Performance Analysis of Supervised Image Classification Techniques for the Classification of Multispectral Satellite Imagery

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Abstract: **Remote Sensing is extensively used for crop mapping and management in current era. High resolution multispectral data of every part of earth is available at relatively low cost. Selection of appropriate decision rule and appropriate spectral bands is critical for obtaining accurate classification results. Need to find an accurate decision rule which is less time consuming and needs less resources leads to the performance analysis of different classification algorithms on the basis of their classification accuracy, time consumption, computational requirements, reliability etc. A SPOT 5 image acquired on 2009-07-03 from Barcelona city of Spain located at 41.3833° N, 2.1833°, and the classification algorithms i.e. Maximum Likelihood, Parallelepiped, and Mahalanobis Distance classifiers were used for the classification of the SPOT image. A spatial subset of the original imagery was created with resolution half of the original image. In this research, imagery was first atmospherically corrected using QUAC (Quick Atmospheric Correction). The spectral signature of different land classes were extracted using the spectral profile of each individual land class. The whole imagery was then classified using three Classifiers/Decision Rules i.e. Maximum Likelihood, Mahalanobis Distance and Parallelepiped Classifier. The post classification procedures i.e. clump and sieve were applied to the classified imagery to improve classification results. Maximum Likelihood Classifier outperforms other classifiers i.e. Mahalanobis Distance and Parallelepiped Classifier with Overall Accuracy (OAA) of 99.17 per cent. However these classifiers show good accuracy for classification of some classes of interest for instance the Mahalanobis Classifier outperforms the Maximum Likelihood Classifier in classifying water bodies. Results also show that the band selection is also critical in accurate classification of the imagery. The spectrally subsetted images (NIR band removed) of the same place showed very less classification accuracy than that of the original image**

Key Terms: Mahalanobis distance, maximum likelihood, parallelepiped classification, overall accuracy, kappa coefficient, Producer's accuracy, User's Accuracy.

I. Introduction

Agricultural Planners need to know the types of crops and the areas in which they are grown as basic information for crop management and yield estimation. Remote sensing technology which includes aerial photography, multispectral and hyper spectral satellite imagery has vastly been used in identification, and mapping of crops in a certain area for long times. The reason for using satellite imagery for crop identification and mapping is its large coverage area, high resolution, increase accuracy and its availability at low cost. High resolution imagery from satellite sensors including Landsat MSS and TM data, SPOT imagery [4] and Indian Remote Sensing (IRS) satellite data [5] have been used for crop identification and area estimation, [1-3].

The crops are separated from each other in acquired satellite imagery on the basis of a supposition that each and every crop has its own unique spectral signature which helps identify and discriminate different crops in the imagery. But it may not be as easy as it seems because of different things affecting the properties of crops including soil type, atmospheric conditions, availability of water, pest attacks etc. [6].

There are different satellite systems which provide high resolution multispectral imagery for the assessment of the vegetation and other applications. They include IKONOS, QuickBird, SPOT etc. [7-8] IKONOS satellite gives us multispectral imagery in three visible bands and one near Infrared band at pixel size of 4 meter. The QuickBird like IKONOS provides imagery in three visible bands and on NIR band at pixel resolution of 2.4 to 2.8 meters. SPOT 5 gives the imagery data in two visible bands, one NIR and one SWIR band at resolution of 2 meters [9].

There are different methodologies employed to separate different classes of data from the satellite imagery for using it in different applications like agricultural land mapping, Disaster management, search and rescue operations etc. The supervised image classification techniques require a sample data (Regions of Interest) to classify the imagery [10-12]. Crop Yield information can accurately be inferred from accurately classified satellite imagery [13] which helps planners to better manage the production round the year.

The remaining paper is organized as follows: The methodology is outlined in section II. Results are explained in section III whereas section IV concludes the research work.

II. METHODOLOGY

A. Image Acquisition

The SPOT5 offers high resolution images that can be used for crop assessment and classification of different crop species. We acquired a SPOT 5 image produced on 2009-07-03, from Barcelona, Spain. The geographical location of the Barcelona is 41.3833° N, 2.1833° E, which mainly comprises of olives, vineyards, nuts, oranges and other fruits. Much of the area in the city is occupied by the forests. The acquired image was preprocessed and atmospherically corrected using QUAC (Quick Atmospheric Correction). In the imagery, the vegetation has reddish color (because of more reflection in NIR band), the water is bluish or dark in color and bare lands have grayish or light brownish tone. The SPOT5 image used for the performance analysis of classification algorithms is illustrated in Fig. 1.

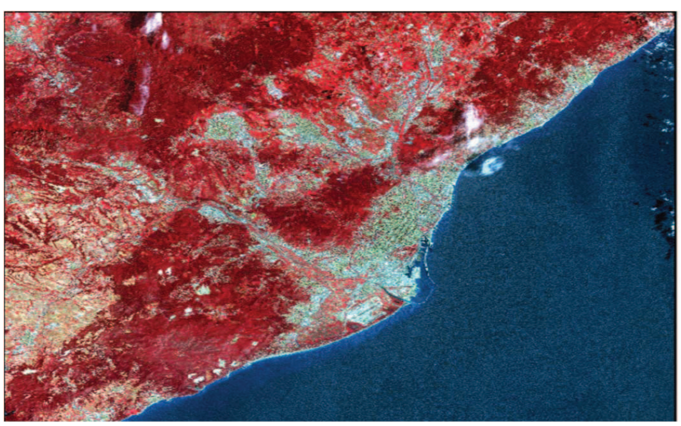

Fig. 1: The Preprocessed image of the Barcelona City Acquired in 2009 from SPOT 5 Satellite at 2m pixel resolution

B. Image Classification

For classification purposes three different classifiers Maximum Likelihood (ML), Parallelepiped (PP) classification and Mahalanobis Distance (MD) classification methods were used. Imagery was divided into four classes, dense vegetation, Water, Forest Vegetation lands and NIC (buildings, roads and developed areas). The performance in terms of classification is compared for these classifiers under different conditions. The subset image of pixel size double of the original image was produced. The classifiers are checked for spatially and spectrally different images. The analysis shows that the change in spatial features (such as spectral resolution) of the image has no major effect on the classification results, but it highly affects the efficiency of the classification.

C. Assessment of Results

Visual interpretation (i.e. Spectral Profile of signature species) is used to group data into the four classes. Error matrix for each classification is created and the accuracy of the classification is determined. Kappa constant which ranges between 0 and 1 shows the total random classification and perfect classification respectively. The user's accuracy corresponds to the total number of the pixels correctly classified in a class that are actually in that class on the ground. Producer's accuracy is the actual number of pixels in a class being correctly classified.

III. RESULTS AND DISCUSSION

Sample imagery was classified in four classes i.e. vegetation, water, NIC (Developed areas, roads etc.), forests. Each class has its own specific spectral signature (Z-profile). The SPOT 5 satellite imagery acquired contains 3 spectral bands i.e. green (500-590 nm), red (600-680 nm) and NIR (780-890 nm).

The four class vegetation map is shown in Fig. 2: Four Class classification map generated from 2m SPOT5 satellite image based on Maximum Likelihood Classifier shows good separation between different classes of the imagery. The classified image shows the considerable separation between the vegetation and non-vegetation classes. The classification results show the accuracy of 64 percent by Parallelepiped classifier to 99.1 percent by Maximum Likelihood classifier. This shows that Maximum Likelihood classifier correctly classified 99.1 percent pixels in the imagery.

The kappa coefficient shows that the classified map agree with the reference ROI's. The kappa constant varies from 0.31 in Parallelepiped classifier to 0.96 in Maximum Likelihood classifier which shows a random classification and nearly perfect classification respectively. Maximum Likelihood also shows good user's and producer's accuracies for the vegetation class i.e. 98.15% and 99.41% respectively but have low user's accuracy in forest vegetation of 77.23 percent because of its neighborhood by vegetation and NIC class in the classification process. These results are summarized in Table I.

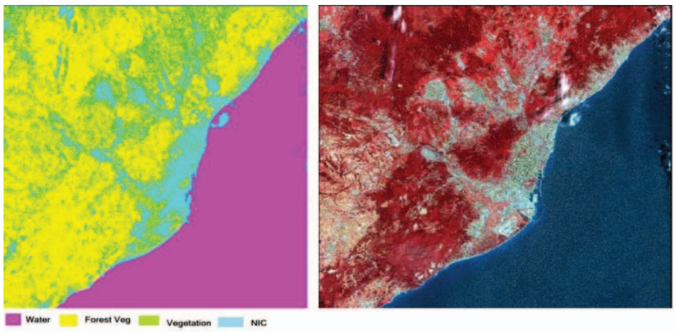

Fig. 2: Four Class classification map generated from 2m SPOT5 satellite image based on Maximum Likelihood Classifier

TABLE I: ACCURACY ASSESSMENT RESULTS FROM FOUR DIFFERENT CLASSIFICATION MAPS GENERATED FROM 2M SPOT IMAGE FROM THE STUDY SITE

Classification Method	Overall Accuracy (%)	Overall Kappa
Parallelepiped	64.0001	0.3154
Maximum Likelihood	99.1702	0.9695
Mahalanobis Distance	99.1925	0.8856

Classification Method	Producer's Accuracy(PA) and User's Accuracy(UA)							
	NIC		***Water***		***Vegetation***		***Forest***	
	UA	*PA*	*UA*	*PA*	*UA*	*PA*	*UA*	*PA*
Parallelepiped	67.8	90.7	64.8	100	44.7	100	23.2	96.9
Maximum Likelihood	95.2	98	99.8	100	99.4	98.1	96.2	77.2
Mahalanobis Distance	77	99.3	100	99.6	94.7	89.9	96.7	49.2

When the image resolution was reduced by making the pixel size double of the original image the classification results show no significant difference in the accuracy as was of the original classified image. The overall accuracy of Parallelepiped classifier decreased from 64 percent to 55 percent which is a significant decrease, but overall kappa coefficient is almost same which shows almost similar classification results as in the high resolution image. However in Mahalanobis Distance classifier the overall accuracy is almost unchanged. Accuracy of image classification by Maximum Likelihood classifier is nearly independent of image resolution.

Fig. 3 shows the classified imagery having coarser spatial resolution using Maximum Likelihood classifier. The results are in accordance to the classified imagery having finer resolution. This shows that the spatial resolution does not affect the classification accuracy of this specific classifier. The summary of results is presented in Table II for this scenario.

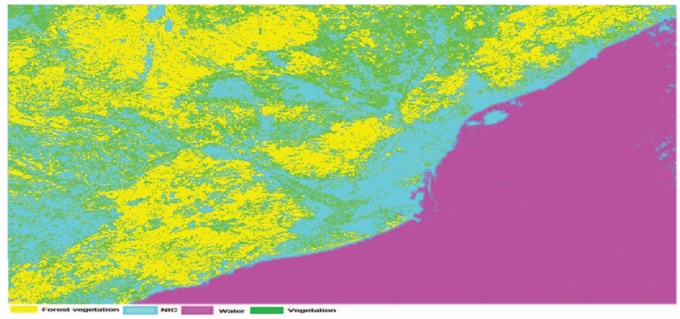

Fig. 3: Maximum Likelihood classification map of spatially subsetted image

TABLE II. OVERALL ACCURACIES AND KAPPA VALUES OF THE CLASSIFIED IMAGE (SPATIAL SUBSET OF ORIGINAL).

Classification Method	Overall Accuracy (%)	Overall Kappa
Parallelepiped	55.0258	0.3744
Maximum Likelihood	99.0213	0.9806
Mahalanobis Distance	97.7606	0.9555

Classification Method	Producer's Accuracy(PA) and User's Accuracy(UA)							
	NIC		***Water***		***Vegetation***		***Forest***	
	UA	*PA*	*UA*	*PA*	*UA*	*PA*	*UA*	*PA*
Parallelepiped	94.5	56.9	100	42.7	99.7	56.4	100	94.5
Maximum Likelihood	93.9	99.7	100	97.6	93.4	97.4	99.7	93.9
Mahalanobis Distance	94.4	99.6	99.5	88.7	90.9	96.6	95.1	94.4

When the NIR band is removed from the imagery, the classification results show significant decrease in the overall accuracies; this is because of the fact that the vegetation classes show significant reflectance in the NIR band. This can be observed in producer's and user's accuracies for the vegetation and forest in the three classifiers. Which shows a huge difference from the previous classification results as vegetation has higher reflection values in NIR. It shows that the selection of appropriate wavelengths is critical in the accurate classification of the remotely sensed data. The results also show a drastic decrease in the kappa values hence representing the total random classification with the less number of bands. This change is depicted in Fig. 4.

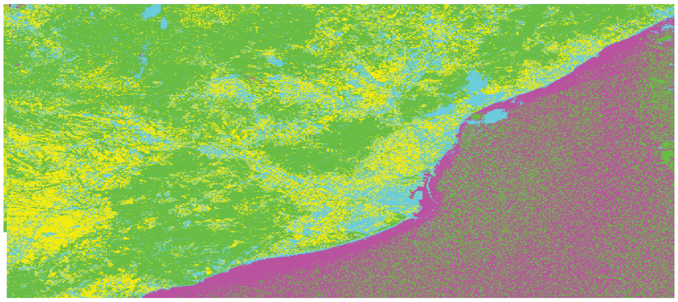

Fig. 4: Maximum Likelihood classification map of the spot 5 image, without the NIR band.

Figure 4 is the four class classification map generated using Maximum Likelihood classifier on the imagery having two bands, i.e. red and green. The NIR band is removed. Results show complete random classification for the vegetation because value of NIR reflectance is largest in the NIR region. The huge values of error of commission and omission are due to the fact that the removal of a spectral band results in significant decrease in the values of reflection in the dominant regions of spectral levels and hence there is a downward spike in the overall accuracy and kappa values. The results are summarized in Table III for this scenario.

TABLE III. OAA, KAPPA ANALYSIS, PRODUCER'S AND USER'S ACCURACIES OF THE IMAGE WITHOUT NIR BAND.

Classification Method	**Overall Accuracy (%)**	**Overall Kappa**
Parallelepiped	65.2583	0.3150
Maximum Likelihood	70.0065	0.3716
Mahalanobis Distance	69.9468	0.3663

Classification Method	**Producer's Accuracy(PA) and User's Accuracy(UA)**							
	NIC		***Water***		***Vegetation***		***Forest***	
	UA	*PA*	*UA*	*PA*	*UA*	*PA*	*UA*	*PA*
Parallelepiped	73.9	80.9	66.1	98.9	39.9	5.9	0.0	0.0
Maximum Likelihood	59.8	93.5	70.6	99.5	81.1	5.4	93	28.1
Mahalanobis Distance	58.4	97.4	71.0	99.3	80.1	5.2	82.7	28.3

Table III shows the statistics of the classification results for Maximum Likelihood classifier, Mahalanobis Distance Classifier and Parallelepiped Classifier, on the spectrally subsetted image. The results still show that the Maximum Likelihood classifier classifies the imagery with best overall accuracy value of 70 per cent. The accuracies for Mahalanobis Distance classifier and Parallelepiped classifier are 69 and 65 per cent respectively.

IV. CONCLUSIONS

The objective of the research is to find out the more robust, and reliable classifier for the classification using ENVI 5 software. More accurate training samples give more accurate results and more evenly distributed data gives more accurate results. Different spatial and spectral resolutions are used to find out more precise results. The main conclusions are as follows.

A. Accuracy

The results obtained for the classification lead to the conclusion that the maximum likelihood classifier is the best tool to classify a SPOT 5 image with best overall accuracy and kappa. However the results also show that the other classifiers work well for some specific classes of interest. It is also deduced that the parallelepiped classifier can work well if the training set is large and evenly distributed over the whole imagery with normal distribution. The statistics show that the overall accuracy depends highly upon the selection of training sites and the distribution of training sites in the imagery. Also the training set data should be same for each class. The pre-processing of the imagery and the post-classification procedures also help in attaining higher accuracies for the tested classifiers.

B. Effect of Spatial Resolution on Classification:

The classification of images having different spatial resolution will not have much deviation in accuracies. The subset image of the spatial resolution of pixel size double to that of the original imagery was extracted from the original imagery using ENVI 5. The subset image of the pixel size double of the original image is used for classification with the three classifiers. The results show that the overall accuracy is same as of the original image i.e. 97 per cent for the maximum likelihood classifier for both images. However the visual interpretation of the two images shows visual changes and blurring.

C. Effect of Spectral Resolution on Classification Accuracy:

There is a huge effect of spectral resolution on the classification accuracy. The selection of the wavelength bands is critical in the classification processes. The spectrally subsetted image with two bands is used for the classification and then compared with the results of classification of original imagery. The result show that the imagery having less no. of appropriate wavelength bands have less classification accuracies. Therefore the great care is needed in selection of the wavelength bands for the hyper spectral imagery, which is not the case with the multispectral images containing limited number of bands. The results of the classification with coarser resolution show 69 per cent overall accuracy (OAA) for the Mahalanobis distance classifier.

ACKNOWLEDGMENT

Special thanks to the Satellite Imaging Corporation for providing SPOT5 imagery free of cost for the evaluation and research purpose.

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