REMOTE SENSING MONITORING OF CROP DISEASE BASED ON FUSION OF DIFFERENT IMAGE SCALES

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ABSTRACT: In order to accurately and quickly acquire crop disease information in Yangtze-Huaihe river region in China area county, this paper studies the fusion effect between medium resolution(30m×30m, HJ-1/CCD) and high resolution(2m×2m, GF-1/PMS) remote sensing data. On the basis of screening suitable spatial scale remote sensing images for the distribution characteristics of winter wheat field, we analyzed the interaction between winter wheat growth condition index and scab disease index, and build a winter wheat scab estimation model based on multi-agronomic parameters and monitor the spatial change of winter wheat scab in county area. The results showed that three spatial scale fusion images of 2 m× 2 m, 8 m× 8 m and 16 m× 16 m have little difference, and there are obvious differences in average gradient and standard deviation. The definition of 16 m× 16m fusion image is the best, and the spectral information is abundant, which is beneficial to the identification of winter wheat in the test area. Leaf area index, chlorophyll content and aboveground biomass weight of winter wheat were the main growth indicators affecting the occurrence of scab. The correlation coefficients(r) between them and disease index were 0.688, 0.709 and 0.669, respectively. Based on the main influence indicators of winter wheat scab, the estimation model of disease index of winter wheat scab was constructed with the REMS of 10.5% and the relative error of 14.6% respectively. The method proposed in this study can effectively monitor the spatial change of winter wheat scab in county area in China.

Scab is one of the main diseases of winter wheat. It not only affects the yield of winter wheat, but also causes the deterioration of wheat grains, which can cause human and animal poisoning in serious cases. winter wheat scab occurs in all wheat regions, mostly in temperate regions with humid and rainy climate. From seedling to grain filling, seedling withering, stem dry rot and ear rot are the main causes, among which ear rot is the most serious. When the florescence of winter wheat exists in the presence of fungi, it is very easy to occur when the temperature is 16 ~25 ℃ in the case of continuous rains and clouds for 3 to 5 days. If it can not be monitored and prevented in time, once the outbreak occurs, it will often cause a large area of winter wheat yield reduction and grain quality decline, which will cause huge economic losses. Therefore, effective monitoring of field winter wheat scab has always been the focus and hot spot of government departments and academia(Zhao C J et al., 2004; Liu L Y et al., 2004; Cao X R et al., 2013). When crops are stressed by diseases, the appearance or internal structure of crops will change, and there will be some differences in spectral reflectance and radiation

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characteristics(Li W G. 2013; Yuan L et al., 20014;Wei L G et al., 2014). This is also the basic theoretical basis of using remote sensing spectral technology to identify crop diseases.

In recent years, some scholars have begun to consider combining remote sensing spectral information with climate and environmental factors to monitor and forecast crop diseases and insect pests because of the obvious relationship between the occurrence of crop diseases and insect pests and the changes of climatic and environmental conditions. For example, Bhattacharya B K et al (2013) combined meteorological data with multiple remote sensing vegetation indices to monitor mustard rot disease by multi-stage remote sensing tracking. Zhang J C et al (2014)integrated remote sensing information and meteorological data to forecast winter wheat powdery mildew at regional scale in Beijing wheat region. Otuka A et al (2014)studied the feasibility of remote sensing monitoring of brown planthopper in the Mekong Delta of Vietnam based on regional climatic and environmental conditions. Silva J R M D (2015) combined MSG satellite data with surface temperature data to study tomato pest risk zoning. When crop diseases and insect pests occur, not only the growth status of winter wheat (such as canopy density, leaf color, morphology, etc.) will change, but also the farmland climate and environment for its growth are different from those in normal years or normal areas (Yin W et al., 2014; Jin W et al., 2018; Huang W J et al., 2009; Ge G X et al., 2014). Therefore, it is possible to identify and estimate crop diseases by remote sensing information and growth parameters from the research mechanism and methods (Wang J H et al., 2008; Ma H Q et al., 2016).

Based on the re-sampling of high spatial resolution GF-1 panchromatic image, the fusion of 2 m×2m, 8 m×8m and 16 m×16m GF-1 panchromatic image and HJ-1 satellite 30m×30m multi-spectral image was carried out, and the fusion remote sensing image of winter wheat field distribution characteristics in suitable regions was screened by fusion quality evaluation and spectral characteristics comparison. The interaction between growth index, spectral information and disease index of scab in winter wheat was further analyzed, and the main growth influencing factors (or agronomic parameters) closely related to scab disease were screened. Based on the main growth influencing factors, establish a model for estimating the disease index of winter wheat scab, and the spatial change of winter wheat scab was monitored with suitable scale remote sensing images. The purpose of this study is to provide reference for accurate information acquisition in plant protection and control in regional winter wheat production.

1. MATERIALS AND METHODS

1.1 Research area

The study area 1 (120.417°E-120.79°E, 32.75°N-33.15°N) is the junction of northeast Dongtai City and Southeast Dafeng City which located in the coastal area of central Jiangsu Province. It has a north subtropical monsoon climate, four distinct seasons and abundant rainfall. The frost-free period of about 220 days throughout the year. The crops are double cropping in one year. Which is a typical rice-wheat continuous cropping area. Although the area is flat, the dense river network and fragmented fields make it difficult to extract the area of Winter Wheat by remote sensing. This geographical situation is universal in central Jiangsu Province. The study area 2 is Xinghua City, Taizhou, Jiangsu Province (119°48'E- 120°18'E, 32°20'N-32°42'N), and the geographical attributes of this area are basically similar to that of the study area 1.

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1.2 Data and Preprocessing of Remote Sensing Images

The GF-1 panchromatic image and 8m×8m multispectral image with spatial resolution of 2m×2m on March 16, 2014, and the HJ-1 multispectral image with spatial resolution of 30m×30m on March 21, 2014 were selected. Because of the fine weather and good image quality during the data acquisition period, it is conducive to monitoring the growth of winter wheat.

Using polynomial geometric correction model In the ERDAS IMAGINE software to correct the remote sensing images according to the acquisition of ground control points, and the correction error is controlled within 0.5 pixels., Using FLAASH atmospheric correction model In ENVI software to do atmospheric correction of image. Finally, using AOI files of the study area, the atmospheric corrected HJ-1 multispectral image and GF-1 multispectral image are clipped to obtain the remote sensing (reflectivity) image of the study area.

1.3 Remote Sensing Image Fusion

Using ortho-correction and Bilinear Interpolation in ERDAS IMAGINE software to resample the GF-1 panchromatic image to form a panchromatic image with spatial resolution of 8m×8m and 16m×16m. By using principal component transform, three panchromatic images were fused with HJ-1 multi-spectral images respectively, and the multi-spectral fusion images of 2m×2m, 8m×8m and 16m×16m were obtained. In addition, the same fusion method is used to fuse the panchromatic image of GF-1 with spatial resolution of 2m×2m and 8m×8m multi-spectral image to obtain 2m×2m multi-spectral image, which can be used as a reference to verify the accuracy of regional winter wheat planting area extraction.

1.4 Quantitative evaluation of fusion images

Mean, standard deviation and average gradient are selected to evaluate the image quantitatively (objectively), which calculated by MATLAB.

Mean value (μ) represents the average gray level of all pixels in the image. It can measure the change of spectral information and reflect the brightness of the image. If the mean value is moderate, it means that the visual effect of the image is good. Its expression is:

$$\mu = \frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} F(i, j) \tag{1}$$

In formula (1), M and N are the number of rows of the image, F is the gray value of the fused image, i and j are the row and column numbers of each pixel in the same band image.

Standard deviation (std) describes the discrete degree of pixel values and mean values in images, and can evaluate the contrast degree of images. Generally speaking, if the standard deviation is large, the image contrast is large and the information contained is large. On the contrary, the image contrast is small, the tone is single and the information contained is small. Its expression is:

$$std = \sqrt{\frac{1}{M \times N} \sum_{i=1}^{M} \sum_{j=1}^{N} \left(F(i, j) - \mu\right)^2} \tag{2}$$

Average gradient (g) is the rate of density change in multi-dimensional direction. It can sensitively reflect the minute detail difference in image. The bigger the average gradient is, the more the image level is, and the clearer the vision is. Its expression is:

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$$g = \frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}\sqrt{((\partial_i F(i,j))^2 + (\partial_j F(i,j))^2)/2} \qquad (3)$$

In formula (3), the gradients of gray values in X (horizontal) and Y (vertical) directions of fused images are respectively $\partial_i F(i, j)$ and $\partial_j F(i, j)$.

1.5 Data Survey in Test Areas

In test area 1, 30 monitoring sites were established by GPS positioning. Each monitoring site selected a large area of winter wheat planting, which could represent the growth of nearby winter wheat fields. The growth information of scab disease, SPAD, biomass and leaf area index of winter wheat were investigated during heading-flowering period of winter wheat at various monitoring sites. The specific time was from 10:00 to 16:00. Green Seeker canopy spectroscopy, Sun Scan leaf area index and SPAD were used to measure the spectral information of winter wheat (including red and near infrared reflectance), leaf area index (LAI) and SPAD in leaves. The aboveground plant biomass was sampled in a sampling bag, and the plant was greened at 105℃ for 20 minutes, and dried at 75℃ and weighed. This data is used for analysis and modeling. Fifteen monitoring samples were set up in test area 2. Data investigation and processing were the same as that in test area 1. Data were used for model validation.

2. RESULTS AND ANALYSIS

2.1 Quality Evaluation of Fused Images at Different Spatial Scales

Table 1 Quantitative evaluation of fusion image on different spatial scales

Scale of fusion	Band	Mean value	Standard deviation	Average gradient
2m×2m	NIR	108.24	18.64	2.53
	R	68.80	15.71	1.67
	G	66.31	13.51	1.71
	Average	81.12	15.95	1.97
8m×8m	NIR	104.60	21.44	5.88
	R	67.81	17.02	3.87
	G	65.38	14.92	3.91
	Average	79.26	17.79	4.55
16m×16m	NIR	106.76	24.69	8.67
	R	67.06	18.58	5.83
	G	64.51	16.51	5.72
	Average	79.44	19.93	6.74

Quantitative evaluation results of three spatial scales (2m×2m, 8m×8m and 16m×16m) fusion images are listed in Table 1. From Table 1, it can be seen that the average values of three spatial scales fusion images are 81.2, 79.26 and 79.44. There is little difference among them,

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indicating that the average brightness of the three fusion images is similar. The average gradient of the three fusion scales is significantly different. The ranking is 16m×16m (6.74)>8m×8m (4.55)>2m×2m (1.97). Among them, 16m×16m fusion image has the best clarity and the strongest detail expression. Standard deviation is an important index to measure information richness. The bigger the value, the bigger the contrast and the more obvious the visual information is. The average standard deviation of the three spatial-scale fusion images is 16m×16m (19.93)>8m×8m (17.79)>2m×2m (15.95), and the information of the 16m×16m fusion image is more. The objective evaluation results showed that the 16m×16m fusion image was more suitable for studying the field distribution characteristics of winter wheat planting in the region.

2.2 Vegetation Index Characteristics of Fused Images at Different Spatial Scales

Using ENVI remote sensing software, 88 winter wheat planting samples were randomly extracted from three fusion images by establishing ROI points of interest. The basic spectral information data of winter wheat samples were formed. Then calculate two vegetation indices: NDVI (normalized difference vegetation index) and RVI (ratio vegetation index).

The scatter plots of Fig. 1 were generated by using 88 winter wheat planting samples as abscissa and two vegetation indices as ordinate. Fig. 1 (a) and (b) are the NDVI and RVI values corresponding to 88 sample points respectively. Each image contains spectral information of sample points of fusion images of 2m *2m, 8m *8m and 16m *16m. In order to show more intuitively the difference of vegetation index of fusion images of three different scales, a linear trend line is added in Fig. 1 to illustrate the change characteristics of vegetation index of fusion images. From Fig. 1 (a), it can be seen that NDVI of winter wheat at jointing stage ranges from 0.19 to 0.54, and most of the samples are concentrated in the range of 0.30 to 0.43. There are significant differences in NDVI between the samples ($P < 0.01$), which indicates that the growth trend of Winter Wheat in different fields is different. According to the trend line of winter wheat sample points, the NDVI value of 16m ×16m fusion image is significantly higher than that of 2m ×2m and 8m ×8m fusion image, which indicates that 16m ×16m fusion image has abundant spectral information. In Figure 1 (b), RVI ranges from 1.49 to 3.45, and is densely distributed around 2.3. Trend lines also show that the spectral information contained in 16m ×16m fusion image is more than 2m ×2m and 8m ×8m fusion image. The increase of spectral information of fusion image is beneficial to the recognition of winter wheat.

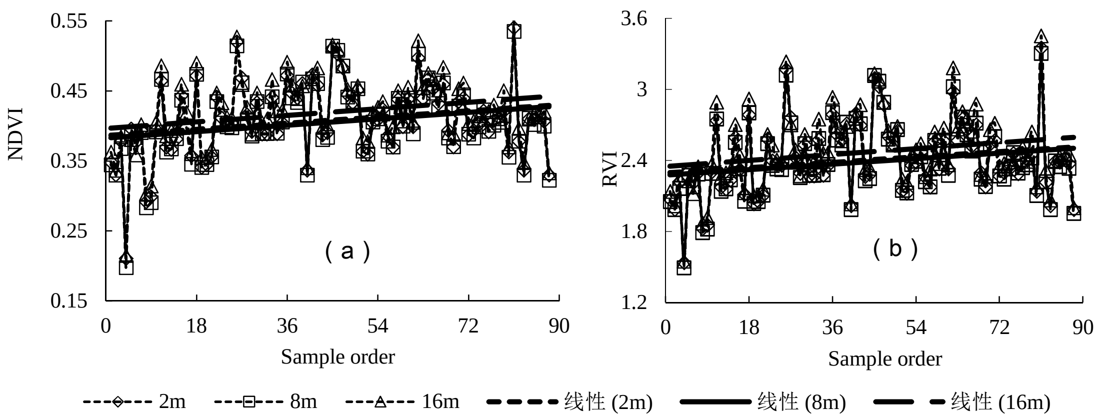

Fig.1 Comparison of vegetation indices b fusion images at different spatial scales

2.3 **Analysis of the Relation between Growth Indicators of Winter Wheat and the Occurrence of Scab**

Leaf area index is the proportion of green leaf area per unit land area to land area. It can directly reflect the number of leaves and canopy structure of winter wheat, but also indirectly reflect the growth density or trend of winter wheat. Through LAI, the ventilation and ventilation degree of Winter Wheat in the field can be understood to a certain extent. Fig. 1a is the characteristic relationship between leaf area index (LAI) and disease index of scab in heading-flowering period of winter wheat. From Fig. 1a, LAI and disease index of scab showed a positive correlation ($P < 0.05$, $n = 30$). That is, with the increase of leaf area index, the disease index increased. It shows that the bigger LAI of winter wheat, the higher the degree of canopy closure in the field, and the less light under canopy, it's easy to lead to scab. Linear fitting of the disease index of winter wheat scab with LAI showed that the coefficient of determination (R^2) between them was 0.688, which could confirm that LAI was one of the growth indicators that could easily lead to scab.

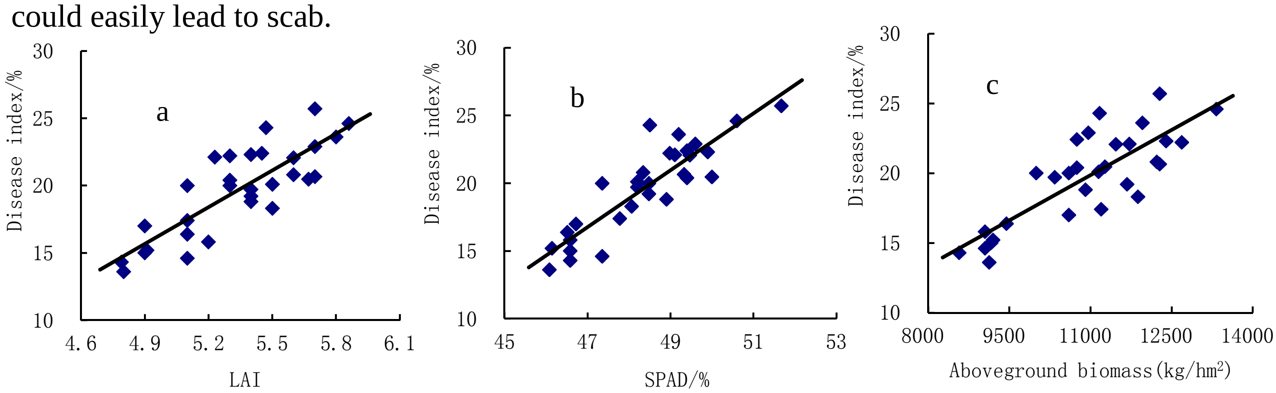

Fig.2 Relationship between LAI (a), SPAD (b) and aboveground biomass (c) and scab disease index of winter wheat

Leaf chlorophyll is an essential substance for photosynthesis of winter wheat plant, which is closely related to photosynthetic effective rate and nutritional status of winter wheat, and is also an important growth index reflecting the growth of winter wheat. The SPAD value and disease index of scab of winter wheat at heading-flowering stage (n=30) were plotted and analyzed by scatter plots, and Figure 2B was obtained. Figure 2B shows that there is a significant positive correlation between SPAD and disease index in winter wheat leaves during heading-flowering period ($P < 0.05$). High SPAD in leaves leads to higher disease index and higher incidence of scab. The SPAD of winter wheat leaves is a reference index reflecting the amount of nitrogen application. The higher SPAD in leaves, the stronger photosynthesis, the more organic matter produced, and the flourishing population growth. Because of the unbalanced nutrition among plants, the disease resistance of plants will be reduced. The coefficient of determination (R^2) of linear fitting between disease index and SPAD in winter wheat leaves was 0.709, which indicated that SPAD in winter wheat leaves was another growth trend index susceptible to scab.

Fig. 2C is the characteristic relationship between aboveground biomass and disease index of scab in heading-flowering period of winter wheat. It can be seen that the correlation between aboveground biomass and disease index of scab is obvious ($P < 0.05$). In mid-late April, the temperature of the experimental area increased, the weather warmed up, the reproductive growth

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of winter wheat was rapid, and the aboveground biomass showed a significant increase trend. Excessive aboveground biomass not only depletes soil nutrients, but also produces a large number of lean plants, which increases the probability of plant susceptibility. The above-ground biomass of winter wheat was also one of the growth indicators affecting the occurrence of scab.

2.4 Remote Sensing Estimation of Scab Occurrence in Winter Wheat at County Level

In the last section, the characteristic relationship between the growth index of winter wheat and the disease index of scab was analyzed. It was concluded that leaf area index (LAI), SPAD of leaves and aboveground biomass of winter wheat were the main growth indexes affecting the occurrence of scab. Therefore, the agronomic parameter estimation model (WSEMgi, winter wheat scab estimation model based on growth index) for the occurrence of scab in winter wheat can be constructed by combining these three growth indicators with multiple regression method.

$$DIws = 2.01\times LAI+1.25\times SPAD+0.00068\times ABG-59.07 \qquad (1)$$

In the above formula, DIws (Disease index of winter wheat scab) the disease index (%) of winter wheat scab, LAI is the leaf area index of winter wheat, SPAD (%) is the SPAD of leaves, and AGB (kg/hm2) is the aboveground biomass. WSEMgi model and leaf area index (LAI), SPAD of leaves and aboveground biomass data can be used to timely estimate the situation of scab in some scattered monitoring sites or a few fields during heading-flowering period of winter wheat.

In order to realize the remote sensing estimation of the occurrence of winter wheat scab at County spatial scale, the 16m ×16m resampled image, which had been evaluated by image fusion quality, was selected as the image data source. The WSEMgi model was revised by using the remote sensing monitoring model of winter wheat growth index constructed by Jin Zhengting [12]. Different vegetation index algorithms were used to replace leaf area index (LAI), SPAD and aboveground biomass, respectively, in order to realize the remote sensing estimation of the disease index of winter wheat scab.

$$LAI = 3.48\times NDVI+2.79 \qquad (2)$$

$$SPAD =18.04\times NDVI+35.29 \qquad (3)$$

$$AGB = -42.62\times RVI^2+1119.4\times RVI+5365.42 \qquad (4)$$

In the Modeler module of the remote sensing image processing software ERDAS IMAGINE, 16m ×16m resampling image, WSEMgi model and growth index monitoring model are imported respectively. After programming, the remote sensing monitoring map of the disease index of winter wheat scab can be generated. The disease grade of winter wheat is divided into four grades according to the disease index of scab. Grade 0 is shown in green and normal growth (no disease); Grade I is shown in yellow, Grade I is a mild disease (disease index 0%~15%); Grade II is a serious disease (15%~25%) and it is expressed in orange; Grade III is a serious disease (25%~35%) and it is shown in red. After the above grading operation, adding legend, scale and finger-north needle information, the thematic map of remote sensing monitoring information of Winter Wheat Scab in county level was finally generated (Figure 3).

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The accuracy of remote sensing monitoring information of winter wheat scab was validated by using 15 test monitoring points established in study area 2. The REMS (square root error) was 10.5% and the relative error was 14.6%. The results showed that the accuracy of remote sensing monitoring algorithm for winter wheat scab was reliable.

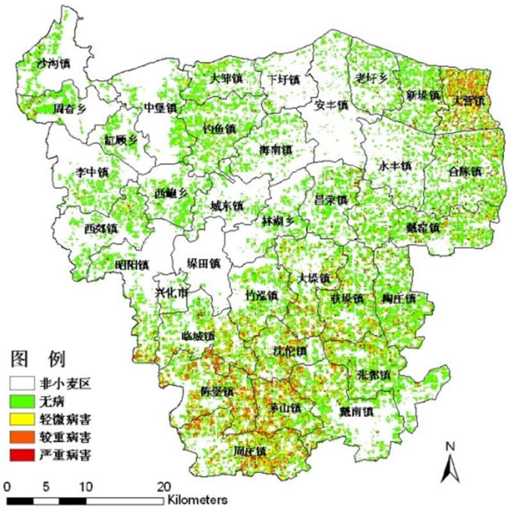

Fig.3 Remote sensing monitoring of winter wheat scab in county area

Figure 3 shows more intuitively the occurrence of winter wheat scab during heading-flowering period in the study area (county level). The colors of Zhou zhuang, Maoshan, Chenbao, Shenlun, Lincheng, Dadu o and Daying towns in the south of county level are more red and yellow, and most of the fields are more serious. Some townships in the southeast of the study area, such as Dainan, Zhangguo, Diduo, Taozhuang, Daiyao and Daying towns in the northeast, are more serious. The fields in Hechen and other townships occur to varying degrees, and other townships also occur sporadically. The blooming period of winter wheat is an ideal period for controlling scab. In view of the different incidence levels of Winter Wheat in the field, corresponding plant protection measures can be adopted in different towns or districts to achieve the purpose of high efficiency and environmental protection.

3. CONCLUSION AND DISCUSSION

Traditional artificial field sampling survey has always been the main means of Monitoring Winter Wheat scab. Although it has played an important role in controlling winter wheat diseases, for the occurrence of large-scale winter wheat diseases, traditional monitoring methods not only cost a lot of manpower and material resources, but also have limited sampling range and sample size. It is difficult to obtain large-scale disease data in time. To a large extent, it affects the effective implementation of prevention and control measures. Therefore, it is necessary to adopt a timely, large-scale and low-cost remote sensing monitoring method to solve the problem of information acquisition of Winter Wheat Scab in a large area of farmland. Remote sensing method estimates winter wheat disease based on single or multiple vegetation spectral information indicators. When the correlation between vegetation spectral information indicators and winter wheat disease indicators is high, the estimation accuracy is better. When the correlation between vegetation spectral information indicators and winter wheat disease

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indicators is weak, it is almost impossible to estimate. The occurrence of scab can be induced by partial application of nitrogen fertilizer, high density and the occurrence of canopy polarity in wheat field. This study combines the phenological and ecological characteristics of the occurrence of scab, integrates the growth indicators of winter wheat (leaf area index, SPAD of leaves and aboveground biomass) and remote sensing spectral information to monitor the occurrence of winter wheat, and evidently improves the explanatory ability of remote sensing monitoring model. It improves the accuracy of disease monitoring.

Xinghua City, Jiangsu Province, which is located in the Yangtze-Huaihe region, has a dense internal water network, fragmented fields and diverse planting structures. Because of the large number of mixed pixels, the use of low and medium spatial resolution satellite images often results in the phenomena of "homology of foreign bodies" and "homology of foreign bodies", which is difficult to meet the accuracy requirements of winter wheat growth monitoring in this kind of counties. Therefore, the selection of remote sensing image data with suitable spatial resolution (spatial scale) becomes the prerequisite and necessary condition for monitoring the growth and disease of winter wheat. In this study, the GF-1 satellite panchromatic image with spatial resolution of 2m×2m was re-sampled and fused with the HJ-1 satellite multispectral image with spatial resolution of 30m×30m, respectively. Three scales of multispectral images, 2m×2m, 8m×8m and 16m×16m, were generated. By comparing and evaluating the quality of multi-scale fused images, it is found that the quality of 16 m×16 m fused images is better than that of original multi-spectral images, highlighting the rich spectral information of vegetation, which is more suitable for the distribution characteristics of winter wheat fields in Jiangsu Province, and is conducive to remote sensing recognition and information extraction of winter wheat. Using 16m ×16m image as image data source, WSEMgi model and growth index monitoring model were used to monitor the occurrence and spatial distribution of scab in county winter wheat during heading-flowering period by remote sensing. This method can be used as a good reference for the formulation of control measures for winter wheat diseases in county.

There are many factors affecting the occurrence of winter wheat scab(Wang J H et al.,2008; Cheng S H et al., 2012; Li 2018). In this paper, the main growth indicators (leaf area index, SPAD and biomass) which are closely related to the occurrence of winter wheat scab are analyzed and studied. The existence and uncertainty of other factors are also the main factors affecting the accuracy of this model. In the future, it is still necessary to improve or improve remote sensing models and methods for estimating winter wheat scab by synthesizing climate, environment and phenology, so as to better realize the accurate monitoring of winter wheat diseases at County level.

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