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INVENTORY OF AGRICULTURAL LAND AREA OF EGYPT USING MODIS DATA

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ABSTRACT

A new generation of satellite data has been emerged since the launch of the Moderate Resolution Imaging Spectroradiometer (MODIS), in 1999, for monitoring land resources and terrestrial environments. Agricultural land area of Egypt in 2005 was estimated using MODIS data. Four scenes were utilized to extract the total country area. MODIS vegetation Indices product (MOD13Q1) was the most suitable to extract the total gross cultivated land area of Egypt. An unsupervised classification algorithm was applied to estimate the cultivated land area, which approached 8.2 million feddans in 2005. The Nile Delta contains the majority of agricultural lands (63.2%). The Nile Valley and El-Fayoum Depression possess 33.9% and the remaining little percent (~3%) represents the scattered agricultural land along the Suez Canal, Sinai and the Western Desert. The classification accuracy of agricultural land reached 84%, revealing higher confidence of assessment. The present study asserts on the importance of using remote sensing in monitoring agricultural land resources.

Keywords: MODIS, NDVI, Egypt, agricultural land.

INTRODUCTION

MODIS is one of the sensors onboard the NASA Earth Observing System (EOS) Terra satellite platform, which was launched successfully on Dec. 1999. MODIS offers several enhancements over the older Advanced Very High Resolution Radiometer (AVHRR) sensor. For example MODIS has a finer spatial resolution, higher radiometric resolution and improved geometric rectification (Aronoff, 2005). MODIS is a scanning instrument viewing the entire earth each 1-2 days with 36 spectral bands ranging from the visible to the thermal infrared wavelengths with a spatial resolution of 250 m, 500 m and 1000 m (Cheng, 2006). The first seven bands are designed primarily for remote sensing of vegetation and land surface across 2330 km swath (Xiao *et al,* 2006). A number of MODIS products have been developed to characterize atmosphere, ocean, and land surface properties (Justice and Townshend, 2002). Among the very useful products of the MODIS data are the Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI). Both indices were calculated from the red and near infrared portions of the spectrum. However, EVI is much complicated

than NDVI. The NDVI is calculated as: NDVI = (NIR-R)/(NIR+R) (Rouse *et al*, 1974), whereas the EVI is given by the equation: EVI = (1+L)*(NIR-R)/ (NIR+C_1R-C_2B+L), where NIR, R and B are reflectances in the near infrared, red and the blue bands respectively, C_1 and C_2 are aerosol resistance coefficients, and L is the vegetation canopy background factor (Huete *et al*, 2002). MODIS data have been widely used worldwide for land cover mapping and land cover change detection (e.g. Bagan *et al*, 2005 and Zhan *et al.*, 2002).

Due to the regional setting in the arid belt of the world, Egypt depends entirely on irrigated agriculture. The main exclusive surface water resource of the country is the River Nile. Desert represents more than 95% of Egypt's area. It depends mainly on the groundwater reserves. Cultivated lands of the country are mainly restricted along the narrow tract of the River Nile Valley and its Delta. Some scattered irrigated agriculture is extended along the Suez Canal and along the coastal zone of the Mediterranean Sea and Sinai. Soil properties and the availability of irrigation water as well as regional topography are the controlling factors for the distribution of agricultural lands in Egypt. For these reasons, cultivated lands of the country are restricted to the Nile Valley and its Delta. Urban encroachment represents a significant threat to the fertile agricultural land. The primary objective of the present study is to utilize MODIS data for mapping and inventory of the entire agricultural land cover of Egypt in the year 2005.

MATERIALS AND METHODS

MODIS Data

Egypt is covered by 63 scenes from the Multi-Spectral Scanner (MSS) and 60 images from the Thematic Mapper (TM) sensors (Abu El-Ennan *et al*., 1990), giving the advantage to the MODIS images which cover the entire Egypt by just four images, as the regional coverage of MODIS extends for 2330 km^2. Consequently, four images of MODIS/Terra Vegetation Indices 16-Day L3 Global 250 m composite product (MOD13Q1) covering Egypt and a part of the Arabian Peninsula (Tiles: H20V5, H20V6, H21V5 and H21V6) were acquired from the United States Geological Survey (USGS). The images represent the Julian day 225 of the year 2005 (the second week of August). At this time of the year all cultivated land in Egypt becomes mostly covered by green vegetation. Estimation of agricultural land is based upon assessment of the area of green vegetation. The major crops grown during image acquisition are rice, maize, cotton, sugarcane, and vegetables. The acquired vegetation indices product uses surface reflectance data (MOD09) corrected for atmospheric interferences. Each image consists of eleven bands (Table 1) in a HDF-EOS format. The pixel size is 250 m and the images are georeferenced to the Sinusoidal (SIN Grid) Projection.

Table 1: The Vegetation Indices (MOD13Q1) product of MODIS. (Source: NASA Land Processes Distributed Active Archive Center).

Band	Units	Data Type
250m 16 days NDVI	NDIV	16-bit signed integer
250m 16 days EVI	EVI	16-bit signed integer
250m 16 days NDVI Quality	Bit field	16-bit signed integer
250m 16 days EVI Quality	Bit field	16-bit signed integer
250m 16 days red reflectance (MODIS band # 1, 620-670 nm)	Reflectance	16-bit signed integer
250m 16 days NIR reflectance (MODIS band # 2, 841-876 nm)	Reflectance	16-bit signed integer
250m 16 days blue reflectance (MODIS band # 3, 459-479 nm)	Reflectance	16-bit signed integer
250m 16 days MIR reflectance (MODIS band # 7, 2105-2155 nm)	Reflectance	16-bit signed integer
250m 16 days average view zenith angle	Degree	16-bit signed integer
250m 16 days average sun zenith angle	Degree	16-bit signed integer
250m 16 days average relative azimuth angle	Degree	16-bit signed integer

Image Processing

Image processing techniques were carried out using ERDAS Imagine 9.0 Software. The first step was mosaicking the four contiguous scenes (eleven bands) into just one image covering the entire Egypt and a part of the Arabian Peninsula. The boundaries of the country were then extracted using the "area of interest" (AOI) built-in function in ERDAS Imagine Software. Since the NDVI correlates significantly with green biomass; i.e. green vegetation (Tucker, 1979) and the EVI is a new version of the NDVI enhancing the vegetation signal and avoiding the canopy background and atmospheric effect (Liu and Huete, 1995), hence it was chosen to increase the vegetation signature in the classification process and consequently facilitating the clustering of pixels representing vegetation. Five bands out of eleven were stacked together (EVI, Red, NIR, Blue and MIR) for image classification. An unsupervised image classification algorithm was applied to the five-band image of Egypt requesting 100 clusters. The Iterative Self-Organizing Data Analysis (ISODATA) algorithms in ERDAS Imagine were used in the clustering process as it is most suitable. After complete classification, we started careful recoding pixels representing cultivated lands. Other classes were left without recoding to show the different geomorphological features of the country.
The total area of agricultural land was estimated from the number of pixels recoded vegetation. Agricultural land of the different regions of the country, e.g. the Nile Delta; the Nile Valley; Suez Canal and Sinai; and the Western Desert were obtained by creating subscene images representing each region. Agricultural land at each region was extracted. Finally, an accuracy assessment was applied to the classified image using the corresponding five-band false-color image in order to get the sense of accuracy of recoding vegetation pixels only. A total of 2000 points were chosen randomly based on a stratified random approach. Points falling in the cultivated land of the reference image were compared with the corresponding pixels in the classified image. The classification accuracy was then estimated.

RESULTS AND DISCUSSION

MODIS image of Egypt is classified into 100 clusters depending on the spectral characteristics of each class. Cultivated land clusters were recoded together and represented in green color (Fig. 1). As the present study focuses on agricultural land, the accuracy assessment was applied only to this class. Accuracy of cultivated land classification is estimated at 84% (44 pixels out of 52 were identified correctly), which indicates a precise and a truthful estimation. According to the unsupervised classification scheme, cultivated land of the country is estimated at 8,227,776 feddans in 2005. Cultivated land in each region of the country is shown in Table (2).

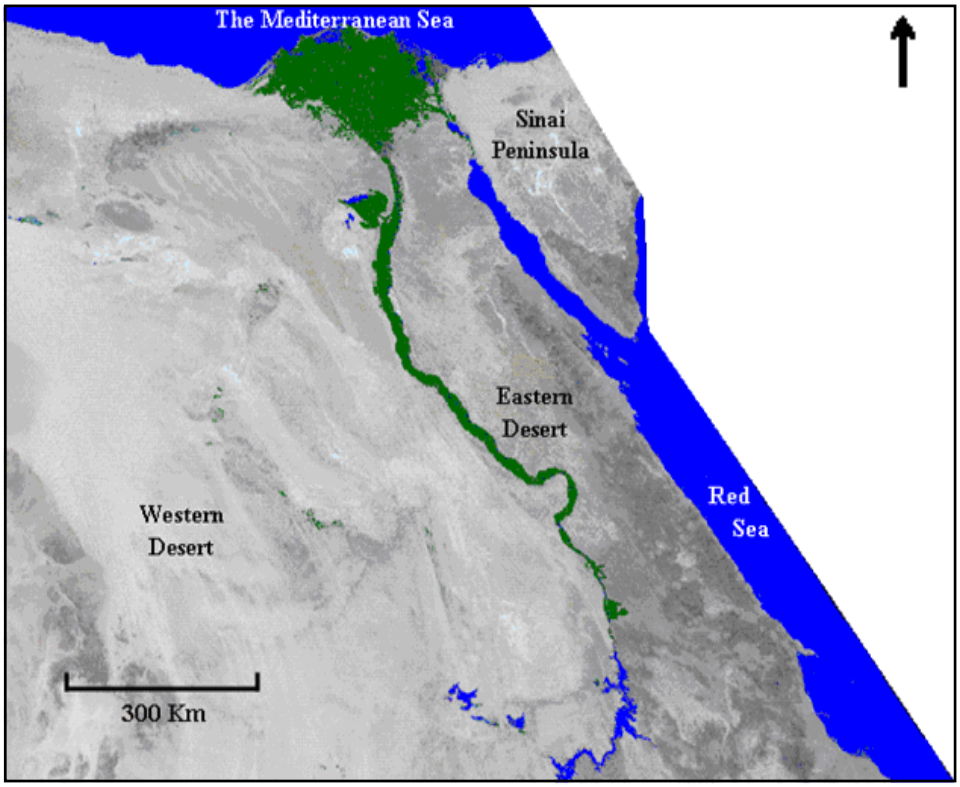

Figure 1: The spectral signatures of MODIS 2005 mosaic reflecting the features of cultivated and bare landscapes.

Table 2: The areas (in acres and feddans) of the cultivated land of Egypt as obtained from MODIS data.

Location	Area (acres)	Area (feddans)	%
Western Desert	77,735	74,626	00.91
Along Suez Canal	164,395	157,819	01.92
Nile Valley and El-Fayoum Depression	2,911,460	2,795,002	33.97
Nile Delta	5,417,010	5,200,330	63.20
Total	8,570,600	8,227,776	100.00

Agricultural land assessment by this study agrees with a previous estimation using finer spatial resolution data from the Thematic Mapper sensor (Hereher, 2006). According to Biswas (1993), based on government reports, the cultivated lands in the Nile Delta represents 62% of the total cultivated land in Egypt. This estimation agrees with the percent of cultivated land of the Nile Delta as obtained by the present study (~63%). Agricultural land in the Nile Valley and El-Fayoum Depression represents ~34% of the total cultivated area. As mentioned earlier, variations of soil quality and availability of irrigation water are among the primary factors controlling the distribution of the country's agricultural land. In addition, the topography and geomorphology play another role. The Nile Delta is flat and wide with very gentle slope. The Nile Valley is also flat but is restricted by terraced alluvium and rocky structure. Egypt started ambitious plans to reclaim many desert areas, such as the Southern Valley Development Project (SVDP) and Northern Sinai Development Project (NSDP). Agricultural lands in these projects have been detected by MODIS images and have been recoded in the classified image.

CONCLUSIONS

MODIS data provide high quality at no cost data for mapping spatial extent of cultivated lands of Egypt. The wide swath of this sensor (2330 km) provides a large regional coverage allowing a little number of images (4 images) to cover the entire Egypt. Egypt's cultivated land approached 8. 22 million feddans in 2005. About 63% of this area is cultivated in the Nile Delta. MODIS products afford an indispensable source of remotely sensed data for mapping irrigated agricultural land.

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حصر مساحة الأراضي الزراعية بمصر باستخدام بيانات القمر الصناعي "موديس"

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تم استخدام بيانات القمر الصناعي الأمريكي موديس (MODIS) لتحديد وحساب مساحة الأراضي الزراعية بمصر خلال عام 2005. وتتميز صور هذا القمر بتعدد المدي الطيفي وباتساع المدي الجغرافي لها مما يسمح بتغطية مصر بالكامل عن طريق اربعة صور متجاورة مع الاخذ في الاعتبار مستوي التفاصيل المراد الحصول عليها. وتم تصنيف صورة القطر المصري عن طريق التصنيف غير الموجه وتم حساب مساحة الأراضي الزراعية بمصر وكذلك في كل اقليم جغرافي بمصر. ولقد دلت النتائج أن مساحة الأراضي الزراعية بمصر قدرت بحوالي 8.2 مليون فدان عام 2005 وتركزت معظم الأراضي الزراعية بمنطقة الدلتا (63%) والوادي (34%) نظرا لجودة التربة وتوفر مياه الري.