The Journal of Animal & Plant Sciences, 25 (3 Suppl. 1) 2015 Special Issue Page: 5-12
ISSN: 1018-7081

FOUR SUPERVISED CLASSIFICATION METHODS FOR MONITORING COTTON FIELD OF *VERTICILLIUM WILT* USING TM IMAGE

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ABSTRACT

The monitoring techniques and methods of *Verticillium wilt* were benefit for increasing yield and efficiency of cotton, and could provide theoretical basis for distribution of crops and disease resistant variety. The study make use of TM satellite multispectral image in the study area as data sources, combining with the ground survey data, find the optimal band combination to monitor cotton fields infected *Verticillium wilt*. Then four supervised classification methods, included minimum distance method, the parallelepiped method, spectral angle mapping classification and support vector machine algorithm, were applied to recognize cotton fields of *Verticillium wilt*. Results showed that false color band combination which from the blue band (band1), near infrared wave band (band4) and the short infrared wavelengths (band5) of the multispectral image, can be used as optimal combination of TM image to monitoring cotton fields of disease. Cotton fields of diseases could all been recognized and classified into different types by four supervisedclassification methods during blooming period; and the results of the parallelepiped method was most closest to reality, the overall accuracy and kappa coefficient were 90% and 85% ,respectively, were highest in the four algorithms. The results could satisfy the production requirements, and be carried out in fast diagnosis of cotton field infected *Verticilliumwilt*.

Key words: Supervised classification, cotton fields, TM satellite image, disease monitoring.

INTRODUCTION

Verticillium wilt of cotton was a major disease which caused reduction in both the quality and quantity of cotton and had become one of the stubborn diseases of cotton. Monitoring cotton disease epidemic situation as soon as possible was benefits to take the effective measure timely to reduce the destruction of *Verticillium wilt*. However, the traditional monitoring method was a laborious and time-consuming effort and couldn't apply in large scale. Lots of researches indicated that with the increasing development of remote sensing technology, using remote sensing data to monitor crop diseases could clearly reflect the plant diseases. Malthus and Madeira (1993) measured the spectra of bean leaf with an integrating sphere connected to a spectroradiometer and found that the most significant changes in reflectance associated with the disease were a flattening of the response in the VIS region and a decrease in the NIR reflectance shoulder at 800 nm. Bulanon*et al.* (2013) developed a multispectral imaging algorithm (four wavelengths were identified) to detect citrus black spots and indicated linear discriminate classifier and artificial neural networks had all overall accuracy of 92%.Huang*et al.* (2013)studied insect-damaged vegetable soybeans using hyperspectral transmittance image, showed four statistical image features (minimum, maximum, mean, and standard deviation) were extracted from the images for classification and given as input to a discriminate classifier, with a 95.6% overall classification accuracy. Zhang *et al*. (2010)proposed a monitoring method based on PHI images via Mahalanobis distance or spectral angle mapping (SAM) for monitoring the severity degree of winter wheat infected stripe rust, coefficient of determination was achieved 0.93.The researchers have been also developed through monitoring crop disease infection using models of remote sensing. For example, Hamid Muhammed (2005) raised a linear transformation model of remote sensing to quantify fungal disease severity in wheat. Zhang *et al.* (2002) make late blight infection on tomatoes could be recognized using modes of the principal component analysis (PCA) and cluster analysis (CA) when the infection severity reaches middle to late stages. Yu*et al*. (2014) selected sensitive wavelengths by visible and near-infrared hyperspectral imaging and established the partial least squares discriminate analysis (PLS-DA) model (overall detection accuracy of 92.3 %), detected defective features in loquat.

In addition, some work has been done on the classification methods for monitoring crop disease by remote sensing. Lü*et al.* (2012) extracted four component images from 600 to 1000 nm using principal component analysis (PCA), then using parallelepiped classification to inspect the hidden bruises on kiwi fruit. The error of detecting was 14.5%. Haff*et al.* (2013) demonstrated that incorporates background removal, application of a Gaussian blur, shareholding, and particle count analysis to recognize locations of fruit fly infestations of mangos, for the same sample set, the lowest overall error rate achieved 2.0%, with 1.0% false positive and 3.0% false negative. Li*et al.* (2014) created a 'extended spectral angle mapping (ESAM)' method to detect citrus greening disease with Hyperspectral imaging, the method had a better detection accuracy of 86 % than those two methods of supervised method (Mahalanobis distance) and unsupervised method(K-means). Jing *et al*. (2010) introduced partial least squares (PLS) regression analysis and established the severity estimating model by the IKONOS image to estimate cotton verticillium wilt , the model based on PLS achieves better accuracy (R^2=0.78).ElMasry*et al.* (2009) probed chilling injury in red delicious apple using hyperspectral imaging (400–1000 nm) and artificial neural network (ANN) technology, the correlation coefficients of ANN models achieved 0.93, 0.91 and 0.92 for the training, testing, and validation sets, respectively. In conclusion, the scholars carried out lots of works about crop disease monitoring with remote sensing technology, including selected sensitive bands, established modes and classified algorithm, etc. In view of the classification methods of image, single classification methods had more applied to recognized disease of plant, two or more classification methods compared application with plant disease were a little research. And the objects of classification were most aimed at wheat, corn, tomato and vegetables etc. However, little effort has been done to classify cotton field of*Verticillium* by different classification methods on the based of remote sensing image. With the development of aerospace project in china, remote sensing data will increasingly become one of reliable and irreplaceable spatial data sources. (Feng*et al.,* 2004)

This paper presents our research on application of remote sensing for monitoring the *Verticillimu* through different classification methods of cotton fields. The objectives of the study were to: (1) optimize selection of bands and its combinations in remote sensing classification from Landset-TM data, and (2) test the performance of different classification methods for monitoring *Verticillium*of cotton field.

MATERIALS AND METHODS

Basic situation of study area: The study area was established in Shihezi Oasis, Xinjiang Province, China. The mean sea level (MSL) Shihezi was about 450 m. The region was characterized by temperate continental aridweather with an average annual temperature of 7.5–8.2℃, a frost-free period on 170–173 days, rainfall of 180–270 mm and evaporation of 1000–1500 mm per year. The study area was important cotton production base in China, cotton production was in intensive management and high mechanization, scientific management. And good condition for the application of remote sensing technique was provided.

Ground data investigation and experiment treatment: As fixed-point observation demonstration farm all the year round in the study area (Fig 1, left), the ground data acquisition date was years of 2008, 2009, selection of satellite ground synchronous investigation and test of transit in cotton flower bell stage. Eight cotton fields were sampled, including health cotton field and perennial *Verticillium wilt* cotton field which were showed in Fig 1 (right), eight cotton fieldswere surveyed act as training samples when satellite passed those region, every sampling point of cotton field center, an area of about 900m^2 (an image pixel), the investigation was made by sampling in five locations for diseases, every sample has 50 cotton plant survey datum, the rate of infection were computed by:

$$P = \frac{m}{n} \times 100\% \qquad (1)$$

Among them: P - incidence; m - disease plant number; n-the total number of survey. At the same time survey every certain radioactive-polluted area of disease.

According to the standard of the People's Republic of China –quarantine rules of division standard of disease area for cotton original seed (GB 7411-1987), the area in cotton fields were divided into three different disease regions: health region, slight disease region and serious disease region based on the survey results of the disease incidence combination with characteristics of satellite images (Feng*et al.,* 2004). Then cotton fields were divided into three different categories: normal cotton field, slight disease cotton field, and serious disease cotton field according to percentage of disease regions account for whose cotton field. The specific division standardmethod saw Chen's method (Chen *et al.,* 2012).The GPS was used to positioning for samples, the test samples were identified, classified and the results were test.

Remote sensing data acquisition and processing

Data acquisition: The *Verticillium wilt* of cotton was serious in northern Xinjiang because of continuous cropping and high-frequency irrigation in cotton field, and it began to occur after budding stage, flowering boll period attained peak (Chen *et al.*, 2011, Zhang*et al.*, 2006). So TM images from China remote sensing satellite ground receiving station(http://www.rsgs.ac.cn/) were selected during boll period (late July to mid-august) in years of 2008 and 2009, which average cloud cover were required less than 10%.

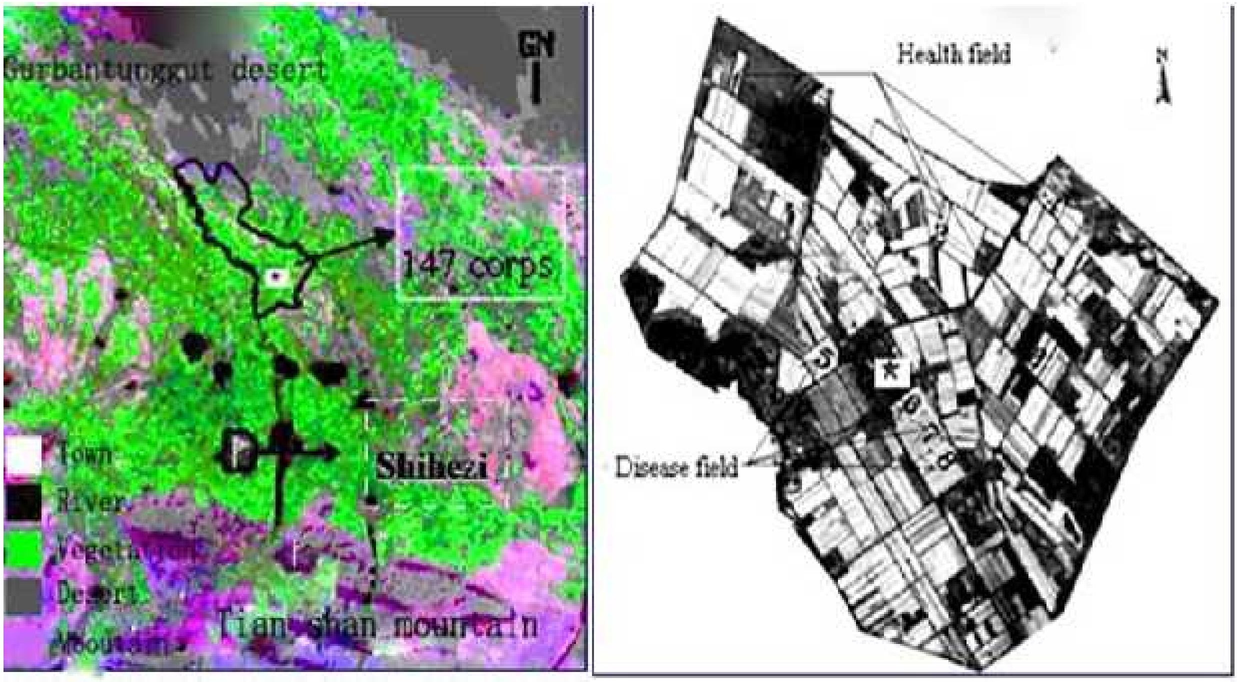

Figure 1. The location of researching region (147 corps) and sample points

Classification categories: ENVI4.8 software was used for remote sensing image preprocessing (Deng *et al.*, 2010). Process of remote sensing image include: geometric correction, atmospheric correction and image enhancement processing (Shen *et al*., 2002). According to the latest map of land condition was provided from the government departments in the study area, combining with survey results of all cotton fields, research area were classification using image classification methods. According to the ROIs of sample (Pan*et al.*, 2010) established training sample regions, each cotton field selected 10 training samples, then training samples of representative disease cotton were input classification categories to classification for cotton fields in the years of 2008, 2009.

In order to explore the most suitable classification method for cotton fields of *Verticillium wilt* , this paper carried on the Minimum Distance (MID), Parallelepiped (PP), Spectral Angle Classification (SAM), and Support Vector Machine (SVM) of methods supervised classification methods.

Classification accuracy evaluation: In addition to the 8 designated cotton fields, a total different types of cotton field 50 plots, including 20 health cotton fields, 15 light disease and 15 serious cotton fields , were selected as training samples to evaluate classifying results . The accuracy of different classification methods were test and compared. Accuracy evaluation referred to the comparison of the two images in a precise image as benchmark, the percentage of correct image pixels were regarded as classification accuracy (Lunetta*et al.*, 2006).

Remote sensing data acquisition and processing Data acquisition: Confusion matrix proposed was one of the import methods of accuracy evaluation (Congalton, 1991). It had three evaluation indexes, user accuracy, mapping accuracy and precision of overall accuracy. User accuracy was probability of random pixel which were correctly classified in the classification result; mapping accuracy was the matching degree of pixel in actual situation and the classification result; Overall accuracy referred to image classification results consistent with the actual type and its corresponding areas of probability. In addition, Kappa coefficient had been also used to accuracy evaluation, it could reflect the overall classification results correctly.

RESULTS AND ANALYSIS

Best combination bands selection: According to the principle of additive color composite, this study selected three bands of TM images, including red, green, blue three primary colors, to combination. Through the three bands overlay, composition color composite image. By enhancing color transform to deepen understanding of the TM image enhancement processing. Existing research showed that: for Landset-TM data, TM4 band could be used as the best single band satellite monitoring disease in cotton fields (Chen *et al*., 2012). According to the TM image of each band correlation coefficient matrix could get smaller correlation band for 1, 4, 5 bands. In different wavelengths depending on the type of different ground objects from spectrum reflection characteristic curve (Fig 2). Fig 2 indicated the most obvious change was 4, 5 bands. Because 1, 4, 5 bands represented the visible light, near infrared and short-wave infrared wavelengths, respectively, so they had the largest amount of information, least amount repetitive characteristics, thus the combination of 1, 4, 5 bands could been the best combination band of TM image to monitoring cotton field of *Verticillium wilt.*

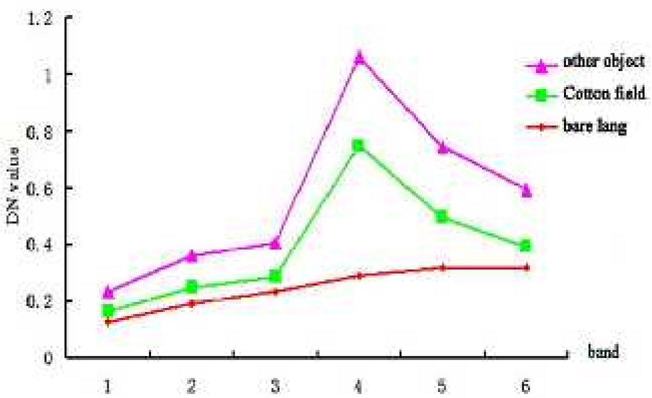

Figure 2: The spectrum graph of different objections in different bands of TM image.

Supervised classification results: The results of different supervised classification algorithm were analysis by comparative way (Figure. 3 & 4). Through cotton fields investigation and theinterpretation, got 295 and 241 cotton fields in study area in 2008 and 2009 year, respectively. In the year 2008, the classification result of the SVM algorithm could divided into two ones, serious disease cotton fields (red area) and normal cotton field (green area), cotton fields of slight disease (blue area) had not almost been classified, the classification results of the SVM algorithm had the same performance as the proportion of severe disease cotton in 2008 and 2009. Because this algorithm was too rough to determine the cotton fields of disease, it had no significant real meaning to guide production. These classification result of MIN algorithm,SAM algorithm and PP algorithm could all divided into three ones, not only serious disease cotton fields and normal cotton field, cotton fields of slight disease could clear classified, so they had better accuracy than SVM algorithm. In adding, MIN algorithm and SAM algorithm were similar, compeer with PP algorithm, the result of PP algorithm was smaller proportion to cotton field area of serious disease than other classification algorithm.

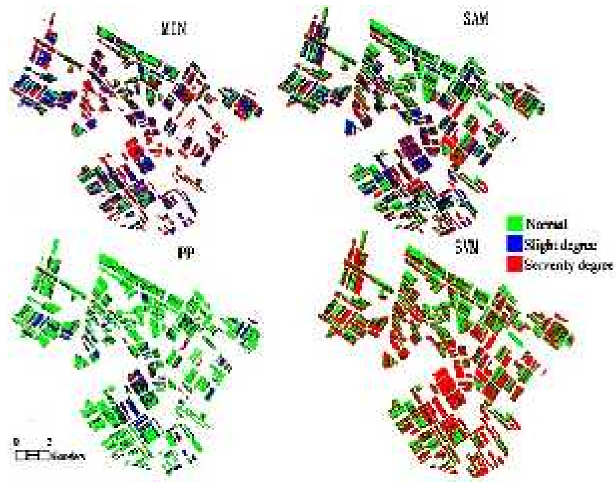

Figure 3. The diagnosing results on cotton fields of *Verticillium* using supervised classifications in 2008

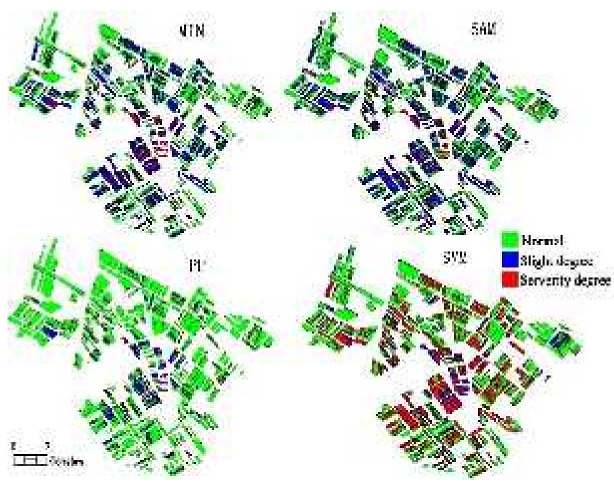

Figure 4. The diagnosing results on cotton fields of *Verticillium* using supervised classifications in 2009.

In order to compared those supervised classification methods difference, the statistic analysis of different classification methods were done between the pixel number and percentage of cotton field samples (including normal, slight and serious cotton fields). Table 1 compared the results of different supervised classification methods. Table 1 showed that: both in 2008 and 2009 year, the result of PP algorithm had largest proportion of the normal cotton fields then others. In 2008 year, the monitoring results of MIN algorithm was significantly different from other three methods, the rest three methods had similar results: the rate of normal cotton field, slight cotton field and the serious cotton field were 4:3:3 roughly; in 2009, the proportion of different disease conditions were 5:3:2 ,respectively. And in 2008, the results showed that the proportion of normal cotton fields, slight cotton fields and serious cotton fields were 71%, 18%,11% ; while the proportion in 2009 were 77%, 10% and 13% ,respectively.

Classification precision comparing and ground test and verify: In order to test and compared our supervised classification methods′ precision, 58 cotton fields (including fixed and random) were extracted as training samples input every algorithm.

Table 1. The result of supervised classifications for cotton field infected *Verticillium wilt* in 2008-2009.

Years Year	Treatments	Items	Classification methods MID	PP	SAM	SVM
2008	Normal cotton field	pixel number	8,604	23,641	17,204	17,936
		（%）	26.39	74.08	38.78	40.42
	Slight cotton field	pixel number	11,104	5,786	12,126	8
		（%）	34.06	18.13	27.34	0.02
	Serious cotton field	pixel number	12,895	2,487	15,030	26,435
		（%）	39.55	7.79	33.88	59.57
2009	Normal cotton field	pixel number	5,650	29,746	20,449	23,236
		（%）	16.80	81.41	49.24	52.61
	Slight cotton field	pixel number	16,604	4,108	15,648	4,789
		（%）	49.37	11.24	37.68	10.84
	Serious cotton field	pixel number	11,375	2,685	5,434	16,142
		（%）	33.82	7.35	13.08	36.55

The result saw table 2, table 2 showed that: compare four supervised classification methods, user accuracy had all highest precision, mapping accuracy and overall accuracy were all lower, but overall accuracy all reached more than 40%. Among them, user accuracy of PP method was highest above 80% in two years; while user accuracy of MID was lowest, even about 20%, the overall precision was less than 62%. The rest of the two classification methods (SVM and SAM) for most of the features of the overall precision were above 60%.In addition, form the test data of two years, the highest Kappa coefficient were also the PP method, more than 80%,the others the Kappa coefficients were less than 60%. Thus the classification result of PP method was highest precision, the most suitable for remote sensing monitoring *Verticillium wilt* of cotton field during the blooming period. In view of above analysis, using best classification method, PP method, combining with the ground investigation, classification precision was validation, in 2008 and 2009 year, the overall accuracy classification results were 90%, 91% respectively, Kappa coefficient were higher than 85%, user accuracy with different levels of disease were higher than 80%, the producers precision were higher than 75%, could meet monitoring accuracy requirements for the farmland management measures to cotton field of *Verticillium wilt*, can provide effective information for cotton growers and decision makers.

DISCUSSION

Xinjiang cotton was unique in large scale and intensive cultivation, this unique provided good condition for using the remote sensing data to monitoring cotton fields. Because of the dynamic characteristics of remote sensing image, scholars have proved that cotton disease monitoring was feasible using multi-spectral remote sensing technology (Chen *et al.*, 2012). Because TM band 1(B1) as the blue band, contains the feature information was the most abundant; band 4 (B4) was a near infrared band, sensitive information to the plant, more used to plant identification and classification; Band 5 (B5) and band 7 (B7) as for shorter infrared wavelengths, B5 was sensitive to soil moisture and plant more, B7 was more used in mineral research, sensitive to hydrothermal alteration rock, different band combination reflected different satisfied results(Pan, 2010). Comprehensive correlation analysis of the TM data of each band in the study area, as well as considering the synthesis of 1, 4, 5 band data resolution was high and the interference information advantage was as less, so selected 1,4,5 band of TM image enhancement processing after comparison and analysis, for subsequent supervised classification. Comparing with research result of Chen *et al.* (2012), this paper found false color synthesis of 1, 4, 5 bands from TM image enhanced monitoring effect to cotton field of *Verticillium wilt* than 7, 4, 3 bands of color synthesis, but this result was similar with Shen *et al*. (2002), who adopted comprehensive index to select image combination band 1, 4, 5 for two consecutive years.

Table 2. The evaluation of supervised classifications for cotton field infected *Verticillium wilt* in 2008 and 2009 years.

Methods	Year	Treatments cotton field	Unclassified	Health field	Slight	Severity	Sum	Prod. accuracy (%)	User accuracy (%.)	Overall accuracy	Kappa coefficient
MID	2008	Health	6	16	5	13	40	40	94.12	40	0.21
		Slight	1	1	13	15	30	43.33	72.22		
		Severity	13	0	0	7	20	35	20		
	2009	Health	5	25	0	0	30	83.33	100	62.86	0.47
		Slight	3	0	5	12	20	60	48		
		Severity	0	0	7	13	20	35	58.33		
PP	2008	Health	1	39	0	0	40	97.5	97.5	90	0.85
		Slight	0	1	27	2	30	90	93.1		
		Severity	3	0	2	15	20	75	88.2		
	2009	Health	0	30	0	0	30	100	93.75	91.43	0.87
		Slight	0	0	4	16	20	80	81.82		
		Severity	0	2	18	0	20	90	100		
SAM	2008	Health	0	32	8	0	40	80	96.97	60	0.41
		Slight	0	1	5	24	30	16.67	31.25		
		Severity	0	0	3	17	20	85	41.46		
	2009	Health	0	25	5	0	30	83.33	100	71.43	0.57
		Slight	1	0	2	17	20	85	58.62		
		Severity	0	0	8	12	20	40	53.33		
SVM	2008	Health	0	33	0	7	40	82.5	97.06	58.89	0.41
		Slight	0	1	0	29	30	0	0		
		Severity	0	0	0	20	20	100	35.71		
	2009	Health	0	30	0	0	30	100	100	67.14	0.5
		Slight	0	0	14	6	20	30	40		
		Severity	0	0	11	9	20	55	44		

In general, image classification methods were include supervised classification method and unsupervised classification method. Two classification methods were all play an important role in the image classification. Although the unsupervised classification method was relatively easier performance, but had a lower accuracy (Zhang*et al.*, 2011), so supervised classification had pay much attention to recognize ground objects in recent years. According to different classification algorithm, supervised classification could be also divided into different methods. Some of them were very classical, for example, maximum likelihood method, minimum distance classification, parallelepiped method, and so on. The different classification algorithm had the different characteristics, therefore, different cotton fields diseases of were classified with the different supervised classification algorithm in this research. By comparing different results of supervised classification algorithm and the field sample verification, it was concluded that the parallelepiped method was relatively better when cotton field of *Verticillium wilt* was monitored in during the blooming period of cotton. This result was similar to research of Chen *et al*. (2012), however different research from Yang*et al*. (2015) which evaluated unsupervised classification applied to multispectral imagery and the normalized difference vegetation index (NDVI) and six supervised classification techniques, including minimum distance, Mahalanobis distance, maximum likelihood and spectral angle mapper, neural net and support vector machine, for mapping cotton root rot from airborne multispectral imagery in USA. Accuracy assessment showed that all eight methods accurately identified root rot-infected areas with overall accuracy values from 94.0 to 96.5 % for field 1 and 93.0 to 95.0 % for Field 2.

Because the supervised classification method of image could simple, practical, rapid monitor cotton field of *Verticillium wilt* in this paper, it was put forward that through monitor disease position, area, severity etc., could provide cotton growers to disease prevention and control measures for policymakers. Because of this research was carried out in the sample training, single cotton fields of *Verticillium wilt*, also found in the classification process with resolution multispectral TM image as the data source analysis of cotton diseases, but in the actual agricultural production, cotton disease types was not a single, it was difficult to distinguish between damaged cotton disease stress and other stress, this work would further research.

Conclusions: In this study multi-spectral satellite TM imagery were took as data source four supervised classification methods were used to monitoring cotton fields of Verticillium wilt ,got the following conclusion:

1. The false color band combination which from the multispectral TM image blue band (band 1) .near infrared band (band4) and the short infrared wavelengths (band5) , could be used as the best satellite remote sensing combination band to monitoring cotton field of diseases.
2. During the blooming period of cotton, all the four supervised classification methods could monitor cotton fields infected Verticillium wilt, but the result which from the classification method of the PP algorithm was most similar with the actual cotton disease occurs condition in fields, the overall accuracy and kappa coefficient were the highest, and classification results could satisfy the production requirement, could lots of more information, including disease degree, location and area of cotton field of *verticillium wilt*.

Acknowledgements: The financial support provided by the National Natural Science Foundation of China (41161068, 31460326), National Science-technology Support Plan Projects of china (2014BAD09B03-3) and Plan of Xinjiang Academy of Agricultural and reclamation Sciences of China (83YYD201508).

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