

Estimation of forest parameters through Fuzzy classification of TM Data



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Abstract

Several studies have investigated the utility of Landsat 5 TM imagery to estimate forest parameters such as stand composition and density. Regression equations have generally been used to relate these parameters to the radiance responses of the TM channels. Such method is not feasible in highly complex landscapes, where forest mixtures and terrain irregularities may obscure the existence of simple relationships. In the current paper a fuzzy approach to the problem is presented. First, some typical forest plots with known features are spectrally identified. A maximum likelihood fuzzy classification is applied to the study image, so as to derive fuzzy membership grades for all pixels with respect to the typical plots. Finally, these grades are used to compute the estimates of the forest parameters by a weighted average strategy. One TM scene and accurate ground references taken in summer 1987 were utilized for the testing. For comparison results first, with PCI Geomatica software (8.1 ver) with supervised classification with maximum likelihood approach were used. Also this image was investigated by a fuzzy approach for the testing. The first results statistically are quite encouraging.

1. INTRODUCTION

In the last few years the high resolution multispectral data acquired by the landsat 5 thematic mapper (TM) have been used increasingly in forest monitoring and mapping. Several forest inventories have been obtained for the identification of forest dominant species even in irregular landscapes. On the other hand, the estimation of forest parameters such as actual stand composition and density has been successful only when there was not a complex combination of these parameters and other environmental factors, such as terrain irregularities. The usual estimation methods are based on maximum likelihood with PCI Geomatica software have been set up between forest parameters measured on the ground and the relevant spectral responses in the individual TM channels or combinations of these. The rationale for these analyses is that the variations in forest parameters affect the spectral behavior in a way which can be easily modeled by simple relationships. Unfortunately, this assumption does not always hold, especially when other factors affect the spectral behaviors of the forest examined. In effect, if the signatures of the forests are disturbed by mixtures in composition, terrain irregularities, under story influences, etc. The existence of simple relationships between stand parameters and spectral responses can be seriously hampered, or even completely obscured.

It can be noted, however, that even if simple relationships do not exist some spectral information is likely to be present in the remotely sensed scenes about the parameters examined.

Actually, the high resolution TM multispectral data acquired at different times of the year contain a great deal of information about the condition of vegetation. The extraction and processing of this information therefore becomes the fundamental issue.

A new methodology is proposed here for the estimation of forest parameters in highly complex landscapes based on a "fuzzy" classification approach. The theory of fuzzy sets is intrinsically suited to dealing with mixed, spectrally undefined cases, and can be adapted to the specific problem as will be shown below. The comparison between results of PCI system and fuzzy method and also by study on TM image, acceptable result can be derived which if can be used in future researches.

2: STUDY AREA, GROUND AND SATELLITE DATA

The study area, of about 15.3x15.3 km in size, is located at approximately 36°32' north latitude, 51°07' East longitudes. This is part of the mazandaran forest on Alborz mountain chain in the north of IRAN.

There are several maps of this area, like Iranian geography organization map (scale: 1/50000) and national cartographic center map (scale: 1/25000).

The TM frame for the present research was taken on the 28 of July, 1987. Also PCI Geomatica (8.1) was used for analysis that was powerful software.

STUDY AREA



Figure1: color composite of TM Image

3: METHODOLOGY:

A-Data processing with PCI software:

The processing of the ground and remotely sensed data was carried out on a P4 computer system. The software consists is PCI Geomatica (8.1) for general processing.

A scene of 512 x512 pixels was extracted from frame and georeferenced by a polynomial interpolation algorithm trained on ground control points. In this process supervise method classification was implemented.

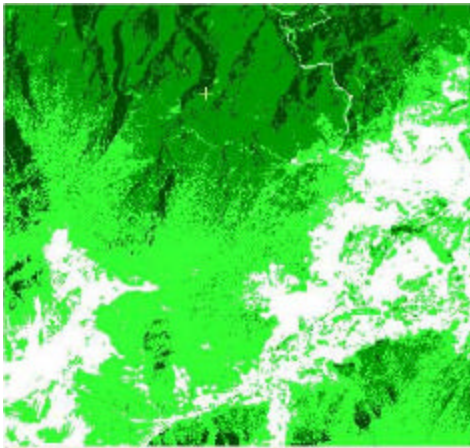


Figure 2: PCI ANALYSIS

B-Fuzzy Estimation:

The supervised classification method for estimating environmental parameters from spectral images is based on a fuzzy strategy already applied to marine investigations. A fuzzy set is characterized by a membership function that associates with each element areas number between 0 and 1 which represents the "fuzzy membership grade". In this way, each element of the set may have partial and multiple membership and mixed, uncertain situations can be properly handled. When applied to the supervised classifications of remotely sensed data, the fuzzy membership grades can be seen as a measure of the extent to which a pixel belongs to all the cover categories. The membership grades have been also demonstrated to be related to the cover proportions of the categories within the pixels. These grades can there fore be used to weight the measured parameters of the known classes by a strategy similar to that adopted for

the statistical estimation of Geological parameters. Once the spectral signatures for each reference class have been defined, the membership grade of each pixel with respect to class i (F_i) can be found as:

$$F_i = P_i / \sum P_i$$

Where:

$$P_i = (2\pi)^{-1/2n} |C_i|^{-1/2} e^{-(1/2) [(X-M)_i]^T C_i^{-1} (X-M)_i} P_{ri}$$

With:

P_i : maximum likelihood probability of attribution to the class considered.

n : Number of measurement variables

C_i : Variance – Covariance matrix of the class considered.

M_i : Mean vector of the class considered

X_i : Pixel vector

P_{ri} : Prior probability of the class considered defined from the frequency histograms of the training sets.

In practice, all the reference categories (plots) can be considered as individuals having representative environmental and spectral features. In this way the spectral signatures are found assigning full membership functions to all the reference pixel of the categories, which corresponds to computing the fuzzy mean vectors and the fuzzy variance – covariance matrices as “hard” ones. Since known environmental parameters are associated to all the reference categories, the same parameters can be estimated for unknown pixels by using the membership grades as weighting factors.

Thus:

$$V_e = \sum F_i V_{x_i}$$

Where:

V_e : Estimated value for the pixel.

V_{m_i} : Measured value of class i .

Clearly, the method is only valid if the entire range of variability of the study parameters is covered by a sufficient number of representative known categories. As was seen above, such an assumption can be considered realistic in the current case.

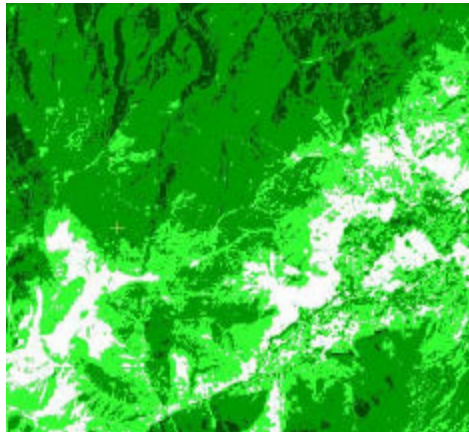


Figure 3: FUZZY ANALYSIS

4: RESULTS:

The results of fuzzy classification and PCI classification show that the algorithm can extremely enhance the classification.

With comparison among RMSE of PCI and fuzzy classification, we can be seen that RMSE decreases from 3.84 m²/h_a in PCI classification to 1.69 m²/h_a in fuzzy classification, this show a promote in classification using fuzzy estimation.

5: CONCLUSION:

The proposed fuzzy methodology showed great promise for the estimation of forest parameters. However the procedure was only tested on a single data set. Further testing in different areas and with other imagery data would be useful to validate the results obtained. In general, the method should benefit from a higher density of references plots, even if this could involve an increasing burden of computational complexity.

From a methodological viewpoint, this approach should be most effective in reducing biases in the estimated parameters. Also, the use of fuzzy classification permits considerable flexibility in the estimation procedures. For probabilistically inserted into the process.

Theoretically, the fuzzy approach to estimation could be applied to an enormous series of problems of environmental monitoring, such as agricultural, oceanographic and geological investigations. In all these cases, the method can be expected to produce optimum performance thanks to its probabilistic, flexible nature. Research is currently directed towards the exploration of these possibilities.

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