Extraction of maize vegetation coverage based on UAV multi-spectral remote sensing and pixel dichotomy

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Abstract: In order to quickly and accurately obtain the vegetation coverage information at the jointing stage of summer maize, drone remote sensing was used to obtain the multi-spectral images of unmanned farms. Seven multi-spectral vegetation indices were extracted from the images, including normalized vegetation index (NDVI), normalized green belt difference vegetation index (GNDVI)), enhanced vegetation index (EVI), difference vegetation index (DVI), soil adjusted vegetation index (SAVI), ratio vegetation index (RVI), and optimal soil adjusted vegetation index (OSAVI) vegetation coverage extraction model. Using Support Vector Machine supervised classification method was adopted to obtain the true value of vegetation coverage of summer maize jointing period and the calculation accuracy of each vegetation coverage extraction model was evaluated. In order to ensure the accuracy and stability of the extraction results, 50 independent verification units were selected in the experimental areas, and the true value of the vegetation coverage in each area was linearly fitted with the vegetation coverage predicted value obtained by the vegetation coverage extraction model, and each was calculated. The coefficient of determination (R^2) and the root mean square error (RMSE) of the vegetation coverage extraction model, were compared with the fitting accuracy and goodness of fit of the linear regression models, and finally an optimal summer maize jointing stage coverage extraction model was obtained. The results show that the vegetation coverage extraction model constructed based on the pixel dichotomy combined with the multi-spectral vegetation index EVI has the best effect on the extraction of summer maize jointing stage coverage and the highest accuracy. Compared with the true value of vegetation coverage, the extraction error of the EVI vegetation coverage extraction model (E_F) is 11.76% with R^2 of 0.9418 and RMSE of 0.0537. Based on the pixel dichotomy and using the multi-spectral vegetation index a vegetation coverage model was constructed, and the vegetation coverage of summer maize at the jointing stage can be quickly and accurately extracted. This study can provide technical support for the realization of precision agriculture.

Keywords: Unmanned farm, UAV, multispectral remote sensing image, pixel dichotomy, vegetation index, maize vegetation coverage

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1 Introduction

Maize has the status of "king of feed" in economic benefits and is an important food crop in China[1]. Nowadays, more and more people pay attention to the role and value of maize. In order to ensure the stable development of the maize grain industry, it is necessary to pay more attention to the function and value of maize. The relevant physiological information is effectively monitored[2-3]. Vegetation coverage[4] (fractional vegetation cover, FVC) usually refers to the percentage of the total area of vegetation (stems, leaves, branches) projected vertically on the ground to the total area of the study area, which can characterize the photosynthesis capacity of green vegetation and growth conditions are important crop growth parameters. The monitoring of vegetation coverage mainly includes surface measurement method[5] and remote sensing monitoring method. The surface measurement method requires a lot of manpower and material resources and has problems such as low efficiency. It is not suitable for large-area coverage evaluation. The remote sensing monitoring method uses UAVs. Or satellite remote sensing technology monitors the coverage of green areas, but satellite remote sensing is easily affected by the

atmosphere, weather, etc., and satellite remote sensing data has low image resolution. It is often difficult to achieve high-precision crop field-scale coverage extraction. UAV remote sensing has the advantages of convenience and flexibility, few affected factors, timeliness and high resolution provide the possibility to accurately and efficiently extract the vegetation coverage at the crop field level. Based on TM remote sensing data, Li Miaomiao et al[6] used pixel dichotomy to improve model parameters, and constructed a multi-spectral vegetation index (NDVI) vegetation coverage extraction model to achieve the extraction of vegetation coverage in the upper reaches of Miyun Reservoir with high accuracy. Zhao Jing et al[7] used UAV remote sensing technology to obtain visible light images of summer maize, extracted the three vegetation indices commonly used in visible light, VDVI, EXG and NGBDI, and used the method of combining supervised classification and vegetation index statistical histogram to use the threshold extraction method to achieve the coverage of summer maize at the field scale is quickly extracted. Niu Yaxiao et al[8] independently developed a set of UAV multi-spectral image acquisition system based on open source flight control to obtain image information of four periods of winter wheat, and proposed a method of combining supervised classification and vegetation index statistical histogram. Scale extraction method of wheat coverage. The method of obtaining vegetation coverage through remote sensing has the advantages of fast and convenient, and the method of using satellite remote sensing technology to obtain vegetation coverage in the planting area has disadvantages such as high cost and poor timeliness. Using UAV remote sensing technology can efficiently and accurately obtain field-scale data. Compared with satellite remote sensing, vegetation coverage information has the advantages of high timeliness and low cost. Compared with visible light, multi-spectral images have more spectral information and have the advantages of efficiently and accurately extracting vegetation coverage. This paper uses UAV remote sensing technology to obtain multi-spectral images of unmanned farms, and uses pixel dichotomy to calculate 7 common multi-spectral vegetation indices to construct 7 vegetation coverage extraction models, and SVM (support vector machine) supervised classification is obtained. The result is used as the true value to evaluate the accuracy of the vegetation coverage extracted by each model, and finally obtain a grade map of the vegetation coverage of summer maize in the Jointing period, which provides technical support for realizing precision agriculture to guide field management.

2   Materials and methods

2.1   Research area and data acquisition

The test site is the ecological unmanned farm in Zhutai Town, Linzi District, Zibo City, Shandong Province (latitude 36°57′8″, longitude 118°12′50″east). The area belongs to the temperate monsoon climate. The summer maize planting method is tractor sowing, the planting row spacing is 60 cm, and the plant spacing is 20 cm. The image data collection time is from 11:00-12:30 noon on July 20, 2020. The drone uses Shenzhen DJI Innovation Technology Co., Ltd. Jingwei M210V1 quad-rotor drone. The battery life is 20 minutes when fully charged. On the day of data collection, the weather was clear and there was no wind on the ground, which satisfies the flight requirements of the UAV platform. The machine is equipped with MS600Pro multi-spectral camera to obtain the orthophoto data of the test site. The image resolution is 1280pixel×960pixel, and the ground resolution is 0.88 cm. The captured image is stored in the SD card. The

experimental design UAV has a flying height of 50 m, a flying speed of 4 m/s, a heading overlap of 85%, and a lateral overlap of 85%. A total of 2964 orthophotos of summer maize were obtained in the experiment. Further pre-processing the images, using pix4Dmapper software to perform geometric correction and stitching of the images. The research area after pretreatment is shown in Figure 1 below.
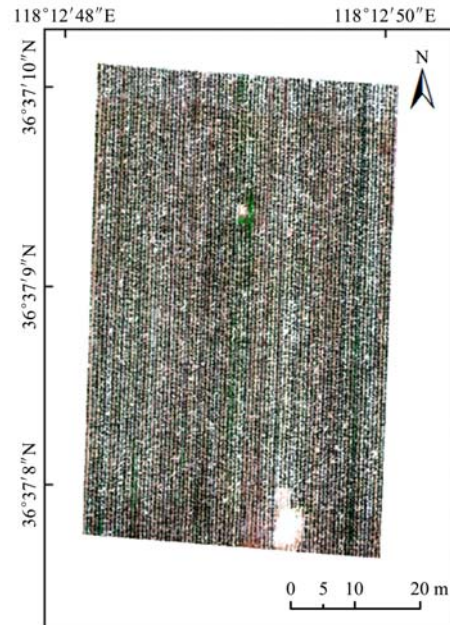

Figure 1   The experimental field

2.2   Extraction method of summer maize vegetation coverage

2.2.1   Pixel dichotomy

The commonly used remote sensing measurement methods for vegetation coverage estimation include: regression model method[9-14], vegetation index method and pixel decomposition model method. The concept of pixel decomposition model method considers that a pixel in an image is composed of multiple components. The types of tables in each region all contribute to the pixel information, and the vegetation coverage can be estimated by using the pixel decomposition model.

In the pixel decomposition model method, the linear decomposition model is the most commonly used. In this paper, the simplest and most efficient pixel dichotomy method is selected to achieve efficient and accurate extraction of vegetation coverage.

The pixel dichotomy[15] is as follows: suppose that a piece of pixel information on an image is composed of two types of surface pixel information in the study of vegetation coverage. All the information of the image is composed of a weighted linear combination of the area ratio of vegetation pixels and soil pixels, which can be obtained:

$$S=FVC\times S_{veg}+(1-FVC)\times S_{soil} \qquad (1)$$

In the formula, S is the spectral information of the pixel, FVC is the vegetation coverage, Vegetation coverage refers to the ratio of the vertical projection area of vegetation (including leaves, stems, branches) in a certain area to the total area of the area, expressed as a percentage. The formula for calculating vegetation coverage using the pixel dichotomy is:

$$FVC=(S-S_{soil})/(S_{veg}-S_{soil}) \qquad (2)$$

In the formula, S_{soil} and S_{veg} represent the soil pixel information and vegetation pixel information in the pixel, respectively.

2.2.2   Construction of vegetation coverage extraction model

According to the spectral characteristics of vegetation, the

spectral bands collected by the sensor are combined and calculated to form various vegetation indices.   The vegetation indices can be used to simply and efficiently measure the surface vegetation conditions, which is an empirical and powerful vegetation observation.

Because green vegetation has strong absorption of red light and high reflection and high transmission in the near infrared, healthy green vegetation has a large difference in reflectivity between NIR and R.   It can be seen that the reflectivity of R and NIR is combined and the calculated vegetation index can reflect the growth of vegetation to a certain extent.   In this paper, we choose to use multi-spectral data to have more spectral information than visible light images and to collect NIR reflectance.   The 7 planting index commonly used in multi-spectrum is selected[16]: Normalized difference vegetation index (NDVI), normalized difference vegetation index (GNDVI), enhanced vegetation index (EVI), difference Vegetation index (Difference vegetation index, DVI), soil adjusted vegetation index (Soil adjusted vegetation index. SAVI), ratio vegetation index (Ratio vegetation index, RVI) and optimal soil adjusted vegetation index (Optimized soil adjusted vegetation index, OSAVI) for the construction of vegetation coverage model, the vegetation index and calculation formula are as follows:

Table 1   Vegetation index

Vegetation index	Name	Calculation formula
NDVI	Normalized Difference Vegetation Index	$(R_{Nir}-R_{Red})/(R_{Nir}+R_{Red})$
GNDVI	Green Normalized Difference Vegetation Index	$(R_{Nir}-R_{Green})/(R_{Nir}+R_{Green})$
EVI	Enhanced Vegetation Index	$2.5(R_{Nir}-R_{Red})/(R_{Nir}+6.0R_{Red}-7.5R_{Blue}+1)$
DVI	Difference Vegetation Index	$R_{Nir}-R_{Red}$
SAVI	Soil Adjustment Vegetation Index	$1.5(R_{Nir}-R_{Red})/(R_{Nir}+R_{Red}+0.5)$
RVI	Ratio Vegetation Index	R_{Nir}/R_{Red}
OSAVI	Optimal Soil Adjustment Vegetation Index	$(R_{Nir}-R_{Red})/(R_{Nir}+R_{Red}+0.16)$

In the table, R_{Nir} is the reflectance in the near-infrared band (compared experimentally, the result of 840 nm in the two near-infrared bands of 840 nm and 940 nm is better than 940 nm, so the selection of the near-infrared band in this article uses 840 nm for data processing), R_{Red} is red light the reflectivity of the wave band, R_{Green} is the reflectivity of the green light band, and R_{Blue} is the reflectivity of the blue light band.

Multi-spectral vegetation index is obtained by the spectral information of the ground object collected by the sensor and calculated by the band, which can quantitatively reflect the value of the ground surface information.   In the pixel dichotomy, the value of a pixel on the image is the sum of the soil pixel and the vegetation pixel.   By the pixel dichotomy and formula (2):

$$FVC_{NDVI} = (NDVI - NDVI_{soil})/(NDVI_{veg} - NDVI_{soil}) \qquad (3)$$

$$FVC_{GNDVI} = (GNDVI - GNDVI_{soil})/(GNDVI_{veg} - GNDVI_{soil}) \qquad (4)$$

$$FVC_{EVI} = (EVI - EVI_{soil})/(EVI_{veg} - EVI_{soil}) \qquad (5)$$

$$FVC_{DVI} = (DVI - DVI_{soil})/(DVI_{veg} - DVI_{soil}) \qquad (6)$$

$$FVC_{SAVI} = (SAVI - SAVI_{soil})/(SAVI_{veg} - SAVI_{soil}) \qquad (7)$$

$$FVC_{RVI} = (RVI - RVI_{soil})/(RVI_{veg} - RVI_{soil}) \qquad (8)$$

$$FVC_{OSAVI} = (OSAVI - OSAVI_{soil})/(OSAVI_{veg} - OSAVI_{soil}) \qquad (9)$$

The FVC in the above formula is a formula based on the vegetation coverage extraction model established under the NDVI, NGDVI, EVI, DVI, SAVI, OSAVI vegetation index, which extracts the vegetation coverage.   Thus, the extraction model of multi-spectral vegetation index coverage is obtained[17].   Based on the pixel dichotomy, the vegetation coverage can be extracted by using the vegetation index.

2.2.3   Extraction of summer maize vegetation coverage

The extraction process of summer maize vegetation coverage is shown in the Figure 2.
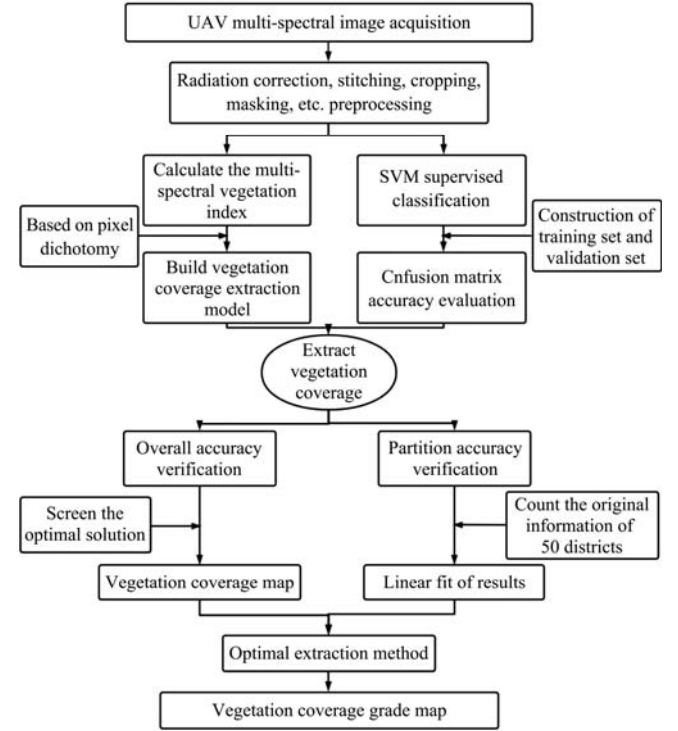

Figure 2   Data processing flow chart

The pre-processed image is based on the vegetation index calculation formula to obtain the 7 planting index map of the multispectral image.   Referring to the pure pixel information estimation method of TM remote sensing image proposed by Li Miaomiao et al[6], the values of VI_{soil} and VI_{veg} are as follows. The value of different images varies with time and space.   Because $VI=VI_{soil}+VI_{veg}$, the value range of VI_{veg} is also determined.   This article uses UAV remote sensing technology to obtain multispectral image data of unmanned farms, which can be ignored for the influence of the atmosphere on VI_{soil}, a certain degree of confidence can be used to study the vegetation coverage of the field scale range[18-25].   Based on the clarity of the obtained image[26], through repeated comparisons, 2% confidence is taken as the pure pixel information of the bare land (that is, VI_{soil} is 2%, $VI_{veg}=1-VI_{soil}=98\%$), according to the formula (3)~(9).   The vegetation coverage extraction model and pure pixel information extract the vegetation coverage of each vegetation index map[27].

The calculation of the true value of vegetation coverage adopts support vector machine (SVM) supervised classification combined with formula (10) to extract the vegetation coverage, and the preprocessed image is manually selected by means of visual interpretation.   The training samples and verification samples of the land use the calculation results as the true values to verify the accuracy of the vegetation coverage obtained by the 7 vegetation index construction models.

$$FVC_{svm} = \frac{N_{maize}}{N_{maize} + N_{soil}} \qquad (10)$$

Among them, N_{maize} is the total number of maize pixel statistics, and N_{soil} is the total number of naked land pixel statistics.

2.2.4   Accuracy evaluation of vegetation coverage

The overall accuracy evaluation plan for extracting vegetation coverage using the vegetation coverage extraction model is as follows: The calculation formula for the extraction error E_F of vegetation coverage is as follows:

$$E_F = \frac{|F_{sup} - F_{VI}|}{F_{sup}} \times 100\% \qquad (11)$$

Among them, F_{VI} is the summer maize coverage obtained using the pixel dichotomy and vegetation coverage model, and F_{sup} is the summer maize coverage obtained using the SVM (support vector machine) supervised classification method.

To verify the accuracy of the above-mentioned model method for extracting the coverage of summer maize at the three-leaf stage, this paper designs a method of regional accuracy verification to verify the accuracy of the test area.   In the test area, 50 accuracy verification plots are selected and the supervised classification results are extracted.   The coverage information is taken as the true value, and the vegetation coverage results extracted from the 7 vegetation coverage models in the community are used as the predicted value.   A linear regression model is established, and the root mean squared error (RMSE) and the coefficient of determination (R^2) are used to compare Results are evaluated for accuracy.   The smaller the RMSE, the closer the true value is to the predicted value; the greater the goodness of fit R^2 of the linear regression model, the better the fit between the true value and the predicted value.

3   Results and analysis

2.1   Supervision classification results and evaluation

By combining the two methods of field investigation and visual interpretation, 100 representative maize plant samples and 100 bare soil samples were selected on the multi-spectral image to form the training set, in order to ensure that different types of ground objects have good classification degree, the method of calculating JM (Jeffries-Matusita) distance[28,29] is often used to calculate the separability of maize and bare land.   Both parameter values are between 0 and 2.0.   When the parameter value is greater than 1.9, the corresponding sample.   The separability is good, if it is less than 1.8, the separability is poor and it is not suitable to continue the classification.   At the same time, 60 locations of bare land and maize samples in the verification set were uniformly selected in the figure to calculate the confusion matrix of the classification results, and to verify the accuracy of the SVM supervision classification results.
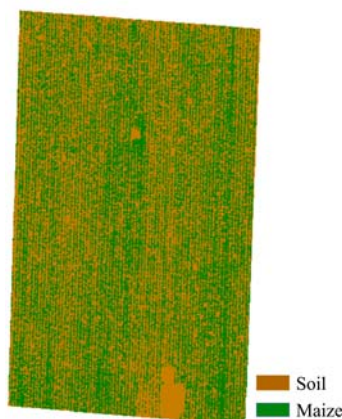

Figure 3   Summer maize supervised classification results

The separability of the two types of ground objects in the training set and the validation set selected for calculation is 1.999999989 and 1.99991650, both of which are greater than 1.9, indicating that the two types of ground objects in the two sample sets have good separability.   Further use the confusion matrix to pair.   The classification accuracy is verified, and the overall classification accuracy is 99.4444%, and the Kappa is 0.9889.   The detailed classification accuracy is shown in Table 2.

Table 2   Evaluation of classification accuracy of summer maize

Category	Maize pixel	Soil pixels	Total sample pixel	User accuracy /%
Maize pixel	23648	56	23704	99.776
Soil pixels	95	31143	31238	99.70
Total sample pixel	23743	31199	54942	
User accuracy/%	99.60	99.82		

From Table 2, it can be seen that the use of SVM supervision classification to classify maize and bare land is better.   Using formula (10) to calculate the average vegetation coverage of summer maize in the Jointing period is 0.443692, and the unmanned farm in the study area in summer.   The vegetation coverage of maize in this period was 44.37%.   According to the research of previous scholars, this paper uses the SVM classification result as the true value to evaluate the accuracy of the model method to extract the vegetation coverage.

2.2   Results and analysis of vegetation coverage extraction

By counting the pixels of the multi-spectral vegetation index image, a total of 2% of the pixels are selected as the original information of the bare land and 98% are the original information of the maize.   (In the process of image processing, the calculated value of the noise pixel value lower than the original information of the naked image is set to 0 by default, and the original pixel value of the noise image that is higher than the original information of the vegetation image is set to 1).

Statistic the VI_{soil} and VI_{veg} information of each VI (vegetation index), as shown in the following Table 3.

Table 3   Vegetation index image number of original information

VI	VI_{soil}	VI_{veg}
NDVI	0.033877	0.666737
GNDVI	0.107601	0.582231
EVI	0.021377	0.448939
DVI	0.017223	0.249841
SAVI	0.024086	0.423150
RVI	1.031326	5.016646
OSAVI	0.026761	0.463123

According to the above vegetation coverage model combined with the VI_{soil} and VI_{veg} information of each vegetation index in Table 3, the vegetation coverage map of summer maize in the Jointing period is calculated.   Because the difference in vegetation coverage images extracted by each model is small, only EVI vegetation is displayed.   The vegetation coverage map obtained from the coverage extraction model is shown in Figure 4.

Calculate the vegetation coverage map obtained from the calculation of each model to obtain the average vegetation coverage of the entire test area.   At the same time, perform statistics on the SVM supervision classification map to obtain the true value of the vegetation coverage to evaluate the accuracy of the vegetation coverage extracted by each model.   The results are

shown in Table 4 below.

It can be seen from Table 4 that the vegetation coverage model constructed based on the pixel dichotomy using the vegetation index RVI has the worst extraction effect on vegetation coverage, with an extraction error of 26.72%.   The NDVI vegetation coverage model has a better extraction effect on vegetation coverage.   The error is 12.62%, and the RVI coverage extraction model has the best extraction effect on vegetation coverage, with an extraction error of 11.76%.
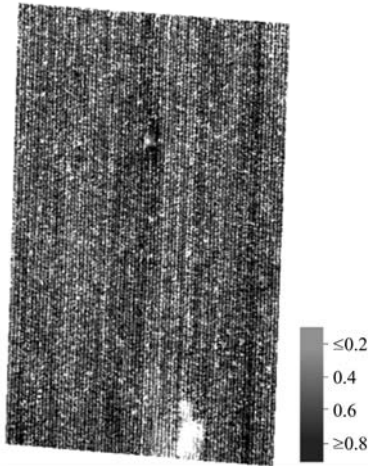
Table 4   Precision evaluation

Vegetation index model	Vegetation coverage			Extraction error
	Pixel dichotomy	Supervised classification	Difference	
FVC_{NDVI}	0.499704	0.443692	0.056012	12.62
FVC_{GNDVI}	0.519437	0.443692	0.075745	17.07
FVC_{EVI}	0.495880	0.443692	0.052188	11.76
FVC_{DVI}	0.536505	0.443692	0.092813	20.92
FVC_{SAVI}	0.526461	0.443692	0.082769	18.65
FVC_{RVI}	0.325151	0.443692	0.118541	26.72
FVC_{OSAVI}	0.512110	0.443692	0.068418	15.42

In order to further verify the extraction accuracy of the vegetation coverage model, this paper uniformly selects 50 100 Pixel × 100 Pixel cells in the test area[30-35], and calculates the vegetation coverage of the 50 selected cells in the vegetation coverage map obtained from each vegetation coverage model. Take the average value of the vegetation coverage in each cell as the predicted value of the vegetation coverage of the cell, and extract the average value of the vegetation coverage in the 50 cells corresponding to the SVM supervision classification map as the true value, and linearize the predicted value and the true value respectively Fit, calculate the coefficient of determination (R^2) and root mean square error RMSE of each scatter plot, and the linear fitting result is shown in Figure 5.
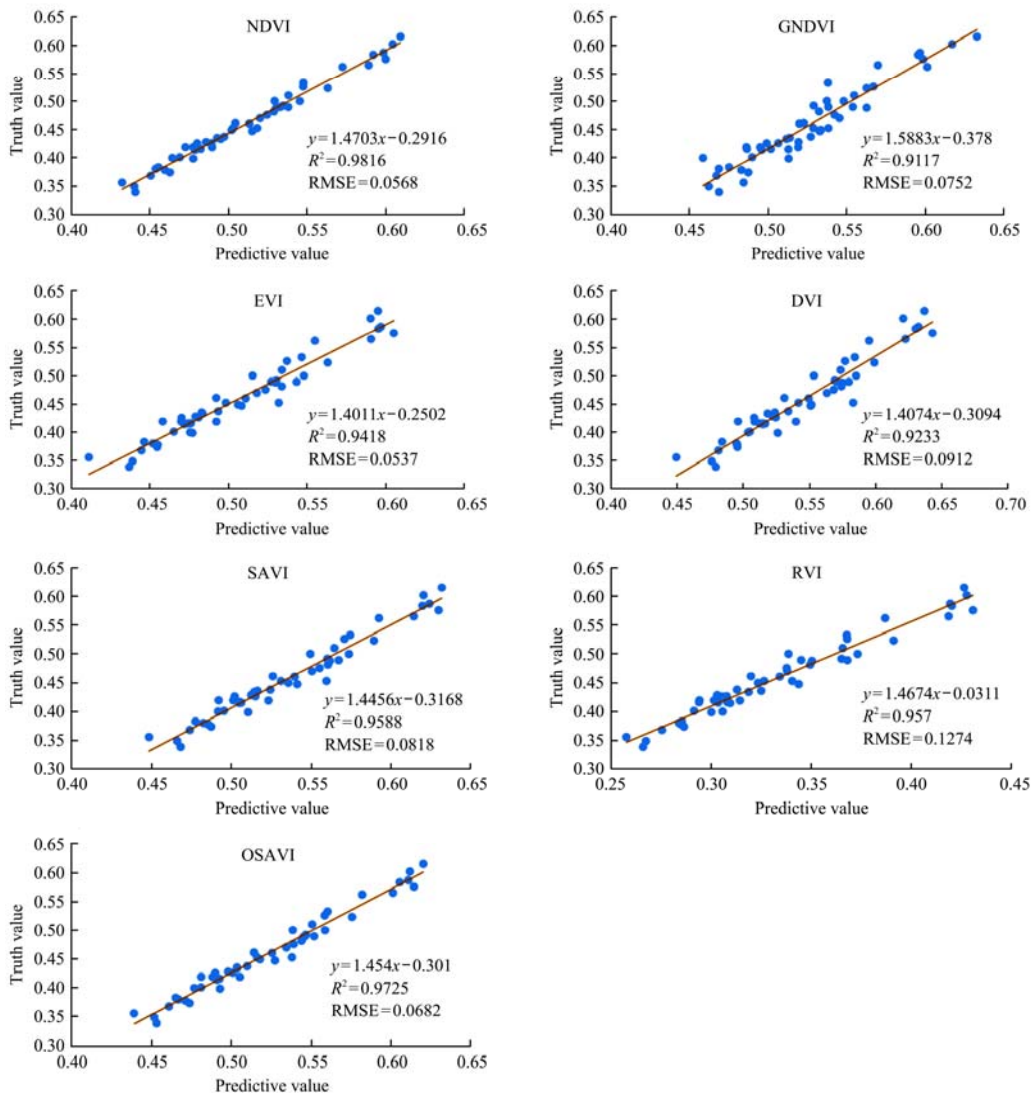

Figure 4   EVI—Vegetation coverage map

Figure 5   Linear fitting results of vegetation coverage extraction model

Table 5 The error analysis

VI	R^2	RMSE
NDVI	0.9816	0.0568
GNDVI	0.9117	0.0752
EVI	0.9418	0.0537
DVI	0.9233	0.0912
SAVI	0.9588	0.0818
RVI	0.9570	0.1274
OSAVI	0.9725	0.0682

From Figure 5 and Table 5, it can be seen that the extraction effect of GNDVI and DVI in the 7 plant coverage extraction model is poor, the coefficient of determination (R^2) is 0.9117 and 0.9233, and the RMSE is 0.0752 and 0.0912, respectively; the other vegetation indices in the comparison table Corresponding parameters of the coverage extraction model, the R^2 of GNDVI and DVI are small, the fitting effect of the true value and the predicted value is poor, the RMSE value is large, and the true value and the predicted value are more discrete.

The overall extraction effect of NDVI and EVI is better, the coefficients of determination (R^2) of the two are 0.9816 and 0.9418, respectively, and the RMSE are 0.0568 and 0.0537, respectively. The true value is close to the predicted value, and the fitting effect is good. The results are compared with those obtained in Table 4. The accuracy results of the whole image verification are consistent.

Combining the two accuracy verification results, it is concluded that the degree coverage extraction model constructed by using the EVI vegetation index based on the pixel dichotomy has the best effect and high accuracy.

In order to guide agricultural production and facilitate field management operations, the vegetation coverage of summer maize is further classified. According to the method proposed by Chen Hongbing[36], this paper selects the EVI vegetation coverage model to obtain the vegetation coverage grade distribution of summer maize in the jointing period. The figure, as shown in the figure, this article divides a total of 10 levels, and the statistical results of the coverage of each level are shown in Table 6 and Figure 6.

Table 6 Results of distribution of vegetation coverage grades

Vegetation coverage	Like the original number	Percentage/%
0~0.1	377941	14.780
0.1~0.2	200353	7.835
0.2~0.3	285005	11.146
0.3~0.4	302694	11.838
0.4~0.5	284553	11.128
0.5~0.6	262911	10.282
0.6~0.7	251540	9.837
0.7~0.8	234134	9.156
0.8~0.9	190975	7.469
0.9~1	166938	6.529
Total	2557044	100

4 Conclusions

The vegetation index vegetation coverage extraction model based on UAV multi-spectral images can be used to efficiently and accurately extract the vegetation coverage of summer maize:

(1) A vegetation coverage extraction model developed by using the seven common vegetation indices of multispectral combined with the principle of pixel dichotomy can be applied to effectively extract the vegetation coverage information of summer maize in the jointing period.
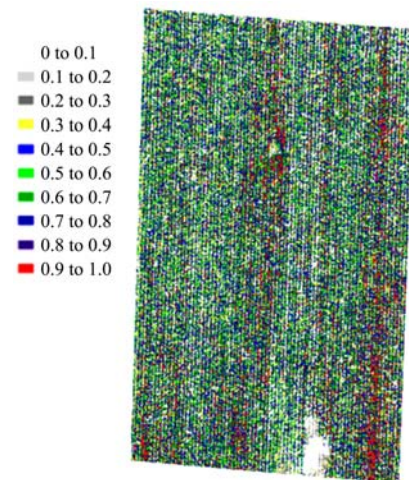

Figure 6 Distribution map of vegetation coverage grade of summer maize

(2) Based on the pixel dichotomy, the vegetation coverage extraction model constructed by the 7 planting index was used to extract the vegetation coverage of summer maize in the Jointing period. Among them, the coverage extraction model constructed by the EVI vegetation index had the highest accuracy and the extraction error (E_F) Is 11.76%, R_2 is 0.9418, RMSE: 0.0537.

(3) Use the EVI vegetation coverage extraction model to generate the vegetation coverage rating map of the summer maize in the Jointing period to provide technical support for the realization of precision agriculture and the guidance of field management.

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