LAND-COVER SUB-PIXEL CLASSIFICATION USING LINEAR MIXTURE MODEL ON LANDSAT ETM + DATA IN EGYPT

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KEY WORDS: Land Cover Mapping, Linear Mixture Model, Landsat ETM+

ABSTRACT One of the most important problems facing land cover mapping effort in Egypt is intensive and mixed landcover areas, which represent the majority of agricultural productive areas. This study was carried out to evaluate the possibility of using Linear Mixture Model as a sub pixel classification technique to extract fraction images from Landsat Enhanced Thematic Mapper data, which may help in future to increase the accuracy of landcover mapping in the mixed agricultural areas. In this study, Linear Mixture Model was applied to classify the main land covers in the study area and the different agricultural types. Relationship between fraction images and NDVI was determined. The fraction images were compared with ground truth data for validation.

Introduction

Land cover information that can be extracted from satellite images using conventional processing procedures depends on the main idea that one pixel represents one class. This idea may be suitable in many cases, but in case of intensive areas with mixed land cover types, there is a high need to apply other classification procedures to solve the problem of pixel heterogeneity and increase the accuracy of land cover maps. Mixing Modeling is considered as a suitable approach for extracting information from ETM+ images to estimate how each ground pixel area is divided up among different land cover types. Many researches have been carried out to solve this problem using MSS and TM data (Adams 1984, Shimaburko 1987) as well as Airborne Visible Infrared Imaging Spectrometer (AVIRR) data (Gillespie et.al. 1990). Zhu and Tateishi, 2000 explored the possibility of using linear mixture model to generate fraction images from 1 km time series NOAA-AVHRR monthly composite NDVI data. In this study, mixing model was applied to Landsat ETM+ using four bands 1,2,3,4 to generate percentage images. The validation of this model was performed by comparing the resulting percentage images with ground truth data, maximum likelihood supervised classification image and NDVI image.

Study area

The study area is located in Eastern Nile Delta, Egypt between 31° 10' to 32° 20' East and 30° to 31° 30' North. The study area is located in El-Sharkya governorate, which is considered as one of the most important agricultural areas in the country representing 9.73% of national agricultural land. The area is in

Mediterranean climate region with two main seasons; hot dry summer and cool winter. The average air temperature is 20.7°C with 38 mm total precipitation for a whole year. The area can be separated into; 1) old agricultural land. Annual crops, fruits and vegetables are cultivated using traditional irrigation methods in two main agricultural calendars. The main soil type in this area is (Vertisols) (Abdulla et al., 1997). 2) Newly reclaimed land with circular irrigation system (PAVOT). Different crops, fruits and vegetables are cultivated in large areas. The main soil type in this area is (Aridisols) (Abdulla et al., 1997). 3) Old reclaimed land under traditional irrigation system. 4) Water bodies and wetland. 5) Desert land, which have not been included in any reclamation effort.

Method

For solving the linear mixing model, Lagrange Method and optimization technique were used. This method was developed for assumed n components in a pixel (Tsolmon and Tateishi 2000). The basic concept of the spectral Linear Mixing Model can be expressed as in (equation1). It estimates the proportion of each component in a pixel by minimizing the sum of squares of errors (equation2).

$$\begin{aligned} R_1 &= a_{11}x_1 + a_{12}x_2 + \ldots + a_{1n}x_n + e_1 \\ R_2 &= a_{21}x_1 + a_{22}x_2 + \ldots + a_{2n}x_n + e_2 \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ R_m &= a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n + e_m \end{aligned} \qquad (1)$$

$$E(x) = \sum_{i=1}^{m} e_i^2 = \sum_{i=1}^{m} (R_i - \sum_{j=1}^{n} a_{ij}x_j)^2 \ - \qquad (2)$$

subject to:

$$\begin{aligned} &x_1 + x_2 + x_3 + \ldots x_n = 1, \\ &x_1 \geq 0,\ x_2 \geq 0,\ x_3 \geq 0 \ldots\ x_n \geq 0, \end{aligned} \qquad (3)$$

where

R_i - radiometric response for a pixel in spectral band *i*
unit: $watts/(metersquared \times ster \times \mu m)$

a_{ij} - spectral response of mixture component *j* in spectral band *i*

x_j - proportion of *j* in a pixel

e_i - error term in spectral band *i*

m - number of spectral bands

n - number of components within a pixel

In this study, linear mixture problem (2) – (3) was formulated as convex programming problem and then solved numerically using Lagrange function and Conditional Gradient Method deriving components x_1, x_2, x_3, x_4 corresponding to water bodies, urban areas, cultivated land and desert respectively within a pixel. The same technique was applied with the main types of vegetation cover in the study area, which are wheat, fruit trees, clover and bean.

Approach

The image was geo-referenced using nearest neighbor resampling algorithm with RMS error of less than one pixel. All bands except band 6 (thermal band) were used in maximum likelihood supervised classification on 19 March 2001 ETM+ image Fig1. Many field checkpoints with different land cover maps were used as ground truth data in the classification process.

Pure pixels for each mixture component were selected and used as input for CGM in two main steps; 1) applying CGM to extract fraction images from Landsat ETM+ data for the main land cover types in the study area figure 2(A, B, C, D) 2) extracting fraction images for the main vegetation cover using the same data figure 3(A, B, C, D). In these fraction images, each pixel is associated with percentage values from 0 to 100 for urban, water, cultivated land and desert in the first stage and wheat, clover, fruit trees and bean in the second stage. These eight land cover classes are deemed sufficient to cover almost all the variability of the study area. The derived fraction images for the main land cover types were compared with both the supervised classification results for Landsat ETM+ as shown in table 1 and NDVI as shown in Fig 4 (A, B, C, D). Different checkpoints were used to perform these comparisons.

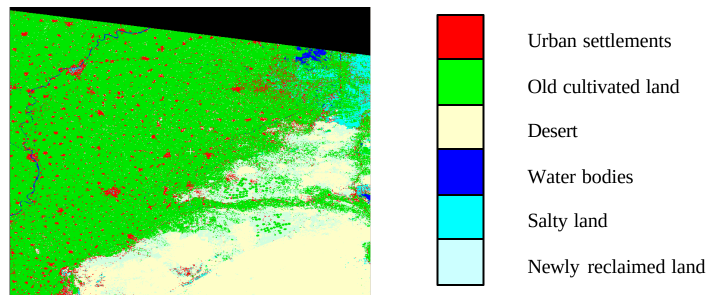
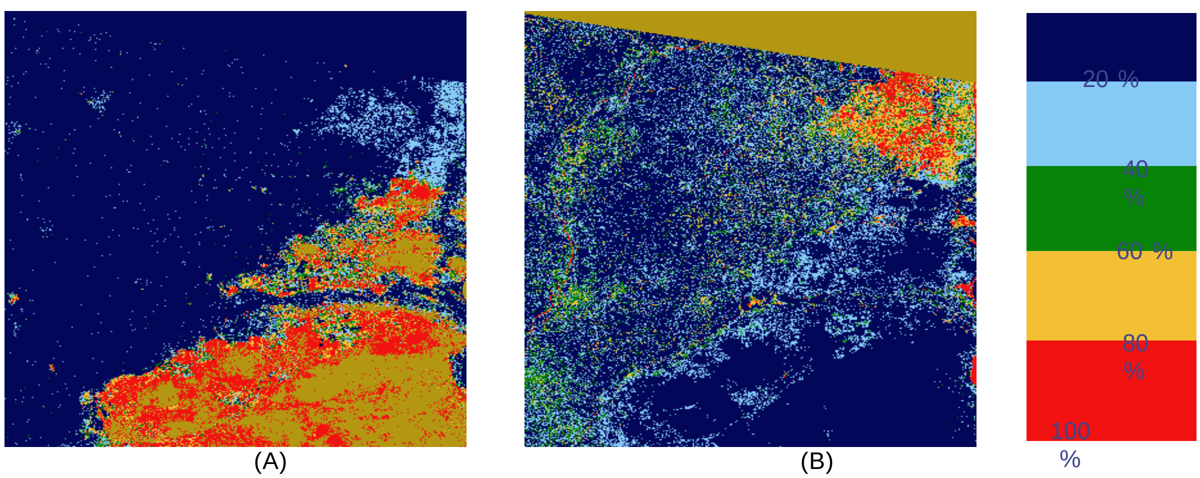
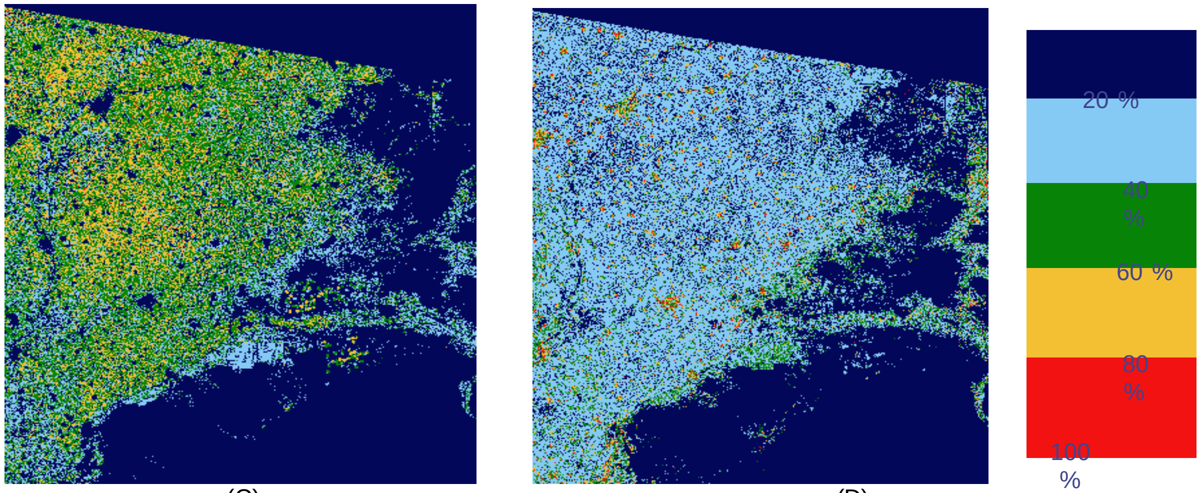


Fig 1 Maximum likelihood supervised classification on March 2001 Landsat ETM+.



(A) (B)



(C) (D)

Fig 2 Fraction images for components (A): desert, (B): water bodies, (C): cultivated land and (D) urban settlements obtained by CGM. Fraction images derived from ETM+ image acquired on 19 March 2001.

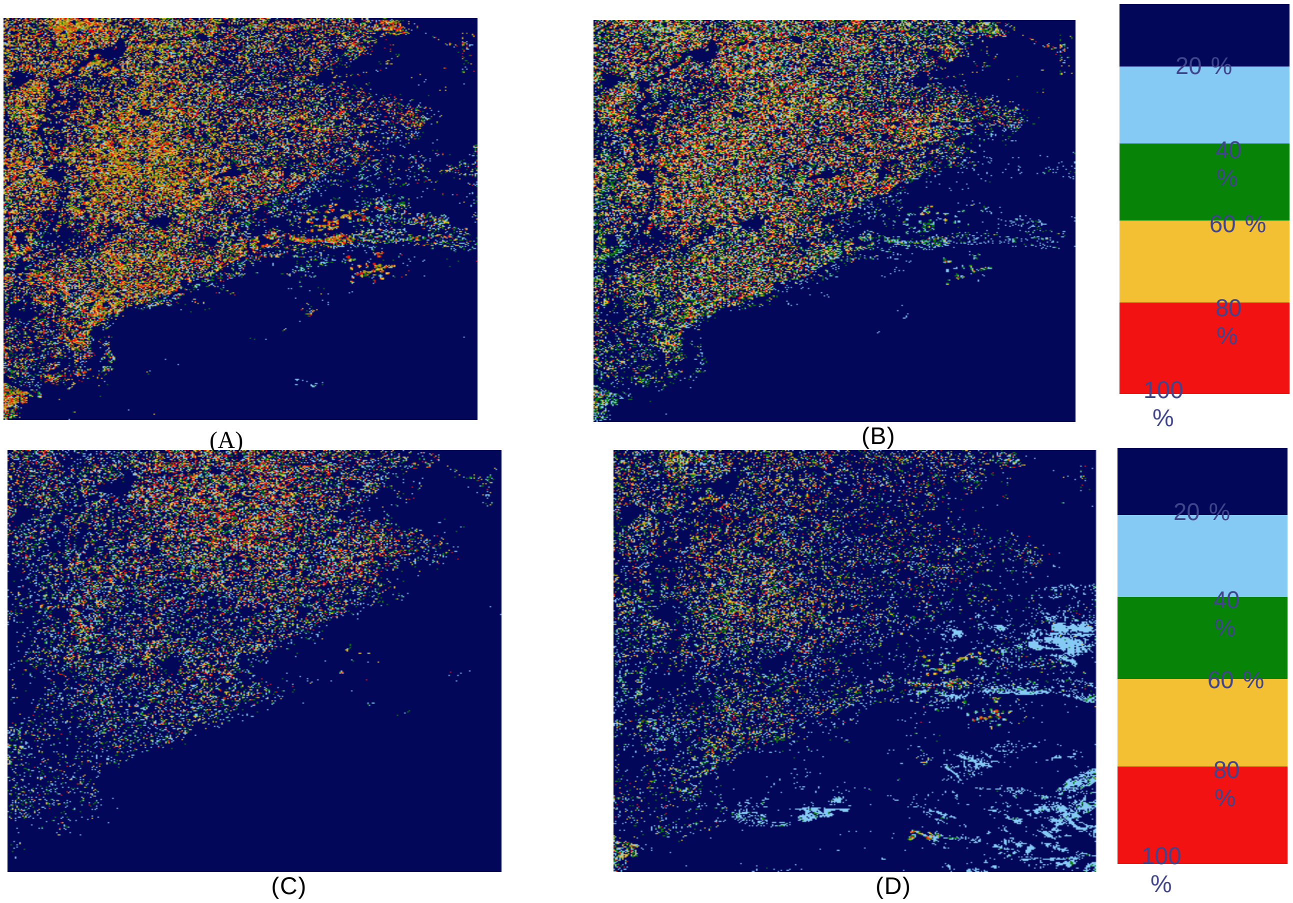


Fig 3 Fraction images for components (A): wheat, (B): fruit trees, (C): clover and (D): bean obtained by CGM. Fraction images derived from ETM+ image acquired on 19 March 2001.

		Classified image				
		Urban	Desert	Water	Cult. land	Total
Fraction images	Urban	60	3	3	5	71
	Desert	4	70	---	5	79
	Water	---	3	81	7	91
	Cult. land	3	2	7	92	104
	Total	67	78	91	109	345
Overall accuracy	87.83%					
Standard percentage error	1.76%					
Accuracy	87.83% ± 1.76					

Table 1 Comparison of Landsat ETM+ fraction image to landsat Supervised classification

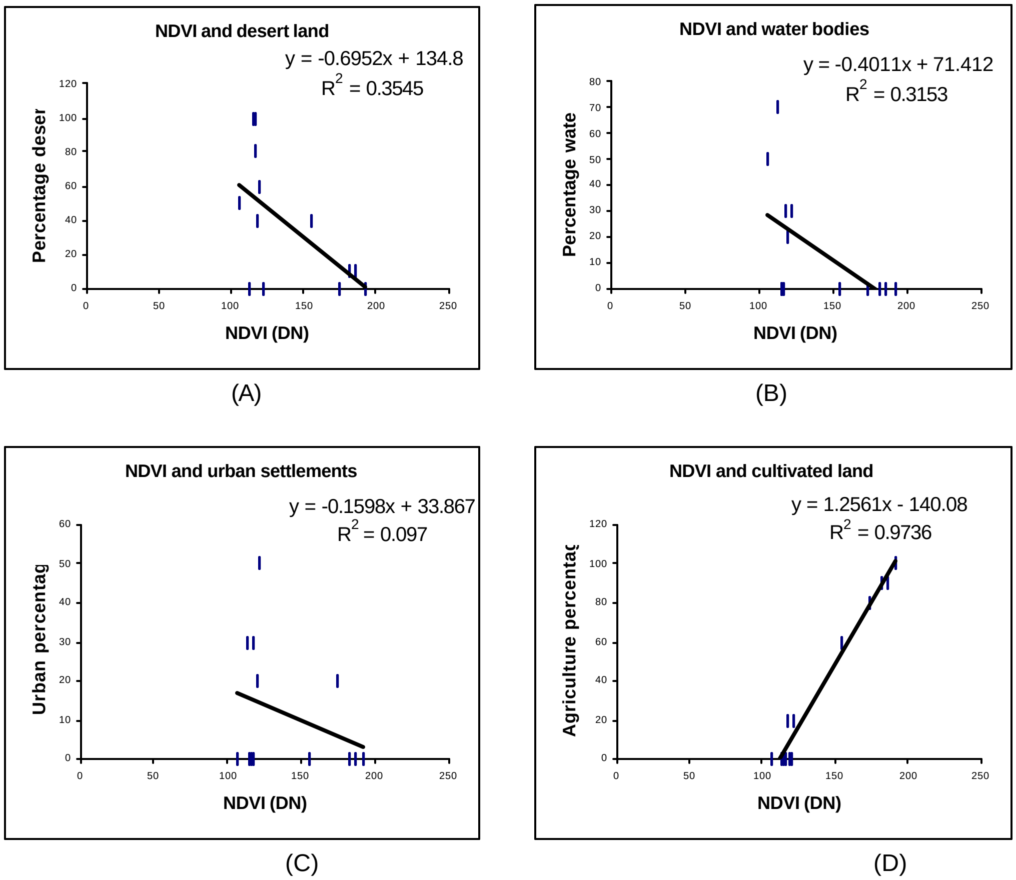


Fig 4 (A, B, C and D): Correlation between NDVI and different percentage images extracted from random points

Results and discussion

The linear mixture model based on CGM was applied to the image. The advantage of the fraction images extracted by this technique is that they contain different land cover components within a pixel. The study focused on applying LMM as a sub-pixel classification technique, which could be used to maximize the accuracy of any land cover study especially in the intensive agricultural areas, which represent the majority of Egyptian agricultural land.

In this study, a comparison between the fraction images and maximum likelihood supervised classification was carried out. The overall accuracy was determined as 87.83% as shown in table (1). It could be discovered visually that the fraction images are more detailed and can reflect the land cover classes reality more well than the results derived from the conventional method. The high accuracy of LMM to differentiate three main land cover classes in the study area (desert, water bodies, urban settlements) could be recognized easily. The area percentage estimation of cultivated land was not so good especially in the old cultivated land. This could be because of the intensive vegetation cover types in these areas or because of the influence of the other land cover types, which are not included in the first mixture components.

The relationship between NDVI and LMM fraction images was studied using randomly selected points. High relation coefficient (0.97) was found between NDVI and the percentage of agriculture while low correlation coefficients were found between NDVI and the percentage images for the other components. This result shows the capability of LMM to differentiate between the cultivated and non – cultivated land and explained the high correspondence between LMM results and vegetation index.

Linear mixture modeling was used to differentiate the different vegetation covers in the study area; wheat, clover, bean and fruit trees. These vegetation covers except fruit trees are so mixed in the study area especially in the old cultivated land. Therefore, LMM could play very important role to classify these vegetation covers within one pixel, which may help to increase the accuracy of the classification process. According to ground truth data including statistical information and different ground checkpoints, LMM showed high capability to classify the main vegetation types.

Conclusion

This work was carried out in order to study the possibility of using LMM as a sub-pixel technique to classify different land covers in the study area in Egypt. The results showed considerable capability of this technique to classify the main land covers. It is clear that this technique gives more accurate results in case of homogenous classes. LMM could be used successfully to classify different vegetation covers in intensive agricultural areas. The validation of such this work requires a lot of ground check points especially in the mixed areas.

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