MONITORING AND RISK ASSESSMENT OF HIGH-TEMPERATURE HEAT DAMAGE FOR SUMMER MAIZE BASED ON REMOTE SENSING DATA

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ABSTRACT

In the context of global warming, high-temperature heat damage to summer maize has occurred in recent years, which has seriously affected the country's food security. At present, the research on high-temperature heat damage of summer maize is mainly based on point source data from ground observation stations, which lacks representativeness for large areas. Therefore, the remote sensing data and ground temperature data were combined to establish a high-temperature heat damage assessment model for summer maize production. The accuracy coefficients R^2 of the model are all above 0.8, and the root mean square error (RMSE) fluctuates within a small range of 2 ° C. The results showed that the high-temperature heat damage of summer maize production area in North China was relatively obvious in 2017 and 2018. And these damaged area mainly distributed in the southeast of Hebei Province, most of Henan Province and western Shandong Province. And the results are consistent with the actual statistics.

***Index Terms*—**Summer Maize; High Temperature Heat Damage; Remote Sensing; Model Establishment; Monitoring and Evaluation

1. INTRODUCTION

According to climate data statistics, the risk of high-temperature heat damage to summer maize in northern China is increasing. It is particularly important to study methods for monitoring and assessing. At present, most of the summer maize heat damage researches are based on ground-based point source data and extended to a wide range through spatial interpolation. The advantages of remote sensing data are real-time and regional, and the accuracy of inversion temperature has been tested. There are many studies on the use of remote sensing data for high temperature monitoring and assessment of rice and other crops [1], but few studies on summer maize. This study mainly uses MODIS land surface temperature products to build a regression relationship between land surface temperature and air temperature [2], and ground-based measurement data is used to fill areas with missing data. Eventually we can build time continuous temperature data for risk assessment of summer maize.

2. STUDY AREA AND DATA

The main producing areas of summer maize in the North China Plain were used as research areas, including the Beijing-Tianjin-Hebei region, Shandong province and Henan province. The data used in this study are mainly divided into two categories: ground measured data and remote sensing data. Ground measurement data includes: summer maize monitoring station distribution data, ground meteorological observation station temperature data. The remote sensing data includes MOD09A1 land surface reflectance data and MOD11A1 / MYD11A1 two kinds of MODIS land surface temperature products. Landsat data is also used to assist our work. The detailed information is shown in Table 1. All the above-mentioned remote sensing data are preprocessed, including geometric correction, atmospheric correction, stitching, cropping and projection conversion.

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Tab.1 Research data introduction

	Data	Function
Ground measured data	Summer maize monitoring site distribution data	Monitoring stations during summer corn development to help with classification
	Air temperature monitoring data	Provide daily ground air temperature measurement
	Summer maize development data	Provide specific time for each stage of summer corn development
Remote sensing data	MOD09A1 Land Surface Reflectance Data	Used to calculate NDVI and extract summer corn planting area through phenological changes
	MOD/MYD11A1 Surface Temperature Product	Provide daily land surface temperature

3. METHODOLOGY

MOD09A1 land surface reflectance data products were used to perform land cover classification, and summer maize pixels on remote sensing images were extracted based on the phenological changes. Then, we use two kinds of land surface temperature products (MOD11A and MYD11A1) to retrieve the daily maximum temperature and average temperature [2]. However, the temperature inversion is affected by cloud occlusion and aerosols, this paper uses ground measurement temperature data to perform interpolation to fill the lack of data [1]. Finally, combining with summer maize high-temperature heat damage judgment indexes and classification results, we use the generated "Satellite-Interpolation" fusion data to monitor high-temperature heat damage of summer maize.

3.1. Extraction and Precision Verification of Summer Corn Planting Area

Combined with the land use data, we select the pixels of summer maize, and then set the thresholds of NDVI in the images at different growing stages according to the phenological change characteristics to extract pure pixels of summer maize. Finally, we use high-resolution satellite images on Google Earth to select summer maize reference pixels, and their NDVI time series were extracted and SG filtered for reconstruction. Comparing the similarity between the NDVI time series of each pixel and the reference curve, we can get high-precision summer maize production area. The results are shown in Figure 1.

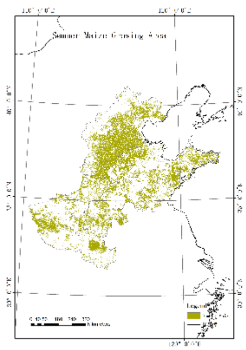

Figure.1 Summer maize distribution in the study area

Landsat8 OLI data with higher resolution and better quality were selected for area comparison verification during the same period, and Google Earth images with higher spatial resolution were used for position accuracy assessment (see Figure 2, MODIS on the left, and Landsat on the right). According to statistics, the planting area of summer maize extracted from the MODIS data is 227,325 hectares, and the planting area of summer corn extracted from the Landsat data is 246,127 hectares, with a relative deviation of 8.27%.

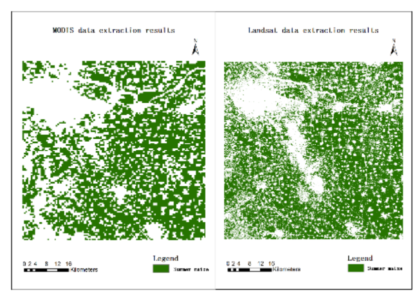

Figure.2 Comparison of MODIS-Landsat classification results

3.2. Processing of Land Surface Temperature Data

In this study, local polynomial interpolation was used to spatially interpolate the ground temperature data. The pre-processing of MODIS land surface temperature products includes image stitching, band extraction, image cropping, cloud removal, and removal of missing data areas. In this paper, air temperature is used as an index of the high temperature heat damage level of summer corn. Therefore, the regression relationship between the surface temperature and air temperature of MODIS is first established, and the surface temperature of MODIS is converted to the air temperature; Generating the final temperature fusion data for monitoring and evaluation of high temperature heat damage. The

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formula for converting pixel values into surface temperature in degrees Celsius in MODIS data is as follows:

$$LST = 0.02T - 273.15 \quad (1)$$

Where LST is the Celsius temperature of the surface unit covered by the pixel, and the unit is ℃; T is the bright temperature index of the pixel (that is, the pixel value), and the unit is K.

3.3. Establishment and Optimization of Regression Model

Taking the Beijing-Tianjin-Hebei region as an example, there are 122 ground observation stations, and 13032 sets of valid data are finally extracted. A total of 10846 sets of data from the first 100 stations are used to establish a regression model. A total of 2186 sets of data from the last 22 stations are used for model accuracy verification. The model was built by using multiple stepwise regression method. The daily average temperature and daily maximum temperature were used as dependent variables, and MOD_Day, MOD_Night, MYD_Day, and MYD_Night were used as independent variables to establish a linear model. The advantage of this method is that it ensures that each new variable introduced has a significant effect on the model dependent variable.

In order to eliminate the multicollinearity problem in the above model, the principal component analysis method is used for dimension reduction, and the final results are shown in the next section.

4. RESULTS

Taking the Beijing-Tianjin-Hebei region as an example, we built four models as shown in Table 2 through multiple stepwise regression.

Tab.2 Daily average temperature regression model

NO.	Model	R^2	Sig
1	Day_ave = 0.785MYD_NIG + 9.320	0.789	0.000
2	Day_ave = 0.644MYD_NIG + 0.228MYD_DAY + 4.165	0.822	0.000
3	Day_ave = 0.368MYD_NIG + 0.210MYD_DAY + 0.306MOD_NIG + 3.711	0.83	0.000
4	Day_ave = 0.375MYD_NIG + 0.174MYD_DAY + 0.262MOD_NIG + 0.091MOD_DAY + 2.843	0.832	0.000

Based on the results in the table above, this paper uses the model 4 with the highest accuracy for subsequent analysis. Then we apply the model to the next 2186 sets of data, and the inversion results and the measured temperature scatter distribution are shown in Figure 3. It can be seen that the determination coefficient R^2 of the model reaches 0.8189 and the RMSE is 1.96 ° C, which has relatively good accuracy.

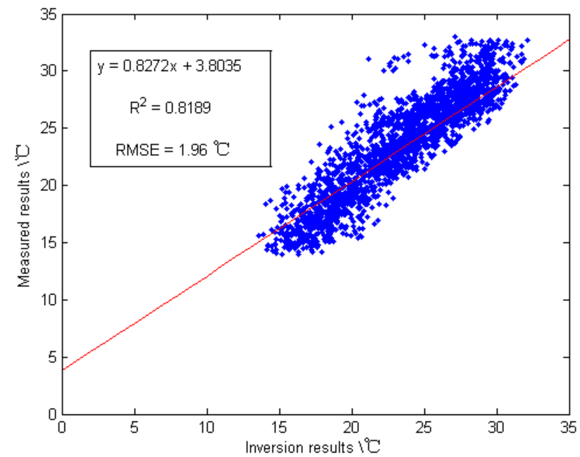

Figure.3 Model verification scatter plot

The results of optimizing the above model by principal component analysis are shown in Table 3.

Tab.3 Optimized final model

		Model	R^2	RMSE
Beijing-Tianjin-Hebei	AVG	Day_ave = 0.085MOD_DAY + 0.444MOD_NIG + 0.176MYD_DAY + 0.323MYD_NIG + 0.299	0.8171	2.08 ℃
	MAX	Day_max = 0.177MOD_DAY + 0.152MOD_NIG + 0.223MYD_DAY + 0.281MYD_NIG + 8.380	0.6727	3.14 ℃

The determination coefficient R^2 is 0.8171, and RMSE is 2.08 ℃, compared with the original model, the difference is small.

Combined with the measured data during the development period of the summer maize ground observation station, by studying the effect of temperature on corn yield and quality, and using commonly used business service level indicators, the summer maize high-temperature heat damage level indicators were established (see Table 4) .The corresponding high-temperature heat damage level can be determined based on the temperature reached by the average and maximum daily temperature and the number of days that last.

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Tab.4 Summer corn high temperature heat damage grade index

Damage level	Daily average temperature/℃	Daily maximum temperature/℃	Lasting days /d
1	≥30	≥35	3≤d<5
2	≥30	≥35	5≤d<8
	≥32	≥37	3≤d<5
3	≥30	≥35	d≥8
	≥32	≥37	5≤d<8
4	≥32	≥37	d≥8

The research focuses on 2017 and 2018, and the results are shown in the figure below.

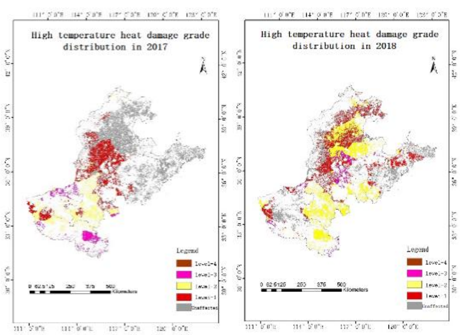

Figure.4 Distribution of disaster levels in the study area

The quantitative statistics of the affected area are shown in Table 5.

Tab.5 Statistics of the affected area from 2017 to 2018

Year	Total Affected Area (Thousand hectares)			Level-1 Affected Area (Thousand hectares)			Level-2 Affected Area (Thousand hectares)			Level-3 Affected Area (Thousand hectares)		
	JJJ	HN	SD	JJJ	HN	SD	JJJ	HN	SD	JJJ	HN	SD
2017	2053.4	3407.7	1218.2	1992.9	1034.4	1218.2	60.5	2187.7	0	0	185.7	0
2018	3420.5	3397.5	3232.9	1806.2	1001.6	1270.8	1498.8	2187.0	1388.9	115.5	208.9	573.3

Where JJJ represents Beijing-Tianjin-Hebei region, HN represents Henan Province and SD represents Shandong Province.

Taking the affected area in 2018 as an example, the statistics of the number of disasters at different levels are shown in Figure 5.

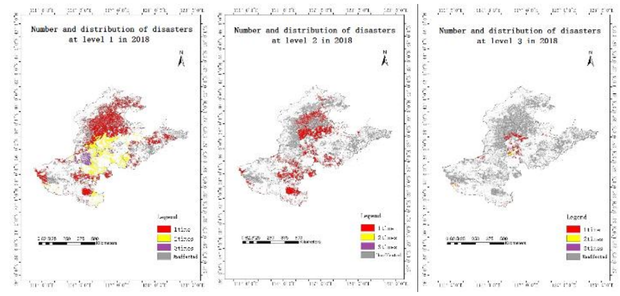

Figure.5 Number and distribution of disasters at various levels in the study area

5. DISCUSSION

Based on remote sensing data and measured data from ground-based meteorological stations, a model for monitoring and evaluating high temperature heat damage of summer maize was established, and its accuracy was verified and further optimized. The model was used to evaluate the high temperature heat damage in the main summer corn production areas, and the conclusions reached were consistent with the actual situation. Different from previous studies that directly used ground-based meteorological station interpolation data, the temperature fusion data produced in this paper has greatly improved the accuracy. In addition, the high temperature heat damage assessment of summer corn not only gives the distribution of the affected areas, but also gives the spatial distribution and frequency of occurrence of different levels of disasters, in order to further understand the damage degree of summer corn in the main producing areas.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] Yao F , Xu Y , Lin E , et al. Assessing the impacts of climate change on rice yields in the main rice areas of China[J]. Climatic Change, 2007, 80(3-4):395-409.

[2] Zhu W.B., Lu A.F., Jia S.F. Estimation of daily maximum and minimum air temperature using MODIS land surface temperature products[J]. Remote Sensing of Environment, 2013, 130:62-73.

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