Research on vegetation cover extraction method of summer maize based on UAV visible light image

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Abstract: The vegetation coverage is the most important indicator to measure the surface vegetation status. In order to effectively extract the vegetation coverage of crops and achieve fast and accurate acquisition of the vegetation coverage information during the small bell mouth period of summer corn. The visible light images of the unmanned farm was obtained using the unmanned aerial vehicle remote sensing technology, and four visible light vegetation indexes, including the Visible-band difference vegetation index (VDVI), Excess green (EXG), Normalized green-blue difference index (NGBDI) and Red-green-blue ratio vegetation index (RGBRI), were extracted from the image. Using three methods: maximum entropy threshold method based on vegetation index, threshold method based on vegetation index, and pixel binary method based on vegetation index, extract vegetation coverage information of summer maize during the small horn mouth period in the experimental area. Using the supervised classification results of Support Vector Machine (SVM) as the true values, evaluate the accuracy of vegetation coverage extracted by the three methods separately. The results showed that the maximum entropy threshold method based on the NGBDI vegetation index image had the best extraction effect and the highest accuracy of vegetation coverage at the small bell mouth stage of summer corn in the experimental area, the coverage was 0.597602, and the extraction error (E_F) was 1.26% compared with the true value; In the vegetation index threshold method, the vegetation coverage extraction effect of EXG is the second, the coverage is 0.558811, and the extraction error (E_F) compared with the true value is 7.67%; The pixel dichotomy based on vegetation index combined with EXG has a good effect on vegetation coverage extraction, the coverage is 0.456506, and the extraction error (E_F) is 24.58% compared with the true value. The NGBDI vegetation index image based on the visible light image of UAV can realize the rapid and accurate extraction of the vegetation coverage of summer corn at the small bell mouth stage using the maximum entropy threshold method, which can provide a reference for UAV remote sensing monitoring.

Keywords: unmanned farm; UAV; visible light shadow image; vegetation index; vegetation coverage
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1 Introduction

As a high-yield food crop in China, corn is one of the important raw materials for food, chemical industry and aquaculture[1], so it is of great significance to effectively monitor the relevant physiological information of corn[2-3]. Fractional vegetation cover (FVC) refers to the proportion of the vertical projected area of the stems, leaves, branches, etc. of plants within the survey range, and is an important indicator to evaluate the growth of green vegetation[4-7]. According to different monitoring methods, vegetation coverage measurement methods are divided into field measurement method and remote sensing interpretation method[8]. Due to the limitation of human and material resources,

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the field measurement method can only obtain a limited number of observation data, and the ground observation range is small[9]; Remote sensing interpretation method is also divided into satellite remote sensing and unmanned aerial vehicle remote sensing. Satellite remote sensing itself is to a large extent affected by atmospheric conditions, and cannot ensure the quality of the image, which will affect the accuracy of the vegetation coverage calculation results. Moreover, the image resolution is low, and it is often difficult to achieve crop coverage extraction at field scale; UAV remote sensing has high flexibility, flying under the cloud, high image resolution, strong timeliness and low cost, and has been increasingly used in remote sensing monitoring[10]. Xie Bing et al.[11] aiming at the problem of extracting vegetation coverage from common visible light vegetation index, a new visible light vegetation index, the red-green-blue ratio vegetation index (RGBRI), was proposed by model inversion, and the reliability of the new vegetation index was verified from the aspects of vegetation coverage accuracy and vegetation information accuracy by using adjacent township aerial films, which provided a new method for the rapid acquisition of vegetation coverage in small areas. Wang Meng et al.[12] took cotton, peanut and corn as the research objects, and selected EXG, VDVI, RGRI, BGRI, RGVI and RGBVI five vegetation index combined with the visible light image vegetation index threshold classification method to perform visible light image threshold segmentation, and the results showed that the VDVI threshold classification method could better distinguish vegetation from non-vegetation with the highest accuracy. Chen Xiangdong et al.[13] based on the proposed new method of vegetation coverage combining the visible light vegetation index threshold method and histogram, and used the three indices of VDVI, EXG and NGBDI to calculate the vegetation coverage of the four stages of summer maize: four-leaf stage, jointing stage, ear stage and flower stage, which effectively solved the problem that the histogram threshold method had poor effect when the vegetation coverage was low. Previous studies have mostly focused on one extraction method to study vegetation coverage, but have not comprehensively compared and studied multiple methods for extracting vegetation coverage. Based on this issue, this article uses drone remote sensing technology to obtain visible light images of unmanned farm experimental areas, extracts 4 vegetation indices from the images, and uses commonly used three vegetation coverage extraction methods to extract vegetation coverage during the small horn period of summer corn in the experimental area. Compare the extraction results with SVM supervised classification results for accuracy evaluation, analyze and compare the results of the three methods, in order to obtain the optimal method for quickly and accurately obtaining vegetation coverage at the field level.

2 Materials and Methods

2.1 Overview of the test site and data acquisition

The experimental site is located at the Hefeng Seed Industry Ecological Unmanned Farm in Zhutai Town, Linzi District, Zibo City, Shandong Province (36°57′11″N, 118°12′46″E). This area belongs to a temperate monsoon climate, with an average annual precipitation of about 650 mm. Two corn varieties, Jinyangguang 6 and Nongxing 207, were planted in the experimental area, as shown in Figure 1. The plot of Nongxing 207 was further divided into eight small areas for field management such as ground weeding. The corn planting method was machine seeding with a row spacing of 60 cm and a plant spacing of 22.5 cm. Organic fertilizer and compound fertilizer were applied as base fertilizer before sowing, and field management was uniformly adopted for later field management.

Collect corn image data during the small bell mouth period of summer corn from 11:00 to 12:00 on July 20, 2020. The DJI Phantom4 RTK drone from Shenzhen DJI Technology Co., Ltd. was selected for the experiment, with a payload of 2 kg and a range of 30 minutes. When the drone collects images, the flight altitude is 50 meters, the flight speed is 4 m/s, the heading overlap is 70%, and the lateral overlap is 80%. Obtain 421 images with a resolution of 5472 piexl×3648 piexl, and a ground resolution of 1 cm. The captured images are stored in the SD card. Pix4DMapper software was used to stitch the images acquired by the drone to generate a panoramic orthophoto of the summer maize small trumpet stage test area (Figure 1).

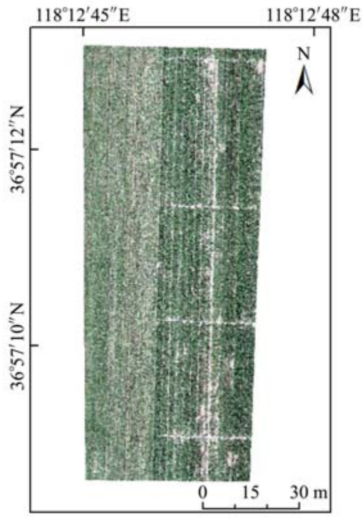


Figure 1 Visible light image of the experimrntal region

2.2 Selection of vegetation index

The visible light images collected by UAVs only include soil and corn two types of features. Green vegetation has a higher reflectivity in the green band than in the red and blue bands, while soil has a higher reflectivity in the red band than in the green and blue bands. The vegetation index obtained by combining the red, green, and blue bands collected by drones using this feature can enhance the difference between vegetation and soil, making it easier to distinguish between vegetation and soil.

Previous studies have shown that the Red-green-blue ratio vegetation index (RGBRI)[11], Visible-band difference vegetation index (VDVI)[12], Excess green (EXG)[13], and Normalized green-blue difference index (NGBDI)[26] have shown good results in extracting vegetation coverage. Therefore, this paper selects four visible light vegetation indices, VDVI, EXG, NGBDI, and RGBRI, to extract vegetation coverage. The calculation formula is shown in Table 1.

Table 1 Vegetation index

Vegetation index	Name	Calculation formula
VDVI	Visible-band difference vegetation index	(2G-R-B)/(2G+R+B)
EXG	Excess green	2G-R-B
NGBDI	Normalized green-blue difference index	(g-b)/(g+b)
RGBRI	Red-green-blue ratio vegetation index	(R+B)/(2G)

In the table, R is the figure red band pixel value, G is the figure green band pixel value, and B is the figure blue band pixel value, g=G/(R+G+B); b=B/(R+G+B).

2.3 Extraction method of summer maize vegetation coverage

There are many commonly used remote sensing measurement methods for vegetation coverage estimation[14-19]. In this paper, three common methods, the maximum entropy threshold method based on vegetation index, the vegetation index threshold method and the pixel dichotomy method based on vegetation index, are selected to extract the vegetation coverage of summer corn in the small bell stage.

2.3.1 Pixel dichotomy

Pixel dichotomy[20-22] is a simple and practical linear model. It assumes that pixel information is only composed of vegetation pixel information and non-vegetation pixel information, and all information of remote sensing image obtained is only composed of the linear combination of the weighted area ratio of these two component factors. It can be expressed as:

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

The percentage of vegetation pixel information in the total pixel information is the vegetation coverage. The calculation formula of vegetation coverage obtained by pixel dichotomy is as follows:

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

In the formula, S is the spectral information of the pixel; FVC is the vegetation coverage; S_{soil} is the soil pixel information, and S_{veg} is the vegetation pixel information.

It can be concluded that the extraction model of the coverage of each visible vegetation index in this paper[23] is:

$$FVC_{\mathrm{RGBRI}}=(\mathrm{RGBRI}-\mathrm{RGBRI_{soil}})/(\mathrm{RGBRI_{veg}}-\mathrm{RGBRI_{soil}}) \qquad (3)$$

$$FVC_{\mathrm{NGBDI}}=(\mathrm{NGBDI}-\mathrm{NGBDI_{soil}})/(\mathrm{NGBDI_{veg}}-\mathrm{NGBDI_{soil}}) \qquad (4)$$

$$FVC_{\mathrm{EXG}}=(\mathrm{EXG}-\mathrm{EXG_{soil}})/(\mathrm{EXG_{veg}}-\mathrm{EXG_{soil}}) \qquad (5)$$

$$FVC_{\mathrm{VDVI}}=(\mathrm{VDVI}-\mathrm{VDVI_{soil}})/(\mathrm{VDVI_{veg}}-\mathrm{VDVI_{soil}}) \qquad (6)$$

2.3.2 Maximum entropy threshold method

The key of the maximum entropy threshold method[24-25] is to determine the classification threshold. First of all, assuming that the classification threshold of vegetation and soil is t, the threshold t divides all pixels of the image into two categories: target O and background B. When the pixels in O and B tend to be uniformly distributed, the entropy of the target and background is the largest. Because of the additive nature of entropy, the entropy of the whole image is the largest at this time, that is, when the entropy is the largest, the target and background can be well distinguished. If the entropy of the target area is $H\,[O\,(t)]$ and the entropy of the background area is $H\,[B\,(t)]$, the corresponding t value when the total entropy $H\,(t)=H\,[O\,(t)]+H\,[B\,(t)]$ reaches the maximum value is the best threshold.

2.3.3 Vegetation index threshold method

The key to extracting vegetation coverage based on vegetation index threshold method[26] is to determine the vegetation index threshold to distinguish soil and vegetation. This method is based on visual interpretation to carry out statistical analysis on the image and obtain the vegetation index threshold to distinguish vegetation and soil pixels. First, the obtained visible light remote sensing images of summer corn in the small bell period are supervised and classified into two categories: corn and soil, and the statistical histogram of each vegetation index is obtained. Then the intersection of corn and soil curves in the histogram is used as the threshold for classification, and then the vegetation coverage is extracted. The calculation formula of vegetation coverage is:

$$FVC=\frac{N_{\mathrm{maize}}}{N_{\mathrm{maize}}+N_{\mathrm{soil}}} \qquad (7)$$

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

2.4 Extraction of summer maize vegetation coverage

The extraction process of summer maize vegetation coverage is shown in Figure 2. After image preprocessing, four vegetation index images of visible light image are obtained from the vegetation index calculation formula. Based on the vegetation index image, pixel dichotomy, maximum entropy threshold method and vegetation index threshold method are used to extract the vegetation coverage of the test area.

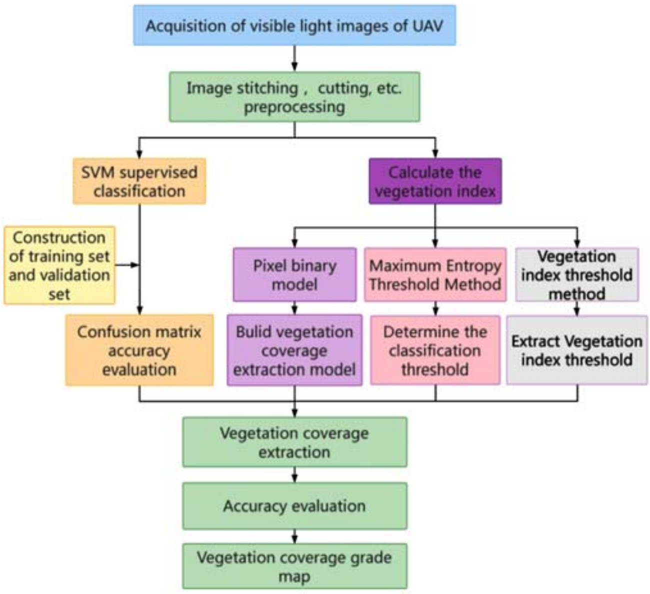


Figure 2 Data processing flow chart

When using pixel dichotomy to extract coverage, it can be seen from the pure pixel information estimation method for TM remote sensing images proposed by Li Miaomiao et al[27]. that due to the inevitable impact of noise, it is necessary to set a confidence level to eliminate abnormal values, and the values of VI_{soil} and VI_{veg} are determined by actual conditions such as geographical area, space-time, image size, and image clarity. Different values for images are also different, but because $VI=VI_{\mathrm{soil}}+VI_{\mathrm{veg}}$, therefore, the value range of VI_{veg} is determined. In this paper, using the visible light image data of unmanned farms obtained by unmanned aerial vehicles, the impact of the atmosphere on VI_{soil} can be ignored. Based on the resolution of the obtained image[28], through observation and comparison, two confidence levels of 2% and 5% are selected as pure pixel information for bare land (i.e., VI_{soil} is taken as 2% or 5%, $VI_{\mathrm{veg}}=1-VI_{\mathrm{soil}}$=98%, or $VI_{\mathrm{veg}}=1-VI_{\mathrm{soil}}$= 95%). The vegetation coverage of each vegetation index map is extracted based on the vegetation coverage extraction model, namely formulas (3) to (6), and pure pixel information[29]. Compare the vegetation coverage under the two confidence levels, and the best extraction effect is the final confidence level.

At the same time, training samples and validation samples of summer corn and soil are selected through visual interpretation of the pre processed images. Using support vector machine supervised classification and formula (7) to extract vegetation coverage from the visible light shadow images collected by unmanned aerial vehicles as the true value of vegetation coverage in the experimental area, and to evaluate the accuracy of vegetation coverage extracted by the other three methods, and the optimal solution is obtained by comparing the extraction accuracy and error to obtain a vegetation coverage grade map of the experimental area.

2.5 Evaluation method for accuracy of vegetation coverage extraction

The accuracy evaluation scheme for vegetation coverage extracted by the three methods is as follows:

$$E_F = \frac{|F_{\mathrm{SVM}} - F_{\mathrm{VI}}|}{F_{\mathrm{SVM}}} \times 100\% \tag{8}$$

where, E_F is the vegetation coverage extraction error; F_{VI} is the summer corn coverage obtained using three methods, and F_{SVM} is the summer corn coverage obtained using SVM (Support Vector Machine) supervised classification method.

3 Results and Analysis

3.1 Monitoring classification results and evaluation

Through visual interpretation and field investigation, 180 typical corn plant samples and 120 relatively independent bare soil samples were selected from the obtained visible light images as training sets. J-M(Jeffries-Matusita) distances were calculated for the training sets to measure the separability of feature subsets between the two categories. Its value is between 0 and 2.0. A higher value indicates better separability. When the value is greater than 1.9, it indicates good separability and belongs to a qualified sample. When the value is less than 1.8, it indicates poor separability and requires a new sample selection. After calculation, the separability of corn and bare land in the training set is 1.99999891, which indicates good separability.

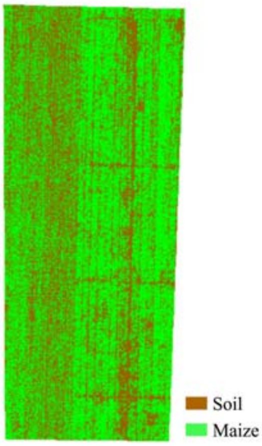


Figure.3 Summer corn supervised classification results

At the same time, uniformly select 120 corn samples and 80 bare land samples pixels on the visible light image to form a verification set, which is used to calculate the confusion matrix for the classification results, and verify the accuracy of the SVM supervised classification results. The results show that the separability of corn and bare land in the validation set is 1.99966566, which indicates that the two types of ground objects still have good separability. Using the confusion matrix to verify the classification accuracy, the overall classification accuracy is 98.4921%, and Kappa is 0.9694. Table 2 shows the precision of the detailed classification results.

Table 2 Evaluation of classification accuracy of summer maize

Category	Corn pixel	Bare pixels	Total sample pixel	User accuracy/%
Corn pixel	67071	4	67075	99.99
Bare pixels	1835	53047	54882	96.66
Total sample pixel	68906	53051	121957	
User accuracy/%	97.34	99.99		

From Table 2, it can be seen that the classification effect of corn and bare land based on SVM supervised classification is better. The calculation formula for vegetation coverage is as follows:

$$FVC_{\mathrm{svm}} = \frac{N_{\mathrm{maize}}}{N_{\mathrm{maize}} + N_{\mathrm{soil}}} \tag{9}$$

Among them, N_{maize} is the total statistical number of corn pixels, and N_{soil} is the total statistical number of bare land pixels. According to formula (9), the average vegetation coverage of summer corn during the small bell mouth period is 0.605248, and it is obtained that the vegetation coverage of summer corn in this area of unmanned farms during this period is 60.52%.

3.2 Pixel dichotomy vegetation coverage extraction results

As can be seen from the previous article, due to the inevitable noise impact, confidence levels need to be set. This article selects two confidence levels: 2% and 5%. (During image processing, if the noise pixel value is lower than the bare ground pixel information, the default value is 0, and if the noise pixel value is higher than the vegetation pixel information, the default value is 1.). Table 3 lists the information numbers of each vegetation index VI_{soil} and VI_{veg} calculated using two confidence levels.

Table 3 Vegetation index image number of original information

VI	2%		5%	
	VI_{soil}	VI_{veg}	VI_{soil}	VI_{veg}
EXG	9.529	135.118	14.314	124.353
NGBDI	0.044	0.467	0.059	0.373
RGBRI	767.453	52427.769	1785.390	45302.208
VDVI	0.013	0.418	0.019	0.338

Table 4 lists the coverage results extracted from vegetation coverage models constructed with two confidence levels corresponding to different vegetation indices. From the coverage results, it can be seen that the calculated results with a 5% confidence level are closer to the supervised classification results. Therefore, a 5% confidence level was ultimately selected.

Table 4 Vegetation coverage of pixel dichotomy based on vegetation index at different confidence levels

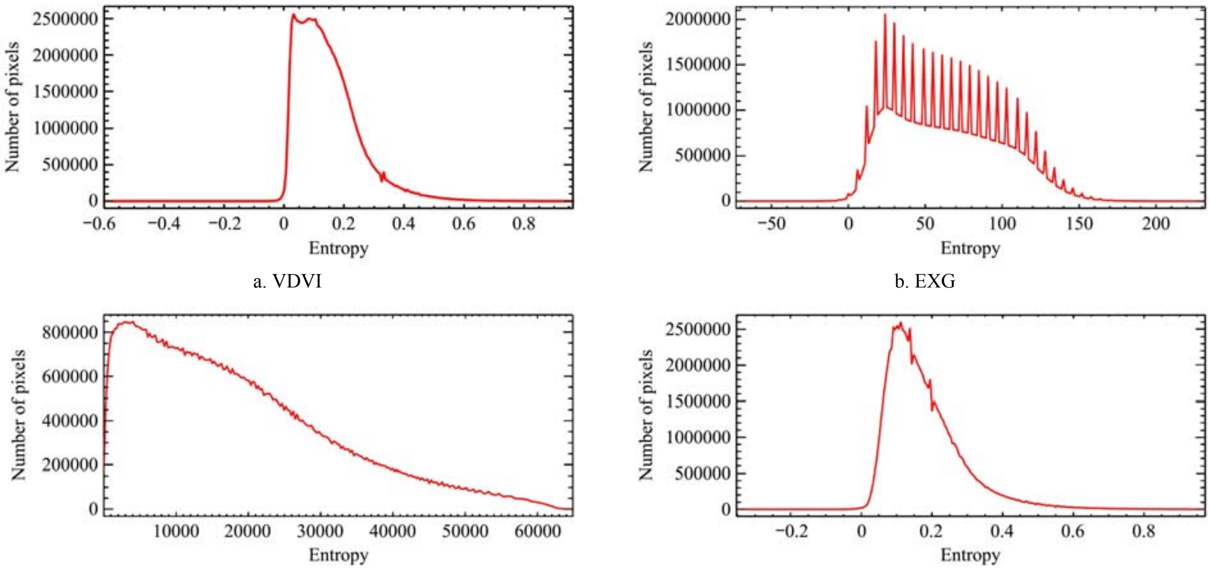
Vegetation index	Vegetation coverage at different confidence levels	
	2%	5%
EXG	0.440208	0.456506
NGBDI	0.318928	0.371545
RGBRI	0.342301	0.377980
VDVI	0.332142	0.393837

3.3 Maximum entropy threshold method vegetation coverage extraction results

Using the entropy statistical tool in the ENVI software, the maximum entropy information of the four vegetation indices VDVI, EXG, RGBRI, and NGBDI during the small bell mouth period of summer corn is calculated. As shown in Figure 4, the values of the four vegetation indices corresponding to the maximum entropy region in the statistical results are used as extraction thresholds for vegetation coverage, with thresholds of 0.149403, 64.990119, 18528.527280, and 0.180428, respectively. The maximum entropy threshold method based on four types of vegetation indices was used to extract summer maize vegetation coverage, which was 0.575456, 0.524376, 0.570918, and 0.597602, respectively.

3.4 Vegetation index threshold method vegetation coverage extraction results

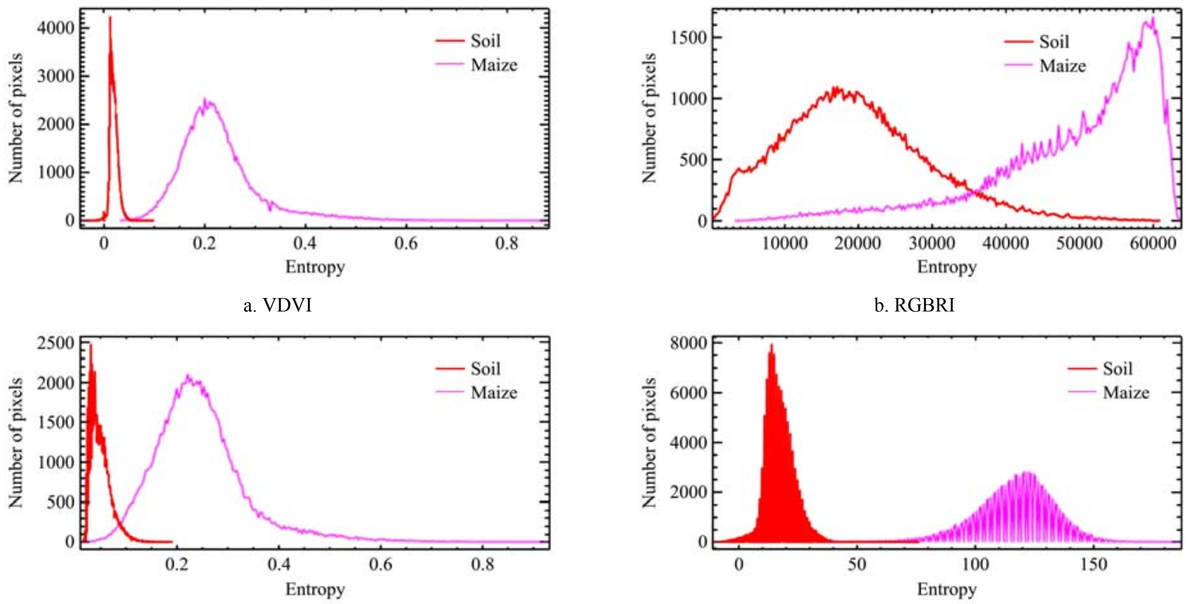
Based on the supervised classification results of summer corn, statistical analysis was conducted on the VDVI, RGBDI, NGBDI, and EXG indexes of corn and soil in the region. The statistical results are shown in Figure 5. In the above four vegetation index statistical histograms, the intersection points of vegetation pixels and soil pixels are 0.0505, 35671.3085, 0.0888, and 55.000, respectively. Taking them as the threshold values for distinguishing maize from soil, it is concluded that the vegetation coverage calculated using the four vegetation indexes RGBRI, NGBDI, EXG, and VDVI is 0.876225, 0.840177, 0.558811, and 0.847895, respectively.



a. VDVI b. EXG

c. RGBRI d. NGBDI

Figure 4 Extraction of maximum entropy of vegetation index



a. VDVI b. RGBRI

c. NGBDI d. EXG

Figure 5 Extraction of vegetation index threshold

3.5 Evaluation of vegetation coverage extraction results

Statistical SVM supervised classification maps and vegetation coverage maps obtained using three methods are used to obtain the true value of vegetation coverage and the vegetation coverage of each vegetation index under the three methods, which are used to evaluate the accuracy of the three methods. The results are shown in Table 5.

From Table 5, it can be seen that the maximum entropy threshold method has the best vegetation coverage extraction effect among the three methods, with the coverage extraction error of each vegetation index extraction being below 14%, and the vegetation index NGBDI has the best extraction effect, with an extraction error of 1.26%; The vegetation coverage extraction effect of vegetation index threshold method is the worst, but the vegetation coverage extraction effect of vegetation index EXG is better than that of RGBRI, NGBDI, and VDVI. Among the vegetation index threshold method and pixel dichotomy method, the vegetation index EXG has the best coverage extraction effect and the highest accuracy, with extraction errors of 7.67% and 24.58%, respectively.

The calculation rules of the three vegetation coverage extraction methods are different, and the results obtained are also quite different. According to the research of Chen Xiangdong et al[13], the vegetation index threshold method has the best extraction effect on the vegetation coverage of summer maize in the four leaf stage. According to the research of Meng Dunchao et al[21], the pixel binary method can effectively extract the vegetation coverage of winter wheat in the greening stage, and in this experiment, it was shown that the maximum entropy threshold method is more suitable for extracting vegetation coverage during the small horn period of summer corn. From this, it can be seen that different vegetation coverage extraction methods are not absolutely good or bad, but should be based on which crops and periods they are suitable for. Further research is needed to analyze the specific reasons for the differences in the results of the three vegetation coverage extraction methods during the small bell mouth period of summer corn. In addition, in the pixel binary method and vegetation index threshold method, the extraction error of EXG is better than the other three vegetation indices. The main reason is that summer corn grows very vigorously during the small bell mouth period, chlorophyll accumulates continuously, and the reflectance of the green band is relatively high. The vegetation index EXG constructed based on the strong reflection of the green band and the absorption principle of the red and blue bands is extremely sensitive to the green band, so the calculation error is small.

Table 5 Precision evaluation

Method of use	Vegetation index	Vegetation coverage	Supervised classification	difference	Extraction error/%
Pixel dichotomy	RGBRI	0.377980	0.605248	0.227268	37.55
	NGBDI	0.371545	0.605248	0.233703	38.61
	EXG	0.456506	0.605248	0.148742	24.58
	VDVI	0.393837	0.605248	0.211411	34.93
Maximum entropy threshold method	RGBRI	0.570918	0.605248	0.034330	5.67
	NGBDI	0.597602	0.605248	0.007646	1.26
	EXG	0.524376	0.605248	0.080872	13.36
	VDVI	0.575456	0.605248	0.029792	4.92
Vegetation index threshold method	RGBRI	0.876225	0.605248	-0.270977	44.77
	NGBDI	0.840177	0.605248	-0.234929	38.82
	EXG	0.558811	0.605248	0.046437	7.67
	VDVI	0.847895	0.605248	-0.242647	40.09

In order to facilitate field management and production guidance in precision agriculture, and further classify the obtained summer corn vegetation coverage results, this paper selects the vegetation coverage model of the vegetation index NGBDI, and obtains a vegetation coverage level distribution map of summer corn in the small bell mouth period divided into five levels according to the method proposed by Chen Hongbing et al.[30] and Cao Yongxiang et al.[31], and calculates the vegetation coverage results of each level, The grade distribution diagram and statistical results are shown in Figure 6 and Table 6.

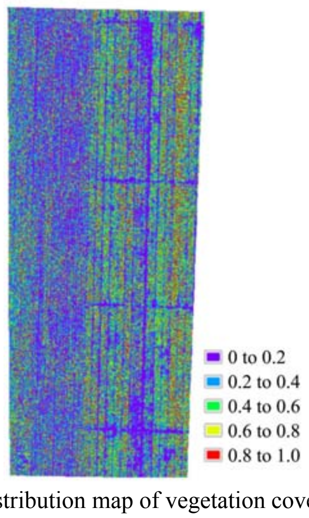


Figure 6 Distribution map of vegetation coverage grade of summer maize

Table 6 Results of distribution of vegetation coverage grades

Vegetation coverage	Like the original number	Percentage/%
0~0.2	60751637	65.954
0.2~0.4	27552605	29.912
0.4~0.6	3321668	3.606
0.6~0.8	441517	0.480
0.8~1	44896	0.048
Total	92112323	100

4 Conclusion and Outlook

This article uses low altitude drone remote sensing to study and explore the vegetation coverage of summer corn during the small horn mouth period. The research results show that:

(1) Using the maximum entropy threshold method based on vegetation index combined with vegetation index NGBDI to extract the vegetation coverage of summer corn at the small bell mouth stage has the highest accuracy, with an extraction error (EF) of 1.26%.

(2) Using the vegetation index threshold method and the pixel dichotomy method based on the vegetation index to extract the vegetation coverage of summer corn at the small bell mouth stage has the best extraction effect and the highest accuracy, with extraction errors (EF) of 7.67% and 24.58%, respectively.

(3) During the small bell mouth period of summer corn, the method of extracting vegetation coverage using the maximum entropy threshold method based on vegetation index is better than the vegetation index threshold method and the pixel dichotomy method based on vegetation index.

(4) Using the NGBDI vegetation coverage extraction model, a vegetation coverage grade map for summer corn at the small bell mouth stage was generated, providing a reference for field management in the later stage of corn.

The vegetation indices selected in this article are commonly used and typical, with some limitations, and only one period of data was collected. In future research, the author will further collect data from multiple years and growth periods, conduct research on vegetation coverage extraction methods for crops at different growth periods, and strive to verify the experimental conclusions on more vegetation indices to promote the further development of drone remote sensing monitoring.

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