GROWTH MONITORING OF WINTER WHEAT BASED ON OPTICAL REMOTE SENSING AND SAR DATA FUSION

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ABSTRACT: Multi-spectral remote sensing image in combination with radar image are conducive to the south area of extraction and crop growth monitoring. This study used three cities about Baoying, Gaoyou and Xinghua in the centre of Jiangsu Province in China as the study area, and made the Landsat / TM image and ERS/SAR image fusion in the winter wheat early jointing period, and then explored the remote sensing method of winter wheat planted area extraction. Based on the Optimum Index Factor (OIF) and spectral separability, selected bands 3-4-5 combination as the best band to classify. The traditional pixel-based classification results vulnerable to “the feature in different spectrum” and "foreign feature with the spectrum" effects. This study used object-oriented image classification approach with an object as a procession unit, and combined with a wealth of features in space, texture information for wheat area extraction, and then compared with pixel-based classification method (SVM classification) results. The results show the classification accuracy of SVM and object-oriented classification method is 78.59% and 94.16%, respectively. The object-oriented classification method can accurately extract the planting area of winter wheat, which is much better than the SVM classification method. Based on the extraction of winter wheat planting area, this study also monitored the winter wheat growth, and availably obtained the data and spatial distribution information of winter wheat in these counties. This method can give a technical support for the winter wheat planting area and growth information rapid access in the South China.

1. INTRODUCTION

Remote sensing technology is suitable for a wide range, dynamic, and accurate monitoring, and provides an effective means of crops identification. In recent years remote sensing has been increasingly applied to the crop production and management of information technology and research (Niel, 2004; Li, 2007). TM image contains a total of seven bands from visible to thermal infrared .It has rich spectral information, so it is suitable for small-scale extraction of winter wheat area. ERS image is interference from clouds, penetrating, and has a high contrast and resolution. ERS has a wealth of detail and texture, but it is lack of spectral information (Long, 2010; Li, 2010). These two types of remote sensing images can be combined to obtain good phase spectral and spatial information, with helping extract crops area (Michelson, 2000; Zhang, 2004; Carrão, 2008).

In condition of the sensor itself and environmental factors constrains, the "synonyms spectrum" and "foreign body with the spectrum" phenomenon is widespread in remote sensing images. Zhou (Zhou, 2008) pointed out that when the pixel-based classification techniques use only single pixel gray-scale characteristics of the spectral classification, it ignores the data space, texture and context information such as characteristics, classification result has the serious "salt and pepper noise". Although the artificial visual interpretation has a high precision (Li, 2009), it has defects of heavy workload, low efficiency, subjective nature, non-quantitative, and poor portability. In recent years, from the remote sensing image segmentation method scholars start the exploratory study of object-oriented classification method (Shackelford, 2003; Zhang, 2008), this method is no longer based on a single pixel, but on the image object. Fist according to the adjacent pixel spectral heterogeneity characteristic, split the image into multiple objects, and then add on the basis of the object space, texture and other characteristics for aid classification. In this study, make Baoying, Gaoyou and Xinghua three cities in Jiangsu Province for the study area, and fuse the Landsat / TM multi-spectral images and ERS / SAR image, then use object-oriented classification method to extract the winter wheat planted area. This study aims at building a suitable the effective extraction method of south crop growing area.

2. MATERIALS AND METHODS

2.1 Data and preprocessing

Study area is located in Baoying, Gaoyou and Xinghua three cities, which are located in Jiangsu Province central, the main crops in the spring are winter wheat and rape .Landforms includes Plains, rivers and lakes and so on. Remote sensing data use Landsat / TM multispectral images in March 9, 2009 and ERS / SAR images in March 25, 2009, Range of coordinates: 33°5′0″ ~ 32°5′13″N, 119°1′36″ ~ 120°6′35″E. TM image width and resolution is 185km and 30m , it has seven wave bands and a good spectral characteristics. SAR image width and resolution is 100km and 30m, contour surface features and Grain are clear and rich, it has a good spatial characteristics. Selecting sample points around the object by GPS in the study area and it uses for geometric correction and classification process. The two images were corrected for atmospheric correction and geometric before planting area extracted. Geometric correction of the projection parameters is Albers under the reference ellipsoid of Krasovsky and control precision within a pixel. Super imposing administrative division vector of the study area, and then made wavelet fusion after cutting images.

2.2 Object-oriented classification

Image segmentation classification uses object composed of adjacent pixels which is similar structure in image as processing unit. According to the characteristics of information objects, surface features and classification hierarchy between the relationships of surface features are in the classification process. Classification process is divided into three steps, (1) Image segmentation (2) Feature selection (3) Establish classification rules and classification. First, selecting the appropriate scale for multi-scale segmentation and dividing into a number of objects of image, then using the normalized difference vegetation index (*NDVI*) to vegetation and non-isolated area of vegetation. Second, according to different vegetation (Winter wheat, oilseed rape, the bushes and grass, etc.) zones in the spectral characteristics of vegetation, *NDVI*, and texture information of different and setting up different types of membership functions (rules) respectively, then extracting from the winter wheat.

2.2.1 Image segmentation: Image segmentation to the image pixel phase separation in homogeneous and heterogeneous pixel merging, the image is divided into a number of meaningful clusters polygon object and each object has the same or similar characteristics such as spatial, spectral, texture and shape, segmentation results directly affect the feature extraction and classification accuracy.

Surface features have a specific spatial scale and image segmentation should select the appropriate scale of opera. Determines the scale of the object divided by maximum degree of heterogeneity and need to consider h_{color} and h_{shape}, the weights of the two is 1.

$$f = \omega_{color} h_{color} + \omega_{shape} h_{shape} \tag{1}$$

$$\omega_{color} + \omega_{shape} = 1 \tag{2}$$

h_{color} is the first condition of determining the object; it has a relation of *n, obj*1and *obj*2 and merges the standard deviation of gray value band. Expression is

$$h_{color} = \sum_{c} \omega_c \left(n_{merge} \sigma_c^{merge} - \left(n_{obj1} \sigma_c^{obj1} + n_{obj2} \sigma_c^{obj2} \right) \right) \tag{3}$$

ω_c is weight band of *c*. The object type expresses the combined changes in spectral heterogeneity before and after the segmentation, and determines whether to expand or create new objects. Segmentation process needs to factor into shape hetero; Shape of the heterogeneity is demanded of smoothness and compactness h_{cmpct} h_{smooth} two indices: smoothness can smooth the object boundary, and Reduce the fragmentation boundary, and then Compactness of compact objects can be optimized, both weights is 1.

Shape of the heterogeneity of expression is

$$h_{shape} = \omega_{smooth} h_{smooth} + \omega_{cmpct} h_{cmpct} \tag{4}$$

$$\omega_{color} + \omega_{shape} = 1 \tag{5}$$

h_{smooth} and h_{cmpct} is relation of n, l, and b. Expression is

$$h_{smooth} = n_{merge} \frac{l_{merge}}{b_{merge}} - \left(n_{obj1} \frac{l_{obj1}}{b_{obj1}} + n_{obj2} \frac{l_{obj2}}{b_{obj2}} \right) \tag{6}$$

$$h_{cmpct} = n_{merge} \frac{l_{merge}}{\sqrt{n_{merge}}} - \left(n_{obj1} \frac{l_{obj1}}{\sqrt{n_{obj1}}} + n_{obj2} \frac{l_{obj2}}{\sqrt{n_{obj2}}} \right) \tag{7}$$

General rule of thumb chooses scale image segmentation, using small-scale segmentation for smaller and more complex features in the distribution category, using large-scale segmentation for larger, texture rules, spatial characteristics of the more obvious features in category. Selecting the split parameters has to adjust the trial to determine the optimal segmentation parameter.

2.2.2 Extraction of vegetation index: Vegetation index is reflecting the crop, type and distribution of vegetation parameters, which is combined by red band and near-infrared reflectance of multiple and has a strong ability. *NDVI* is the most commonly used vegetation index, groups may reflect the growth status of crops, the expression is

$$NDVI = \frac{NIR - R}{NIR + R} \tag{8}$$

NIR is near infrared reflectance, and *R* is the reflectance of red band, When $NDVI > 0.05$ is the area of vegetation, When $NDVI < 0.05$, is the non-vegetation area. Vegetation zone in the main vegetation types are winter wheat, oilseed rape and grass trees (hereinafter referred to other vegetation and so on). A large range of *NDVI* range overlap, simple use of vegetation indices for crop classification is not enough, information is need to introduce more effective texture classification.

2.2.3 Extraction of texture information: Texture analysis is the spatial distribution of the image gray value model extraction and analysis to obtain qualitative or quantitative description of the process. Selecting the four parameters used, inverse gap, entropy, angular second distance and contrast. Extract 3×3 window three types of vegetation texture information.

f_{Hom} is reflecting the homogeneity of the texture of local indicators, the greater the value the smaller the local area texture changes and the more uniform. Expression is

$$f_{Hom} = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} \frac{P(i,j)}{1 + (i-j)^2} \tag{9}$$

$P(i, j)$ is the image at pixel (i, j) the gray value of point, and N is the image gray scale. f_{Ent} indicators reflect the image the amount of information, the greater its value the greater the amount of information of the texture. F_{Asm} is reflecting the image gray-scale uniformity measure, the greater the value the more coarse texture, the smaller the more delicate texture. It also reflects the image of homogeny. Expression is

$$f_{Asm} = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} P(i,j)^2 \tag{10}$$

f_{Con} is reflecting the contrast between black and white image texture and clarity of the indicators, the greater the value the more eye-catching texture and more clearly. Expression is

$$f_{Con} = \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} P(i,j)(i-j)^2 \tag{11}$$

2.3 Determining the sample space

To ensure an adequate number of samples, using a combination of GPS receiver types collected samples throughout the material directly on the TM image to extract the standard sample set in this study. Select 95% of the sample crops in the training sample classification, and use the remaining 5% of the sample as the test samples for accuracy assessment. The study area is divided into water bodies, buildings and roads, winter wheat, oilseed rape and a total of five categories forest and grassland feature type.

3 RESULTS AND ANALYSIS

3.1 Segmentation of remote sensing images

Using the fusion images of TM with 3-4-5 band combinations and SAR, select the segmentation scale according to the spatial distribution of different objects in the study area and visual effect. The resolution of image is medium and the surface feature spectrum feature is relatively outstanding, shape feature and texture feature is not obvious, but the vegetation types of the study area are rich, the distribution is complex. Using the winter field as segmentation foundation, determine the segmentation scale is 55, spectral heterogeneity weight is 0.8. The scale of vegetation and vegetation area can be completely separated, at the same time; various types of vegetation types can get better distinction.

3.2 Extraction of vegetation feature

Before classification, feature extraction is needed. First of all, separate the vegetation area and not vegetation area with *NDVI*. Then, extract the *NDVI* of three vegetation types -- winter wheat, rape and other vegetation. The value range of *NDVI* is that 0.3274 ~ 0.7073 of winter wheat, 0.2394 ~ 0.4054 of rape, other vegetation in 0 ~ 0.2222. As can be seen, winter wheat and other vegetation can be separated by *NDVI*, but rape and other two types of *NDVI* have overlapping regions, especially with the overlapping range of Winter Wheat, Single with *NDVI* is basically indistinguishable. Therefore, texture information of three vegetation types is needed to be extracted. Calculate the gray level co-occurrence matrix of images with 3×3 windows, draw the texture information of three vegetation types, the results can be seen in table 1.

Table 1 Texture characteristics statistics

Classes	f_{hom}	f_{Ent}	f_{Asm}	f_{Con}
Winter Wheat Field	0.53	2.20	0.14	9.78
Rape Field	0.42	1.89	0.16	14.00
Others	0.27	2.04	0.11	19.33

From table 1, the order of f_{Hom} from big to small is winter wheat > rape > other vegetation, it can be described that winter wheat field distribution is relatively regular and large, texture structure is single, rape secondly, other vegetation distribution is fragmented mess. Winter wheat field has the highest amount of information with the maximum f_{Ent} as 2.20. But the f_{Con} of winter wheat is the lowest at 9.78, the images show that the details are not rich and striation is not obvious. Bushes and grass distributed in small areas, irregular in shape, with the highest f_{Con} 19.33. Rape has the lowest f_{Ent} as1.89, but the f_{Asm} is the highest as 0.16, field is slightly smaller than winter wheat, delicate texture is more uniform, but contains less information. The four indicators can be synthesized in auxiliary classification.

3.3 Planting area extraction of winter wheat and accuracy evaluation

To compare the effect of classification that based on pixel, extract the area of winter wheat by using support vector machine (SVM) method from the fused image. Analyze and compare the results with the results based on object oriented, as shown in Figure 1.

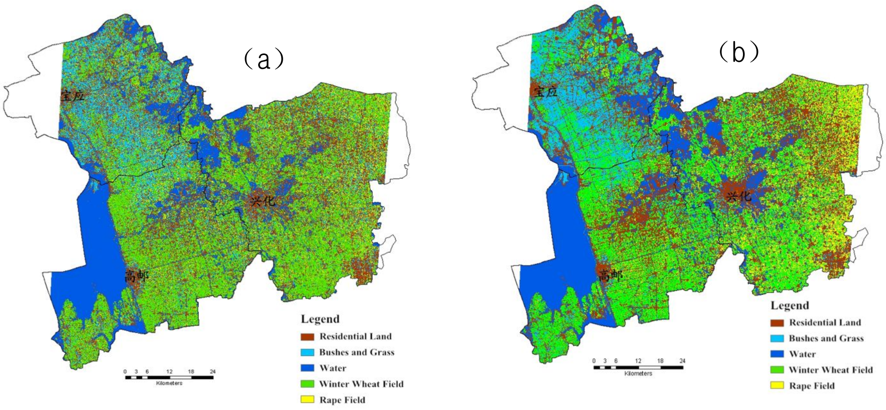

Figure 1 SVM classification (a) and object-oriented classification (b) results

Figure 1 shows that the classification results of the two methods have big difference. The result of object oriented classification is more meticulous than SVM classification," foreign body in the same spectrum" and" foreign body with different spectrum" phenomenon is effectively improved. The winter wheat area extracted by two methods has much difference, but the distribution situation is basically the same. The area and distribution of rape, bushes and grass has much deference, the distribution of residential land is more fragmented which based on object oriented classification.

Use of test samples on two kinds of classification results to evaluate the accuracy, the classification accuracy of SVM is 78.59%, Kappa coefficient is 0.64, the result of object-oriented classification is 94.16%, Kappa coefficient is 0.92, the classification accuracy has been greatly improved. Various types of vegetation area extracted by two methods can be seen in table 2.

Table 2 Three types of vegetation area extraction by two methods in three cities

Classes	SVM Classification (hm^2)				Object-oriented classification (hm^2)			
	Baoying	Gaoyou	Xinghua	Total	Baoying	Gaoyou	Xinghua	Total
Winter Wheat Field	23,646	64,077	63,389	151,112	21,640	64,127	80,420	166,187
Rape Field	3,003	12,931	46,940	62,844	7,940	11,412	22,962	42,314
Others	45,208	12,671	7,046	64,925	39,414	21,248	23,902	84,564

As can be seen from table 2, compare the results of the SVM and object oriented, winter wheat planting area all increased, increase by 15,075 hm^2. Among them, vegetation area of Xinghua City changes greatly, increasing from 63,389 hm^2 to 80,420 hm^2, two other cities change a little. Rape area is greatly reduced, three cities are reduced by 20,556 hm2, Xinghua City is the most reduced from 46,940 hm^2 to 33,962 hm^2, but Baoying City is increased from 3,003 hm^2 to 7,940 hm^2. Other vegetation area has greatly increased, three cities increase of 19,649 hm^2 as a total, area of Gaoyou、Xinghua mainly increased, Xinghua increases the most from 7,046 hm^2 to 23,902 hm^2, Gaoyou times, increases from 12,671 hm^2 to 21,248 hm^2, but other vegetation area of SVM is reduced by object-oriented classification from 45,208 hm^2 to 39,414 hm^2 in Baoying. The main sources of error in rape and the others is spectral cross range, vegetation types of mixed pixel subdivision caused serious, a large number of training samples confuses the poor winter wheat region with the addition of two types of vegetation. Pixel based classification (SVM) method uses a single pixel gray value on the classification, therefore, the other two planting was wrong to rape too much. Due to the low vegetation coverage, and spectral features of other vegetation and the residents are similar, SVM classification confuses with each other. With the texture of other vegetation and the residents is different, the object oriented classification can separate them out.

3.4 Winter wheat growing remote sensing monitoring in different counties

After winter wheat planting area accurately extracted, the paper calculated winter wheat NDVI using the fusion image, estimated of winter wheat leaf area index (LAI) by the LAI estimation model (Li, 2007), and get winter wheat in different growing level distribution of three counties (table 3).

Table 3 Winter wheat area distribution of different growth condition levels in different counties

Class name	Range Of LAI	Growth condition levels	Baoying county (21640 hm^2)		Gaoyou county (64127 hm^2)		Xinghua county (80420 hm^2)	
			Wheat area (hm^2)	Proportion of total area (%)	Wheat area (hm^2)	Proportion of total area (%)	Wheat area (hm^2)	Proportion of total area (%)
LAI- Ⅰ	LAI≥4	Luxuriant	670.8	3.1	2116.2	3.3	2332.2	2.9
LAI- Ⅱ	3.5≤ LAI < 4	Normal	13092.2	60.5	39951.1	62.3	47930.3	59.6
LAI-Ⅲ	3≤ LAI < 3.5	Weak	4869	22.5	15262.2	23.8	18657.4	23.2
LAI-Ⅳ	LAI < 3	Poor	3008	13.9	6797.5	10.6	11500.1	14.3

Can be seen from table 3, winter wheat LAI from 3 to 4 in three counties were in the majority, is growing better, accounting for 82.6% ~ 86.1% of the total area. LAI, more than four plots in growing strong, accounting for 2.9% ~ 3.3% of the total area. LAI, less than 3 plots grew worse, accounting for 10.6% ~ 14.3% of the total area. Different counties of winter wheat growing and their distribution are different; the winter wheat field management measures need to be adjusted or modified.

4 CONCLUSIONS AND DISCUSSION

Compare with traditional manual survey methods, remote sensing technology become the primary means of winter wheat acreage. Winter wheat jointing stage is the most suitable period for wheat area extraction. This study fist chose Baoying, Gaoyou and Xinghua three cities as the study area, second based on the band selection, and then fused TM multi-spectral image and ERS/SAR image for object-oriented classification to extract the winter wheat acreage. Classification accuracy with a satisfactory result is 94.16%.

The previous pixel-based image classification methods factors only contain spectral features, which accuracy is lower. In the object-oriented classification, we use object-processing as a unit, and in combination with NDVI and texture characteristics for ancillary classification. The results are far superior to the traditional classification. There is a better solution to impact of the “synonyms spectrum” and “foreign body the same spectrum”, and achieved a high accuracy.

In the winter wheat area for the extraction of object classification, there are still some shortcomings. The key lies in the optimal segmentation scale image selection, and experimental studies are needed to be further improved. Image segmentation is the basis of classification and the core issue. Image segmentation will affect the classification accuracy. However, there is no extensive use of quantitative methods to access separate scale, only have to trying and changing scales, and relying on experience to determine the artificial scale. But the same split-scale is difficult to apply into the large-scale image segmentation, there are over or due to split segmentations in the local area. In the next step, the self-adaptive segmentation scale is needed to study and improve.

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