Plain.

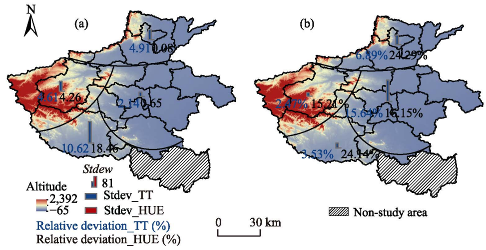

Figure 5 Standard deviation and relative deviation of effective accumulated temperature and heat use efficiency of wheat and maize in Henan province

Authors Contributions

Wang, J. put forward and promoted the research, designed the dataset, edited and revised the data paper; Chang, Q. collated, compiled and analyzed the critical data, and wrote the paper; Yu, W. D., Zhang, N., Li, M. W., Meng, J., Li, W. K., and Huang, M. X. participated in the processing and analysis of this study.

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