Prediction of Winter Wheat Growth Trends Based on NDVI Vegetation Index

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Abstract

As modern technology emerged, the level of agricultural remote sensing has been further improved. This paper takes winter wheat as the research object, studying on Liangshan County in Shandong Province, where the planting coverage of winter wheat is high. Image preprocessing is carried out using ArcGIS, combined with ENVI to invoke satellite data in the near-infrared and infrared bands to calculate the NDVI index from the regreening stage to the maturity stage of winter wheat in this area. During the maturity stage of winter wheat, NDRE is used instead of NDVI to solve the problem of inaccurate NDVI measurement in high-density vegetation coverage. The simulation results show that the test data matches the actual winter wheat output value.

Keywords: NDVI, winter wheat, agricultural remote sensing, ENVI, ArcGIS

1. Introduction

The most important thing for the people is agriculture. Agriculture is the foundation of the national economy. With the continuous development of science and technology and agricultural digitization, agricultural remote sensing stands out with its advantages of wide observation range, large amount of information and long monitoring duration, and has become one of the important means of current agricultural management [1,2]. Winter wheat is one of the three major food crops in the world. How to accurately monitor crop growth and establish agricultural disaster intervention system has become an important task for agricultural workers. In this paper, by combining remote sensing and GIS technology, the typical vegetation index NDVI was selected to analyze the growth of winter wheat. This paper provided new ideas for decision-making management of winter wheat production.

2. Research areas and methods

2.1. Overview of the study area

Shandong Province is located in the middle and lower reaches of the Yellow River, with a warm temperate monsoon climate type, mild climate and sufficient sunlight. Shandong Province is suitable for the growth of various crops. Winter wheat is widely planted in the province, accounting for about 14% of the national wheat planting area. As one of the typical representatives of winter wheat planting areas, Liangshan County has the characteristics of suitable climate and flat terrain. Its planting area remains high, and the planting area will reach 938,000 mu in 2024. At the same time, most other crops are in the sowing period during the winter wheat growth period, with less interference.

2.2. Data source and preprocessing

The Landsat8 satellite is loaded with multi-spectral and thermal infrared sensors. Its panchromatic band can clearly capture the subtle features of the earth's surface. The data spatial resolution reaches 30 meters, and some resolutions are as high as 15 meters. At the same time, due to its long-term series and multi-band coverage, it can provide rich surface information. And it has significant advantages in analyte growth and changes.

On the geospatial data cloud platform, locate Liangshan County and select Landsat 8 OLI satellite products to download satellite data of Liangshan County. Then use the downloaded shapefile data of China's administrative regions. Query Liangshan County according to the attribute table of the surface data, export the graphical data of Liangshan County and combine it with the downloaded spatial data in ENVI. Image cropping was performed to obtain Liangshan County spatial remote sensing data. The spatial remote sensing data of Liangshan Count is shown in Fig1.

Fig.1. Atmospheric correction remote sensing image

2.3. NDVI Index Calculation

Vegetation normalization index (NDVI) is an important parameter used to reflect vegetation growth status and coverage. It can transform multispectral data into a single image band to characterize vegetation distribution characteristics [3]. At the same time, NDVI can reflect the background influence of plant canopy, such as soil, wet ground, snow, dead leaves, roughness, etc. Its value is between-1 and 1. The closer its value is to 1, the more vegetation is distributed and the greater the coverage rate. When it is 0, it represents the corresponding place for rock,

bare soil, etc. While when its value is negative, it means that the ground cover is water, snow and other non-vegetation substances. The reflectivity of chlorophyll to the spectrum is obviously different. It mainly absorbs red light and blue-violet light for photosynthesis and reflects green light, making plants appear green. The near-infrared band is the main band reflected by the internal structure of plant leaves (such as cell wall, mesophyll, etc.). The NDVI is calculated by using near-infrared (Band5) and infrared band (Band4). The calculation formula is:

$$\mathrm{NDVI} = \frac{\mathrm{NIR} - \mathrm{RED}}{\mathrm{NIR} + \mathrm{RED}} \quad (1)$$

(where, NIR Is the reflectivity in the near infrared band,REDIs the reflectivity in the infrared band)

Although NDVI can quantitatively determine the growth of winter wheat in the region, NIR is difficult to reach the lower part of the plant canopy. Some of the lower canopy NIR light was ignored, and high levels of chlorophyll had already accumulated in the leaves during the winter wheat growth spurt. Measurements using NDRE are more accurate than NDVI. Using NDRE in its maturity stage, it can not only reflect its maturity, but also evaluate the health status of crops. In the mature stage of vegetation, NDRE begins to decrease due to the change of wave band, but it decreases slowly. If it decreases rapidly, it means that the vegetation may be in danger of pests and diseases, so it can be found and treated in time. At the point where NDVI falls to a certain threshold, it means that the winter wheat can start to be harvested. Harvesting winter wheat at this time of year prevents damage to yields by harvesting too early or too late. Utilization helps predict the timing of harvesting winter wheat and corresponding field management. The calculation formula is:

$$\mathrm{NDRE} = \frac{\mathrm{NIR} - \mathrm{RE}}{\mathrm{NIR} + \mathrm{RE}} \quad (2)$$

(HIRis the reflectivity in the near infrared band,RE is the reflectivity of the red edge band)

In order to visualize the growth of winter wheat, this paper establishes a geographic information display platform for crop growth. The Brouser-Server (BS) architecture is utilized so that the browser acts as a client in conjunction with the server to form the architecture, as shown in Fig.2. That is, the customer only needs to have a browser to carry out the appropriate services, and log in to the system by means of an account password, etc., in order to obtain the relevant privileges and services of the system. This paper utilizes the vs code integrated development environment to write a geographic information management system front-end framework, call leaflet open source JavaScrip library. The paper realizes the online map development of Liangshan County, as shown in Fig.3. The paper calls the Baidu map API interface to use Baidu map information as the core content of the visualized geographic screen and import the processed NDVI data into the Mysql database. It predicts the future growth condition of winter wheat in Liangshan County as well as the yield situation. And it sets up the early warning function through the threshold method discovers the abnormal state of winter wheat growth in time. It also discovers the abnormal state of winter wheat growth in time. The above measures enable rationalization suggestions and initiatives, and finally the platform is piggybacked to run on AliCloud servers.

Fig.2. Platform login interface

Fig.3. Liangshan County Visual Large Screen

3. Results and analysis

3.1. Analysis of horizontal differences in NDVI

The phenological stage of winter wheat shows temporal and spatial characteristics [4]. The main phenological stages are divided into regreening stage, jointing stage, heading stage and maturity stage. In different growth intervals, the chlorophyll content of winter wheat is different, and the corresponding NDVI changes. The four-month remote sensing data of winter wheat phenology in 2018 were processed as Fig.4, and two NDVI trend curves were fitted and drawn three times as Fig.5 Comparison of the results of the analysis shows that, in time, the two trend curve changes converge to show faster growth. Winter wheat thrived during the phenological period and chlorophyll area began to increase significantly, leading to a decrease in NIR. RED began to increase, and the NDVI index changed significantly from 0.373348 at the regreening stage to 0.735383 at the heading stage. In June, the regional average NDVI reached the highest value of around 0.44, and then entered a period of slow growth or even declined. At this time, winter wheat reached the maturity stage, chlorophyll began to decrease, RED began

to decrease, and NDVI began to decrease in some areas. Spatially, the NDVI in the eastern and southern parts of Liangshan County took the lead in increasing to a high value, while the growth in the western parts was slower. As shown in Fig.4, the regional difference results were also highly correlated with the winter wheat yield in this region in 2018. So far, studies have confirmed this idea [5], and realize the application [6,7]. There is also a constant low-value area in the middle. According to the characteristics of remote sensing images, it can be further found that this area has been widely developed as a commercial area. And this area has been widely developed as a concentrated population residence. This conclusion can also be used to judge the prosperity of the city.

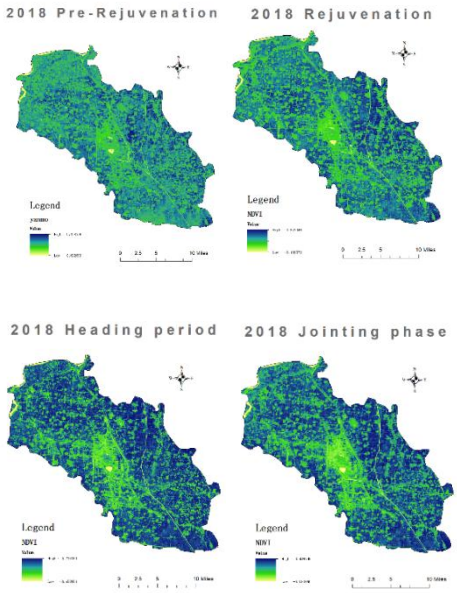

Fig.4. Distribution of NDVI in the winter small phenological period of 2018

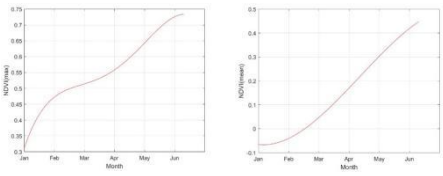

Fig.5. NDVI trend curve of winter phenology in 2018

According to the fitting data of two trend curves and using the method of threshold setting, we can evaluate and analyze the growth of any area in any period and draw the evaluation grade chart. The value of NDVI near the regional average is regarded as normal growth, the value far lower than the average is invalid, and the value significantly higher than the average and close to the maximum value is growth preference. The growth evaluation of the regreening period in 2018 is shown in Fig.5. The image intuitively shows the crop growth status of each village and town, and the information content is large. On the whole, the plants grow well in the north and south of Liangshan County. But not in the east, it has a certain guiding effect on the growth of winter wheat.

3.2. Comparison of longitudinal interannual changes of NDVI

Taking the regreening period as an example. This paper processed and analyzed the 2016-2021 five-year winter wheat regreening period tele-imagery (2017 data quality is poor). It was found that there were large inter-annual differences in NDVI. The overall trend shows an increase, which can be considered as an increase in winter wheat production. The results showed that there was a large interannual difference in NDVI, and the overall trend showed an increase. It can be considered that the yield of winter wheat increased. In order to eliminate the influence of irrelevant factors and judge the interannual difference of NDVI from the whole, the NDVI distribution image is binarized. 0 represents the part where NDVI is less than 0.3 and 1 represents the part where NDVI is greater than 0.3. As shown in Fig.7, the result is more intuitive. From the change curve in Fig.8, it can be intuitively seen that 2020 and 2021 have a certain fluctuation trend compared with previous years, from the average NDVI of regional winter wheat regreening period of 0.047593 in 2016 to the average NDVI of 0.127220 in 2020 and 0.058684 in 2021. The NDVI of winter wheat in the annual phenological period is treated by regional average value, and the results can be made as the evaluation grade map shown in Fig.6, and the growth of winter wheat in Liangshan County can be observed from the interannual scale. By consulting the relevant local policies and regional technology introduction strategies, it can be inferred that the winter wheat harvest in Liangshan County has been considerable in recent years. It shows that the introduction of new technologies has improved the agricultural yield and quality.

Fig.6. Grade Chart of Winter Wheat Growth Evaluation in Phenological Period in 2018

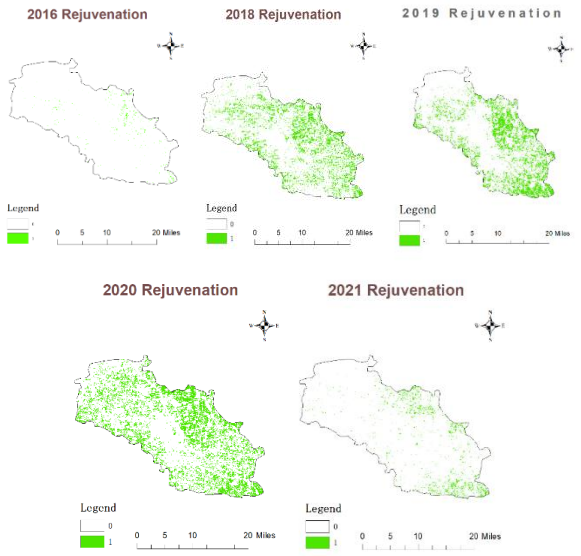

Fig.7. NDVI binarization image of Liangshan County from 2016 to 2021

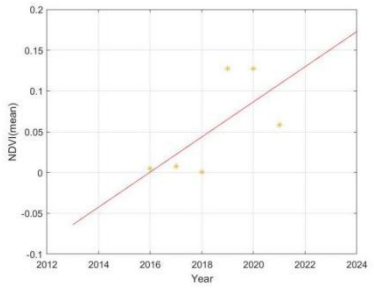

Fig.8. Interannual trend curve of NDVI

4. Conclusion and Prospect

In this paper, winter wheat was used as the research object and positioned in Liangshan County. In this paper, we use remote sensing technology tools to analyze the growth of winter wheat by calculating NDVI. The results showed that NDVI index could better reflect the growth status of winter wheat, and had a positive correlation with the yield. At the same time, the index had interannual and short-term temporal changes, which had important research significance for judging the growth and overall maturity of winter wheat in a region. Using NDRE instead of NDVI for follow-up analysis in the mature stage of winter wheat can better reflect the growth status of high-density vegetation and solve the problem of crown shading. In this paper, NDVI prediction of winter wheat growth also has some areas to be improved, and the influence of human activities and extreme weather may lead to the occurrence of outliers [8]. Some non-wheat crops may affect NDVI values to a small extent.

In future research, the application of other remote sensing indices in crop growth analysis can be further explored. Information from multiple sources can be combined for comprehensive analysis to improve the accuracy and reliability of the analysis. The latest research results generated are applied in the growth analysis of other crops to provide more comprehensive support and services for agricultural production.

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References

1. Zhang Yeping, Zhang Mingwei, Sun Ruijing, et al. Application of Fengyun Meteorological Satellite in Agricultural Remote Sensing. Science and Technology Herald, 2021, 39 (15): 39-45.
2. Zhuang Jiayu, Bao Weijia, Su Wuzheng. Present situation and prospect of agricultural remote sensing application. Agricultural Outlook, 2024, 20 (04): 68-74.
3. Liu Qinghua, Ren Jintong, Ren Fang. Analysis of NDVI Variation Characteristics in Liuchong River Basin Based on PIE-Engine. Science and Technology and Innovation, 2023, (12): 26-28 +34.
4. Zhao Yijing, Wang Xiaoli, Hou Xiyong, et al. Spatial and temporal characteristics of key phenological stages of winter wheat in Shandong Province from 2003 to 2019. Acta Ecologica Sinica, 2021, 41 (19): 7785-7795.
5. Pan Yangyang. Remote sensing monitoring and yield evaluation of leaf area index of jujube garden. Tarim University, 2024. DOI: 10.27708/d.cnki.gtlmd.2024. 000157.
6. Wu Yulun. Early rice yield estimation in Tianmen City, Hubei Province based on NDVI Modern Agriculture Research, 2023, 29 (09): 18-23. DOI: 10.19704/J.cnki.xdnyyj.2023. 09. 026.
7. Zhang Lei, Yao Mengyao, Liu Zhigang, et al. Estimation of corn yield based on UAV multispectral NDVI value. Xinjiang Agricultural Science, 2024, 61 (04): 845-851.
8. Liu Haihong, Yin Shuyan, Xu Liting, et al. The impact of extreme climate and human activities on NDVI of different vegetation types in Shandong Province. Journal of Ecology, 2023, 43 (21): 8780-8792. DOI: 10.20103/j.stxb.202209092577.

Authors Introduction

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