Real-Time Monitoring Technology of Potato Pests and Diseases in Northern Shaanxi Based on Hyperspectral Data

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Abstract. When using traditional monitoring technology to monitor the disaster area of potato in Northern Shaanxi, there was a problem of insufficient monitoring accuracy. In view of the above problems, a real-time monitoring technology for potato pests and diseases based on hyperspectral data is put forward. Firstly, the geological environment of the monitoring area is briefly introduced. Hyper Spectral Remote Sensing is used to obtain the hyperspectral data of the damaged area of the potato in the study area, and pretreatment is performed to establish a regression model. Finally, the pre-processed hyperspectral data is obtained. Substituting data into the model, the area of potato pests and diseases in the research area is obtained. The results showed that the accuracy of the method was 20.29% higher than that of the traditional potato pest and disease monitoring technology, and the accurate monitoring of the disaster area was realized. It has practicality and superiority.

Keywords: Hyperspectral data · Potato · Diseases and insect pests · Affected area · Monitor

1 Introduction

The northern Shaanxi region is the old revolutionary area and is the central part of the Loess Plateau in China. It includes Yulin City and Yan'an City in Shaanxi Province. They are all in the northern part of Shaanxi, so they are called Northern Shaanxi. The terrain is high in the northwest and low in the southeast. The area is a continental monsoon climate. The annual average temperature is 9.4°, the annual precipitation is 550 mm, and the frost-free period is 52 days. It is very suitable for the growth of crops, of which potato is one of the main crops in the area. It accounts for about 23% of the country's total crop output. However, pests and diseases are important factors that affect potato yield and quality. The common diseases and pests of potato in northern Shaanxi mainly include early blight, late blight, black shank, potato tuber moth, aphids, leafhoppers, golden needles, and ladybugs [1]. An early blight occurred in 2009, which resulted in a 10% reduction in the output of potato, a huge loss to the local agricultural economy, and a great impact on the agricultural production and ecological environment construction in China, which seriously restricted the sustainable development of agriculture in China. Therefore, people urgently need an effective method to monitor

S. Liu and G. Yang (Eds.): ADHIP 2018, LNICST 279, pp. 108–117, 2019.
https://doi.org/10.1007/978-3-030-19086-6_12

the occurrence and development of potato pests and diseases in time, control the area of damage and reduce the degree of harm.

The traditional real-time detection technology of crop diseases and insect pests based on GIS has obvious regional limitations, so it is impossible to predict crop diseases and insect pests in adjacent and similar planting areas. The real-time detection technology of crop diseases and insect pests based on Kinect is used to collect data in disaster-stricken areas. The result is unsatisfactory and the accuracy of detection is low, which can not provide effective technical support for pest detection. The use of Hyper Spectral Remote Sensing technology for real-time monitoring of potato diseases and insect pests has the advantages of large area, short period, and information obtained without interference. It has been paid more and more attention and has a broad prospect of development [2]. Taking the potato planting area of Yulin city in Northern Shaanxi Province as an example, the pests and diseases are monitored in real time. Firstly, the geological environment in the planting area was briefly introduced. Then Hyper Spectral Remote Sensing technology was used to obtain the hyperspectral data of the area affected by the potato in the study area, and pretreatment was carried out to establish a regression model. Finally, the pretreated high Spectral data were substituted into the model to obtain the area of potato pests and diseases in the study area. In order to verify the effectiveness of the real-time monitoring technology of potato pests and diseases in northern Shaanxi based on hyperspectral data, a comparative experiment was conducted together with the traditional pest and disease area monitoring technology. The results showed that comparing with the traditional monitoring technology of pests and diseases, the accuracy of the method was improved by 20.29%, and accurate real-time monitoring of potato pests and diseases was achieved.

2 Real-Time Monitoring Technology of Potato Pests and Diseases

Hyper Spectral Remote Sensing is the abbreviation of Hyperspectral Remote Sensing, it refers to the use of many very narrow (usually band width <10 nm) electromagnetic wave band to obtain relevant data from the target object, these data can form a complete and continuous spectral curve. Hyper Spectral Remote Sensing is one of the major technological breakthroughs made in the field of earth observation at the beginning of this century, and it is the leading edge technology of today's remote sensing [3]. Compared with the traditional remote sensing technology, Hyper Spectral Remote Sensing has the advantages of narrow band, many channels, and the combination of image and spectrum, and so on. It is imaging of the ground objects at the high spectral resolution and several hundred to hundreds of bands at the same time. Therefore, the spectral information of the ground objects is continuous and fine. This feature of Hyper Spectral Remote Sensing is very conducive to accurate real-time monitoring of the area affected by the feature [4]. The variation of spectral characteristics in the damaged potato area is the main basis for monitoring the area of potato pests and diseases by remote sensing. There are many diseases and insect pests of potato, such as early blight, late blight, black shank, potato tuber moth, aphid, leaf leafhopper, golden needle worm, ladybug and so on. The growth of potato is affected and appearance changes, such as leaf blight, falling or rhizome dead and so on. Therefore, according to the differences and structural anomalies of spectral reflectance obtained through remote sensing, especially the fine detection method with the help of Hyper Spectral Remote Sensing data, and under the support of geographic information system and expert system, the effective monitoring of the location and area of potato pests and diseases can be effectively realized.

2.1 Research Area

The study area is located in Yulin city of Northern Shaanxi, Yulin is located in the north of Shaanxi Province, Gansu, Ningxia, Inner Mongolia in the west, the Yellow River and Shanxi in the East, and Yanan in the south of Shaanxi. The geographical coordinates are: 36°57′–39°35′N, 107°28′–111°15′E. The sunshine time is long, and the average sunshine percentage is 59%–66%. In the continental monsoon climate, the temperature is evident throughout the four seasons. The pressure is high, the weather is clear, and there are many high clouds. Potatoes are the main grain crops in this area. The annual planting area is nearly 260 thousand hectares, accounting for about 30% of the grain crop area in the region. In recent years, because of the large amount of bacteria in the provinces and counties, the resistance to diseases and insect pests is not strong, and the outbreak of diseases and insect pests in the region is not strong, which leads to the serious reduction of wheat production in Yulin. In particular, early blight and ladybird pest were found in the potato field survey in 2009. The incidence time was the most serious in the past 20 years [5]. In addition, Yulin City Plant Protection Station randomly investigated 205 fields after the recurrence of potato pests and diseases, and found that 95 have been infected with pests and diseases, and the average disease and field rate reached 46.34%, which directly threatened potato planting safety.

2.2 Hyperspectral Data Acquisition and Preprocessing

On-site field observations were conducted on the study area on April 21, April 22, and April 25, 2009. A total of 34 sites were measured. In order to ensure the representativeness and validity of the spectral data, the selected observation sites covered the entire Yulin city, and the focus was on potato areas that were affected by pests and diseases. In all stations, potatoes in 26 site areas were affected by pests and diseases, and potatoes in the 8 station areas were not harmed. For the site where the potato was exposed to pests and diseases, spectral data of the four crop canopies were obtained at the same time, and two groups of data were collected from potato fields and neighboring normal potato areas under the pests and diseases. Ground field spectral observation instrument for ASD FieldSpec ProFR2500 spectrum radiometer, spectral range is 350–2500 nm, sampling interval in 350–1000 nm is 1.4 nm, in 1000–2500 nm is 2 nm. During observation, the probe is vertical downward, the height of the probe is 1.3 m, the angle of the field of view is 250, and the average value is repeated 30 times in the field of view, and the standard whiteboard is corrected before each spectrum measurement [6].

This study attempts to explore a commercial method for monitoring the disease and insect pests of Winter Wheat with wide band CCD images. The measured spectral reflectance of all winter wheat canopy is averaged according to the band width of satellite images: 520–600 nm (Green light wave band), 630–690 nm (light wave band), 760–900 nm (Near Infrared wave band), it matches ground measured spectrum data with remote sensing image data.

The pretreatment of the imaging spectrometer includes spectrometer calibration, spectral recovery, geometric correction, and atmospheric radiation correction. The complete pretreatment process for hyperspectral data of potato pests and diseases is shown in Fig. 1.

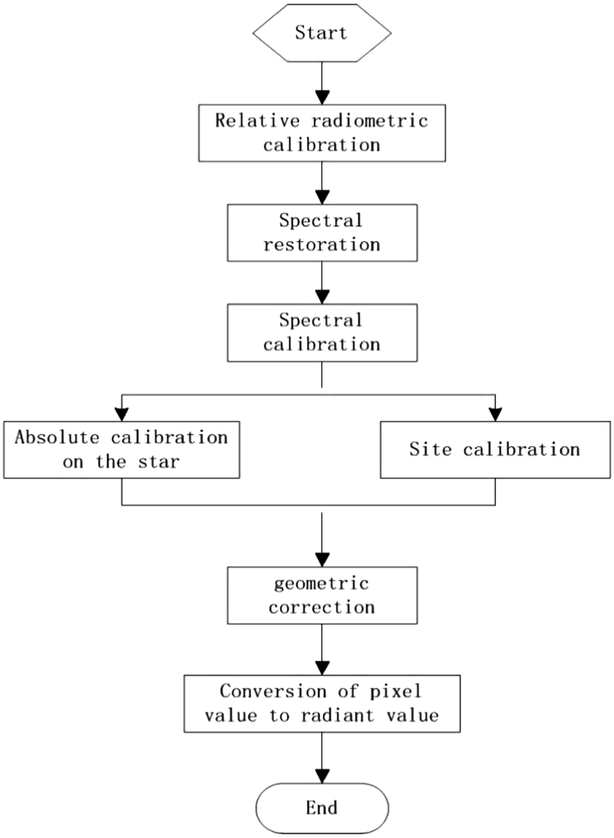

Fig. 1. Hyperspectral data preprocessing process

2.3 Potato Planting Range Information Extraction

In this study, the HJ-lA-CCD2 images obtained on January 22, 2008, were selected and supervised classification methods were used to extract potato planting areas in the study area. During the supervised classification process, the dispersion value of the transformation between the potato training sample and the other sample woods reached 2000, indicating that the separation between the potato and other land objects is very good for the selected sample and can be expected to be used. This training sample gets a better classification result [7].

Figure 2 shows the results of the classification, in which the green area is the extent of potato cultivation. The classification accuracy of the two ground objects of potato and non potato was taken into consideration, and 51 ground reference samples were selected to verify the accuracy. Table 1 shows the classification accuracy evaluation table. The overall accuracy of the classification is 94.12%, and the kappa coefficient is above 0.8. The planting area of potato in the classification results is 97 thousand and 930 ha, which is only 2.1% of the 100 thousand hectares recorded in Yulin plant protection station, which shows that the accuracy of the classification can meet the requirements.

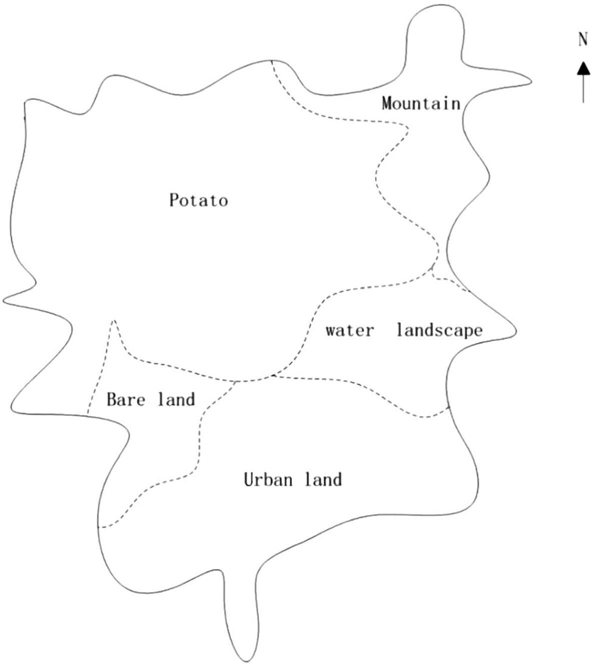

Fig. 2. Results of information extraction of potato planting range

Table 1. Classification accuracy evaluation table

Category	Reference data	Random sample number	Correct sample number	Producer's accuracy 5	User accuracy	Kappa coefficient
Non potato	35	36	35	95.44	98.14	0.9129
Potato	16	17	15	94.33	88.50	0.8329
Overall accuracy	94.14%					

2.4 Establishing a Logistic Regression Model

Above, we introduce hyperspectral data acquisition and pretreatment, and potato planting range information extraction. On this basis, the regression model should be established, and the data extracted before should be substituted into the model. The range of potato diseases and insect pests should be analyzed by AdaBoost algorithm in the model, and the area of potato diseases and insect pests in the study area should be obtained. Therefore, it is necessary to establish Logistic regression model.

The model takes the AdaBoost algorithm as the core and trains the different classifier (weak classifier) for the same training set. Then the classifier is set up to form a higher precision classifier (strong classifier). With the increase of the number of weak classifiers, the classification error rate decreases steadily. Moreover, the model can not be overfitted and the weak classifier can define itself, so it is suitable for application in various classification scenarios [8]. It is often used in the field of image processing, such as face detection, target detection, target tracking, etc. Considering the cost problem, the sampling amount is less. A limited number of training samples will lead to the limitation of classification accuracy. In this case, the AdaBoost algorithm is used to improve the accuracy rate.

AdaBoost constructs a strong classifier $\mathrm{A_m(x)}(\mathrm{m} = 1, 2, \cdots, \mathrm{M})$ by combining multiple weak classifiers linearly. The x here is the input vector. The AdaBoost algorithm is as follows:

Algorithm 1: AdaBoost algorithm

Sample data: $(x_1, y_1), \cdots, (x_m, y_m), y \in \{-1, 1\}$.

Step 1: Normalize each sample weight $D(i) = \frac{1}{N}$;

Step 2: For $\mathrm{m} = 1, 2, \cdots, \mathrm{M}$,

If you find the classifier $\mathrm{A_m}(\mathrm{x})$, Make sample weight $D(i)$ distribution error B

minimum, $B = \sum D(i)$.

Calculate the trust rate by error rate C, $C = \frac{1}{2} \log B$

Update sample weight $D_1(i) = \frac{1}{N} \mathrm{A_m}(\mathrm{x})$

The final strong classifier is:

$$\mathrm{A_m}(\mathrm{x})' = D_1(i)\sum C \tag{1}$$

The principle of disease and pest monitoring is to use the spectral information obtained on the basis of the difference between the disease and the normal sample, the more significant the difference, indicating that the extracted spectral features are easier to separate the disease samples from the healthy samples. The barren coefficient is a measure of the similarity between the two statistical samples, which can be used to measure the correlation of the two groups of samples, and often measure the separability between the classes in the classification problem [9]. Therefore, the vegetation index is used as the feature vector, and the similarity measure of the feature vectors is defined by the Babbitt coefficient, and the similarity of the sample points to the normal samples and the disease samples is calculated respectively. Among them, F^H is the average value of the eigenvectors of all healthy samples, and F^D is the average value of the eigenvectors of all the disease samples. F^G represents the eigenvector of an arbitrary sample. According to the similarity between sample and disease sample and the difference between sample and healthy sample, a weak classifier is established, as shown in formula (2).

$$\Im\left(F^H, F^D, F^G\right) = \sum^{\delta} \sqrt{F^H F^D F^G} \tag{2}$$

Among them, δ is a domain value, and when the model is trained, it will be updated with the iteration of the AdaBoost algorithm to minimize the error rate on the training dataset.

2.5 Disaster Area Monitoring

The potato planting range information is substituted into the above established regression model, and the range of potato pest and disease is analyzed. When the probability is greater than 0.5, it is considered that the disease is endangered by pests and diseases, thus obtaining the area of potato infected by pests and diseases. Figure 3 is the area of potato and pest stress caused by the real-time monitoring technology of potato disease and insect pest area in Northern Shaanxi based on hyperspectral data. The red area is the potato under the stress of disease and insect, and the green potato growth area is in the picture. According to the statistical analysis, the proportion of Potato Planted by the method is 13.29% of the potato planting area in Yulin.

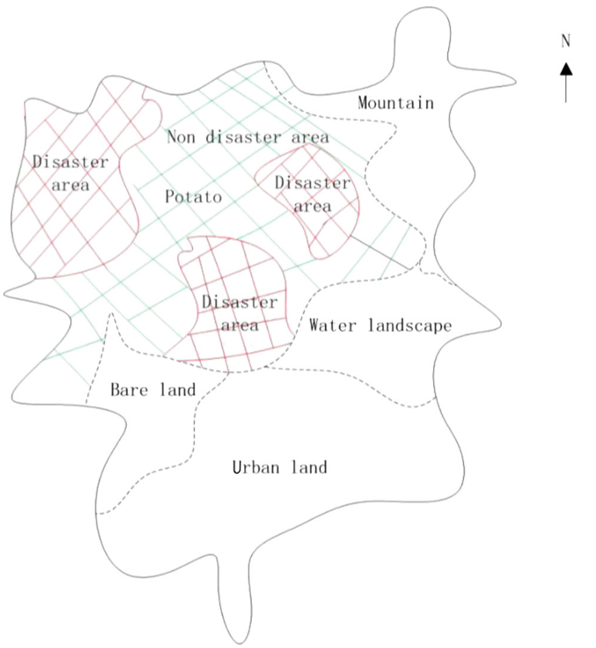

Fig. 3. Distribution of potato under disease and pest stress (Color figure online)

3 Contrast Experiment

To further analyze the monitoring accuracy of real-time monitoring techniques for potato pests and diseases in northern Shaanxi based on hyperspectral data, it matches the growth status of the potato on the site with the potato's disease-tolerance range, and analyze whether the results monitored by this method are consistent with the actual observations [10]. The potato growing area is divided into 34 site areas. The pests and diseases are monitored and the results are shown in Table 2.

Table 2. Comparison of monitoring accuracy of potato pests and diseases

Name	Number of insect pest stress stations	Point number of Health Station	Overall accuracy
Real time monitoring technology for potato diseases and insect pests in Northern Shaanxi Based on hyperspectral data	25	9	96.76%
Area monitoring technique of traditional diseases and insect pests	20	14	76.47%
Actual value	26	8	-

As can be seen from Table 2, there are a total of 34 measured sites, of which 26 wheat plants are under the threat of pests and diseases, and 8 sites are in a healthy growth condition. When using the method of this study to extract area information of pests and diseases, 25 sites of stress and 9 healthy sites are obtained, respectively, and the overall accuracy of monitoring is 96.76%. When using the traditional pest area monitoring technique, 20 diseases and insect pests and 14 healthy winter wheat sites are detected, and the overall precision reached 76.47%. In comparison, the real-time monitoring technology of potato disease and pest area based on hyperspectral data could meet the requirements of monitoring the disease and insect pests of the potato.

4 Conclusions

In this study, potato planting area in Yulin was taken as the research object. Using land acquisition data and hyperspectral remote sensing method, the hyperspectral data of potato affected area were collected and pretreated. The results were substituted into regression model to study the affected area of potato in planting area. The real-time monitoring of potato diseases and insect pests was realized, which provided technical support for the control of potato diseases and insect pests in planting area. But in practice, there are still some shortcomings. Because the geological conditions and environment in the disaster-stricken area of potato are not unified, the method in this paper is not satisfactory in the detection of the severity of the disaster. Therefore, this will become the focus of the next study, but also need to improve and update the real-time monitoring technology of potato pests and diseases, to achieve more accurate and comprehensive detection.

Fund Project. Agricultural Science Research Plan in Shaanxi Province of China: "Research on key technologies and application of Intelligent Prediction and Forecasting of Potato diseases and pests based on the Internet of Things" (NO. 2016NY141).

References

1. Guo, H.Y., Liu, G.H., Wu, L.G., et al.: Hyper-spectral imaging technology for nondestructive detection of potato ring rot. Food Sci. **37**(12), 203–207 (2016)
2. Bai, X.Q., Zhang, X.L., Zhang, N., et al.: Monitoring model of Dendrolimus tabulaeformis disaster using hyperspectral remote sensing technology. J. Beijing For. Univ. **38**(11), 16–22 (2016)
3. Xu, M.Z., Li, M., Bai, Z.P., et al.: Identification of early blight disease on potato leaves using hyperspectral imaging technique. J. Agric. Mechanization Res. **38**(6), 205–209 (2016)
4. Zhao, M.F., Liu, Z.D., Zou, X., et al.: Detection of defects on potatoes by hyperspectral imaging technology. Laser J. **37**(3), 20–24 (2016)
5. He, C., Zheng, S.L., Zhou, S.M., et al.: Estimation models of chlorophyll contents in potato leaves based on hyperspectral vegetation indices. J. South China Agric. Univ. **37**(5), 45–49 (2016)
6. Hu, Y.H., Ping, X.W., Xu, M.Z., et al.: Detection of late blight disease on potato leaves using hyperspectral imaging technique. Spectrosc. Spectr. Anal. **36**(2), 515–519 (2016)

7. Li, X.Y., Xu, S.M., Feng, Y.Z., et al.: Detection of potato slight bruise based on hyperspectral image and fruit fly optimization algorithm. Trans. Chinese Soc. Agric. Mach. **47**(1), 221–226 (2016)
8. Shi, F.F., Gao, X.H., Yang, L.Y., et al.: Identifying typical crop types from ground hyperspectral data: a case study in the Huangshui river basin, Qinghai province. Geogr. Geo Inf. Sci. **32**(2), 32–39 (2016)
9. Package seventy-three.: Spectral Image Analysis of Chinese Medicine Component Content Detection. Comput. Simul. **34**(07), 369–372 (2017)
10. Wang, G.B., Liu, W., Ming-Shan, L.I.: Green control technology of rice pests and diseases and integrated demonstration. J. Anhui Agric. Sci. **46**(09), 269–271 (2017)