Monitoring of Irrigation Area in Chuanhang Irrigation Area Based on MODIS Daily Surface Temperature Range

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Abstract. Monitoring and analysis of irrigated area is of great significance to evaluate irrigation benefit, agricultural drought situation and regional water resources utilization. This article selects MODIS surface temperature products from 2016 to 2020. Using the method of daily difference in surface temperature, eliminating the influence of precipitation, realizing remote sensing monitoring of irrigation intensity and spatial distribution of irrigation area. The results showed that the average number of irrigation times in five years was in the range of 6-8. Due to factors such as rainfall during the irrigation period, the overall irrigation frequency from 2016 to 2018 is less than the overall irrigation frequency in 2019 and 2020. On June 11, 2018, remote sensing images detected irrigation areas of Buzi Town, Longhe Town, Yangbei Town and Chenji Town, which were consistent with the data of irrigation areas.

1. Introduction

Accurate monitoring of the irrigation area is of great significance to the rational allocation of water resources in the irrigation area, the prevention of drought, and the optimization of the crop planting structure. China’s agricultural irrigation water consumption accounts for more than 60% of the total water consumption, of which the water used for irrigation accounts for more than 90% of the agricultural water consumption⁴. At the same time, China is a country with a shortage of arable land resources and water resources. At present, China's total water resources are more, but the per capita possession of water resources is very low. Due to geographical location and other factors, water resources in China are not evenly distributed in time and space. In terms of time, most of the annual precipitation in my country is concentrated in summer, with less precipitation in winter and large seasonal differences. Therefore, the rational allocation of water resources in irrigated areas has become the basis for the healthy development of agriculture in China⁵-⁷. It is of great significance to strengthen the optimal management of agricultural water, improve the utilization efficiency of water resources, and promote the modern management of large and medium-sized irrigated areas.

Monitoring methods for irrigation area include decision tree algorithm⁸-⁹, support vector machine⁹, machine learning algorithm¹⁰, spectral matching¹¹ and vegetation index¹². However, the essence of most
methods is to monitor the irrigated area based on the vegetation index, which is also related to soil properties, crop types and sowing time, etc., and the vegetation index changes little in a short period of time, so the response to soil irrigation information has a certain lag and uncertainty. Monitoring of irrigated area using surface temperature\cite{10} is characterized by direct, short monitoring period and so on. During the day, the surface temperature is lower than that of unirrigated land due to solar shortwave radiation and water evaporation. However, at night, the cooling rate of irrigated land is much lower than that of unirrigated land due to the influence of long wave scattering and the “heat preservation” effect of water. When crops are present, the water content in irrigated land is much higher than that in unirrigated land. Therefore, the temperature of irrigated land is lower than that of unirrigated land due to transpiration in the daytime. Di Lanjie\cite{11} used TVDI model of temperature vegetation index and ATI method of thermal inertia to retrieve soil temperature in Hebei Province, and verified the feasibility and accuracy of its application in soil moisture inversion. Shen Jing\cite{12} and Yi Zhenyan\cite{13} respectively adopted the method to determine the threshold value of PDI MPDI difference, combined with a few measured data, the irrigation area is extracted and good results are obtained. He Jiaojiao et al.\cite{14} compared the changes in surface and vegetation canopy temperature before and after irrigation based on the LST inversion of remotely sensed land surface temperature and the vegetation water supply index VSWI, and speculated that the water changes extracted the irrigated area of Shijin irrigation area.

This paper presents a method for dynamic monitoring of irrigated area using MODIS surface temperature data, meteorological data and crop phenological characteristics. It can provide basic data for crop structure adjustment, irrigation informationization and management, optimal allocation of water resources, drought monitoring, emergency and disaster reduction.

2. Research area and data

2.1 Study area
Chuanhang Irrigation District is located in the southwest of Sucheng District, Suqian City, Jiangsu Province. Geographical location is between 34° 02' to 34° 13' north latitude and 118° 100' to 118° 40' east longitude. It is adjacent to Suqian City and Zaohoe Irrigation District in the north, Beijing-Hangzhou Grand Canal in the east, Xisha River and Xuhong River in the west, bordering Xuzhou and Anhui, and Yaohe River and Dongfanghongdagou in the south facing Yunnan Irrigation District. It is one of the large irrigation areas that use the water source of the Beijing-Hangzhou Grand Canal. The irrigation area involves 7 townships (town and street offices), including Sankeshu, Buzi, Chenji, Luoweit, Nancai, Yangbei and Longhe. According to statistics, the total control area is 325.1 km², the arable land area is 320000 mu, the effective irrigation area is 314,000 mu, and the designed irrigation area is 320,000 mu. The irrigation area is mainly used for agricultural water supply. In 2019, the actual total water supply was 168.5 million cubic meters, of which 150 million cubic meters of farmland irrigation water, accounting for 89% of the total water consumption. The main crops planted in the irrigation area are rice, wheat, cotton, corn, vegetables and other crops. Rice-wheat rotation and wheat jade rotation are the main local planting modes.
2.2 Data source

Irrigation in large irrigated areas usually lasts for more than ten days or even a month. Real-time monitoring of the irrigation area requires remote sensing data with high time resolution. Therefore, we select the daily-scale MODIS surface temperature product MOD11A1. Since the irrigation time of the Chuanhang irrigation area is mainly concentrated from May to September, the MOD11A1 products of the study area during the 2016-2020 irrigation period can be downloaded for free on the website (https://e4ftl01.cr.usgs.gov/MOLT/). The data is daily-scale data with a spatial resolution of 1km. According to the latitude and longitude range of the marine irrigation area, query the horizontal number and vertical number of the data in the range, and the code of the image covering this study area is: h27v05. Use the MRT tool to perform band extraction, reprojection, mosaic, resampling, and cropping of the MODIS surface temperature data on the image. The historical weather in the study area can provide the meteorological data of the irrigation area, which can be obtained on the website (https://m.tianqi.com/lishi/suchengqu/index.html). Historical meteorological data such as the weather conditions, daily maximum temperature, daily minimum temperature, and daily temperature difference in the study area from May to September, 2016-2020, are used as the basis for the stage division and threshold calibration during the irrigation period. The rainfall data can be downloaded from the data website of the China Meteorological Administration.

3. Research method

3.1 Theoretical data

Affected by factors such as solar radiation, ground features, physical state, thermal characteristics, geometric structure, ecological environment, soil physical parameters, etc., there are significant differences in surface temperature and daily changes of different features. The general ground is irradiated by solar radiation during the day, and the temperature is higher. The ground scatters at night and the temperature is low.

The magnitude of this temperature change depends on the thermal inertia of the ground objects. The diurnal variation of temperature of different ground objects is significantly different, as shown in Figure 2, which shows the change curve of relative radiation temperature of different soil cover types (sandy land, grassland, woodland and lake) within 24h of a day. Since the specific heat capacity of the water body is greater than that of other ground objects, the temperature difference between day and night of the water body does not change much, so the daily temperature difference of the water body is smaller than that of other ground objects such as bare soil.

The increase of moisture in bare soil will make the daily temperature difference of the surface temperature smaller than that of dry bare soil. For the cultivated land area with vegetation coverage, the surface temperature retrieved by satellite remote sensing is affected by vegetation and soil [15]. Due to
the transpiration of crops, crops lack water during the day, transpiration and heat absorption are reduced, and leaf temperature rises. When crops are short of water at night, the heat preservation effect of water makes the surface temperature cooler faster than that of non-water crops. The daily temperature difference of water-deficient crops is larger than that of non-water crops. After irrigation, the soil water content of the cultivated land increases, and the daily difference in surface temperature is smaller than that of the unirrigated cultivated land. Therefore, a threshold value can be determined to determine whether the cultivated land is irrigated.

Figure 2: Daily variation of surface temperature of typical features

3.2 Threshold calibration
Agricultural irrigation in China is carried out by households, and the area of farmland in a single household is small, and the distribution is relatively scattered. Therefore, it is difficult to find the "pure pixel of irrigation" in the image to determine the threshold value. Using MODIS LST data, in the lateral direction, the daily LST range will become smaller after irrigation from single view analysis. In longitudinal analysis, using multi-scene images over a period of time, there will be a diurnal variation curve of surface temperature within a period of time after irrigation (that is, it will first decrease, then increase, and finally stabilize). Combine horizontal and vertical analysis, and use historical meteorological data such as daily maximum temperature, daily minimum temperature, and daily temperature difference in the study area to calibrate the threshold to determine whether irrigation occurs.

3.3 Removal of rainfall data
The effect of precipitation should be taken into account when the threshold value is used to determine irrigation. Using historical meteorological data in the study area, the data on the day of precipitation and the first day after precipitation are first excluded. The data from the second to the fifth day after precipitation are judged based on the data on the first day after precipitation. That is, if irrigation is not displayed on the first day after precipitation, and irrigation is displayed on the second or later days after precipitation, it means that it is not affected by precipitation and does not need to be excluded. If irrigation is shown on the first day after precipitation, and irrigation is shown on the second to the fifth day after precipitation, and the daily range of surface temperature gradually increases, it indicates that it is affected by precipitation and needs to be eliminated.

3.4 Determination of irrigation intensity
According to meteorological factors such as annual precipitation in the study area, the annual irrigation cycle is not fixed. The interval between the two irrigation sessions was about 10-20 days. However, the area of a pixel with a spatial resolution of 1 km is large, and the irrigation time of the cultivated land in different areas within the pixel is often different, which will cause the same irrigation to be identified multiple times. In addition, after irrigation, the soil moisture content in the study area would maintain a high value for several days, which would also make the same pixel in an irrigation cycle be recognized.
many times. Therefore, the decision tree method (see Figure 3) is used to take the day as the period (the first irrigation monitored by the pixel as the starting time). If multiple irrigation occurs in the same pixel within a period, it is only regarded as one treatment.

![Decision tree for calculating irrigation area and irrigation intensity](image)

**Fig. 3 Decision tree for calculating irrigation area and irrigation intensity**

**4. Result analysis**

**4.1 Land use classification**

The total area of Chuanhang Irrigation Area is 608,000 mu. The land use classification of Chuanhang Irrigation Area is carried out by using the method of supervision classification. The results are shown in Figure 4: the land use types in the irrigated area are cultivated land, construction land, woodland and water area. The area is dominated by cultivated land, with an area of 345,000 mu, accounting for 56.7% of the total area of the irrigated area. Next is the construction land, construction land mainly includes buildings, roads, etc. They are mainly concentrated in the east and south of the study area, covering an area of 194,000 mu, accounting for 31.9% of the total area of the irrigated area. The woodland area is 62,000 mu, accounting for 10.2% of the total area of the irrigated area. The water area is mainly the Beijing-Hangzhou Grand Canal, Xisha River and Xinminbien River, and the water area accounts for at least 1% of the total area of the irrigated area. The proportions of different land use types are shown in Fig. 5.

![Land use classification](image)

**Fig. 4 Land use classification**
4.2 Irrigation area and irrigation intensity analysis
Crops such as rice and wheat are mainly grown in the irrigated area. Irrigation is mainly carried out from June to September. Due to the influence of meteorological factors such as rainfall, the number of irrigation times will vary annually. The data of 2016-2020 is relatively good, and the available data amount meets the monitoring requirements of irrigation area. According to precipitation and crop requirements, the irrigation conditions in different years are different, and the results of remote sensing recognition can effectively reflect the temporal and spatial distribution characteristics of irrigation times. According to the variation of daily temperature range during irrigation period and the phenological characteristics of main crops, the irrigation period was divided into four periods: May 20 - June 29, June 30 - July 23, July 24 - August 20 and August 21 - October 15. Determine the daily difference thresholds for identifying irrigation in four periods during the irrigation period: 10°C, 9°C, 8°C, 10°C. Data on the day of rainfall and the first day of precipitation were excluded. Precipitation 2-5 days rainfall data is determined according to the change of daily difference whether to exclude. In different years, different irrigation cycles are determined by meteorological data such as precipitation and crop growth period data. The irrigation cycle is between 10 and 20 days.

As shown in Fig. 6, distribution of irrigation frequency and irrigated area from 2016 to 2020. The results of remote sensing identification can effectively reflect the distribution characteristics of irrigation times. The irrigation times in five years were 4 or more than 5 times, and the average irrigation times were within the range of 6-8 times. Among them, due to the high rainfall during the irrigation period from 2016 to 2018, the overall irrigation frequency in 2016-2018 was less than that in 2019 and 2020. In 2016 and 2017, there were mainly 5 and 6 irrigations. In 2018, it was mainly 6 and 7 irrigations. In 2019 and 2020, it was mainly 7 and 8 irrigations. On the basis of the identification results of irrigation times, we calculated the accumulative irrigation area of Chuanhang irrigation area from 2016 to 2020. As shown in Table 5, the accumulative irrigated area increased by about 650,200 mu during 2016-2020, among which the accumulative irrigated area in 2016 and 2017 was smaller than that in 2018-2020. This is due to more precipitation in 2016 and 2017 than in 2018-2020.
Fig. 6 Distribution of irrigation intensity and irrigated area from 2016 to 2020

Table 1 Statistical table of irrigated area and accumulated irrigated area in shipborne irrigation area

| Year | Irrigation times | 4    | 5    | 6    | 7    | 8    | 9    | Cumulative irrigated area (ten thousand mu) |
|------|------------------|------|------|------|------|------|------|--------------------------------------------|
| 2016 |                  | 1.05 | 13.46| 19.98| -    | -    | -    | 191.38                                     |
| 2017 |                  | 1.87 | 21.80| 55.04| 21.36| -    | -    | 187.27                                     |
| 2018 |                  | -    | 8.91 | 94.63| 119.05| -    | -    | 222.59                                     |
| 2019 |                  | -    | 0.20 | 21.54| 109.22| 111.04| 13.03| 255.03                                     |
| 2020 |                  | -    | 4.98 | 15.76| 86.49| 144.55| 4.62 | 256.40                                     |
4.3 Accuracy Verification

The method of remote sensing monitoring and identification of irrigated area based on land surface temperature is more sensitive to the change of soil water content. After irrigation, soil moisture content will rise. This will enable the irrigation area on the day of irrigation to be monitored by remote sensing. According to statistics from the shipping irrigation area, irrigation was carried out on June 11, 2018. The result image of the day monitored by remote sensing image is shown in Figure 35. The irrigation areas on that day were Buzi Town, Longhe Town, Yangbei Town and Chenji Town, which were consistent with the irrigation area data. The accumulative irrigated area in 2016-2017 was smaller than that in 2018-2020, because the precipitation weather during the reirrigation period in 2016 and 2017 was about 30 days. While, there are fewer days of precipitation in 2019-2020, so the cumulative irrigated area and irrigation intensity in 2019-2020 are greater than those in 2016 and 2017, which is consistent with the actual situation.

5. Conclusion

This study uses MODIS surface temperature data, meteorological data and other auxiliary data from 2016 to 2020. Using the method of calculating the daily difference in surface temperature, combined with the irrigation system, and eliminating the influence of water. The irrigation intensity, irrigation area and their spatial distribution were monitored by remote sensing, and the cumulative irrigation area was calculated. The conclusions are as follows:

(1) According to the variation of daily temperature range during irrigation period and the phenological characteristics of main crops, the irrigation period was divided into four periods: May 20 - June 29, June 30 - July 23, July 24 - August 20 and August 21 - October 15. Determine the daily difference thresholds for identifying irrigation in four periods during the irrigation period: 10℃, 9℃, 8℃, 10℃.

(2) The remote sensing recognition results can effectively reflect the distribution characteristics of irrigation times, and the five-year average irrigation times are in the range of 6-8 times. Among them, due to the heavy rainfall during the irrigation period in 2016-2018, the overall irrigation frequency in 2016-2018 is less than the overall irrigation frequency in 2019 and 2020. In 2016 and 2017, there were mainly 5 and 6 irrigations. In 2018, it was mainly 6 and 7 irrigations. In 2019 and 2020, it was mainly 7 and 8 irrigations.

(3) Irrigation was carried out on June 11, 2018, and the results of that day were detected by remote sensing images in the irrigated areas of Buzi Town, Longhe Town, Yangbei Town and Chenji Town, which were consistent with the data of the irrigated areas. The cumulative irrigated area in 2016-2017 was smaller than that in 2018-2020, because the rainfall during the re-irrigation period in 2016 and 2017 was about 30 days. The number of precipitation days in 2019-2020 is relatively small, so the cumulative irrigated area and irrigation intensity in 2019-2020 will be greater than in 2016 and 2017, which is consistent with the actual situation.
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