Land cover change detection using NOAA AVHRR images taken from 1989 to 2002 for the Eastern part of the Mediterranean region as a tool to support decision-making

Gitas I.Z., Mitri G.H., Barbosa P.M., Assad N., Jomaa I., Papageorgiou C., Turk T.

in

Gitas I.Z. (ed.), San Miguel Ayanz J. (ed.).
Environmental monitoring in the South-Eastern Mediterranean region using RS/GIS techniques

Chania : CIHEAM
Options Méditerranéennes : Série B. Etudes et Recherches; n. 46

2003
pages 51-55

Land cover change detection using NOAA AVHRR images taken from 1989 to 2002 for the eastern part of the Mediterranean region as a tool to support decision-making

I.Z.Gitas[1], G.H.Mitri[1], P. M. Barbosa[2], N. Assad[3], I. Jomaa[4], C. Papageorgiou[5], T.Turk[6]

[1]Mediterranean Agronomic Institute of Chania (CIHEAM-MAICh), Chania, Greece
[2]Joint Research Centre, EC
[3]General Organization of Remote Sensing, Syria
[4]National Centre for Remote Sensing, Lebanon
[5]Ministry of Agriculture, Natural Resources and Environment, Forestry Dept., Cyprus
[6]Ege University, Centre for Environmental Studies & Akser, Turkey

---

Abstract: Undoubtedly, vegetation is one of the most sensitive indicators of environmental and global change. Aside from the expected seasonal variations, it reveals how human activities, such as deforestation and urbanization, are having a serious effect on ecosystem characteristics. Today, space-based platforms provide us with a considerable amount of information. In this study, the Advanced Very High Resolution Radiometer (AVHRR), precisely LAC/HRPT data, were used to monitor vegetation change in the Mediterranean. Pre-processing of satellite images prior to image classification was performed. Two change detection techniques were tested using NOAA-AVHRR images for detecting areas of changes in the eastern region of the Mediterranean. The change detection techniques considered were Vegetation Indices (VI) differencing and Multidate Unsupervised Classification (MUC). The Vegetation Indices (VI) used in this study were the Normalized Difference Vegetation Index (NDVI) and the Soil Adjusted Vegetation Index (SAVI) which have proved to be good indicators of vegetation vigour. The significant changes identified from the images taken between 1989 and 2002 were found to be similar when the two different techniques (VI differencing and MUC) were applied. Most of the changes occurred in bare soil areas converted to agricultural lands.

Keywords: Land cover, change detection, support decision-making, NOAA–AVHRR.

Resumé: Sans aucun doute, la végétation est un des indicateurs les plus sensibles de changement environnemental et global. À part des variations saisonnières attendues, elle révèle comment des activités humaines, comme le déboisement et l'urbanisation, ont un effet sérieux sur des caractéristiques d'écosystème. Aujourd'hui, des plates-formes d'espace nous fournissent une somme considérable d'information. Dans cette étude, the Advanced Very High Resolution Radiometer (AVHRR), précisément les données LAC/HRPT, ont été utilisées pour détecter le changement de végétation en Méditerranée. Le prétraitement d'images satellites avant la classification d'image a été exécuté. Deux techniques de détection de changement ont été évaluées utilisant NOAA-AVHRR des images pour détecter les secteurs de changements de la région orientale de la Méditerranée. Les techniques de détection de changement considérées étaient : Végétation Indices differencing et la classification multitemporelle non surveillée (MUC). Les indices de végétation (VI) utilisés dans cette étude étaient the Normalized Difference Vegetation Index (NDVI) et le Soil Adjusted Vegetation Index (SAVI) qui se sont avérés être les bons indicateurs de végétation. Les changements significatifs identifiés à partir des images prises entre 1989 et 2002 étaient semblables dans les deux techniques différentes appliquées (VI differencing et MUC). La plupart des changements sont arrivés dans des secteurs de sol nus convertis aux sols agricoles.

Mots-clés : La couverture de terre, détection de changement, soutient du processus décisionnel, NOAA – AVHRR.

Introduction

Nowadays, it is well accepted that the future of the Earth is threatened due to the degradation of ecosystems, the loss of biodiversity and the irrational use of natural resources. These processes are very pronounced in the Mediterranean basin where fragile ecosystems result from the confluence of natural and anthropogenic factors, leading to erosion, desertification, deforestation, overgrazing, overpopulation and urban industrial pollution (Khreim and Lacaze 1997). As a result of the aforementioned, the Mediterranean region is currently undergoing rapid, wide-ranging changes in land cover.

Remote sensing provides a viable source of data from which updated land-cover information can be extracted efficiently and cheaply in order to monitor these changes effectively. Thus, remotely sensed data can be applied to detect changes because of repetitive coverage at short intervals and consistent image quality. The basic premises in using remote sensing data for change detection is that changes in land cover result in changes in radiance values (Mas, 1999).

Satellite sensors are sensitive to vegetation differences and variations, especially in the infrared part of the spectrum. Time series AVHRR data have the potential to extract large land cover change areas (Tateishi and Park, 1999). Detecting change from satellite imagery is based on a temporal comparison of two or more images, recorded some years apart. These images are georeferenced and then processed to highlight change.

The aim of this work was to detect land cover changes in the Eastern Mediterranean on a regional scale by using NOAA-AVHRR images for the period 1989-2002. The specific objectives were:

- to investigate the use of Vegetation Indices (VI), namely the Normalized Difference Vegetation Index (NDVI) and the Soil Adjusted Vegetation Index (SAVI), to detect land cover change on a regional scale;
- to investigate the use of Multidate Unsupervised Classification (MUC) for the same purpose; and
- to integrate the two techniques (VI differencing and MUC) to detect permanent changes and inter-annual seasonal changes.

Data Characteristics and Pre-Processing

The AVHRR is a broad-band, four or five-channel scanner that senses in the visible, near infrared, and thermal infrared portions of the electromagnetic spectrum. This sensor is carried on board NOAA's Polar Orbiting Environmental Satellites. The average instantaneous field of view (IFOV) of 1.4 miliradians yields a LAC/HRPT ground resolution of approximately 1.1 km at the satellite nadir.

The data acquisition consisted of importing original NOAA-AVHRR images taken each year from 1989 to 2002 for three different months. February, March and August were considered to be the most appropriate periods to detect vegetation change in the different parts of the study area. Visual selection of the images was performed. All the night images were discarded, as well as those of bad quality (cloudy, noisy, night images, 4 km images). However, some cloudy images were kept in order to be composited later on. In total, thirty-three images were selected.

The pre-processing of satellite images prior to image classification and change detection is essential. It commonly comprises a series of sequential operations, including radiometric correction, image registration and geometric correction. Calibration and radiometric correction of the images was performed using the gain and offset as well as the sun zenith angle. Each of the images, for the months of February, March, and August, starting from 1989 until 2002, was registered using one reference image for each month. First order, ground control point collection and nearest neighbour resampling of the uncorrected imagery was performed. In most of the cases, NOAA scenes covered an area larger than the area of interest. In these instances, the image file was subset to include only the study area.

The study area (upper left 42N, 22E, and lower right 25N, 43E) included Lebanon, Syria, Cyprus, Turkey, North Egypt and part of Greece. The Maximum Value Composite of NDVI (Holben, 1986) was applied to the months that had more than one image in the same year in order to eliminate cloud cover over the area of interest and to complete missing parts from the study area. Figure 1 shows the flowchart that was followed in this work.

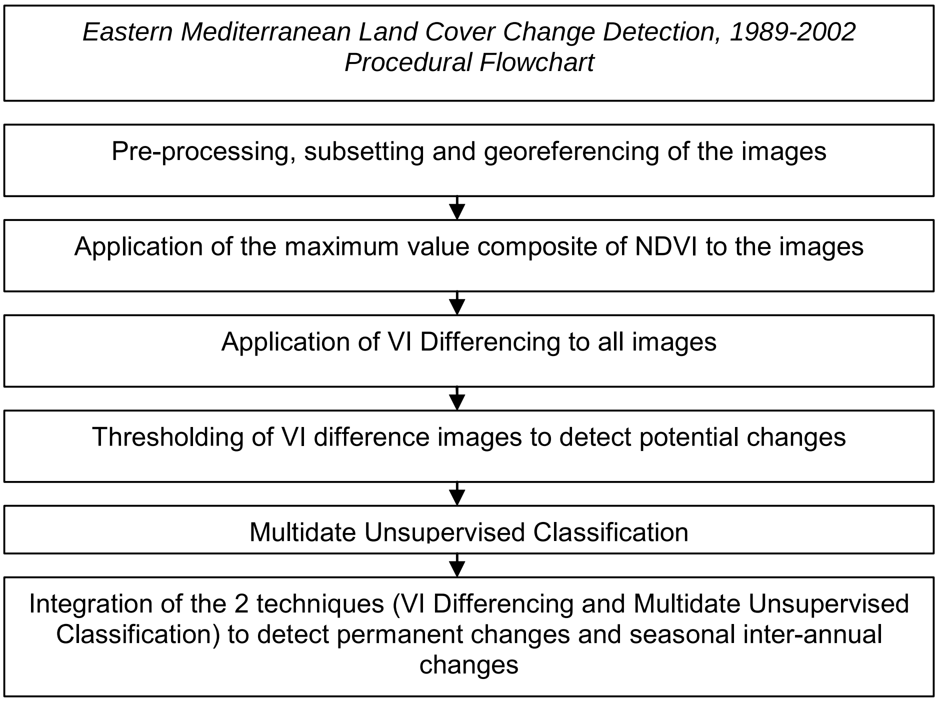

Figure 1. Flowchart of the methodology

Methodology

The change detection study included the integration of the two methods (VI Differencing and MUC) in order to detect permanent or semi-permanent changes and seasonal inter-annual changes.

Method 1: VI Differencing

Vegetation indices frequently represent different combinations between red (R) and near infrared (NIR) channels. These channels often contain more than 90% of the information relating to vegetation (Bannari et al., 1995). They represent quantitative measurements that show better sensitivity than individual spectral bands and thus allow a more accurate assessment of the vegetation's vigour (Asrar et al., 1984). The vegetation indices used in this study were NDVI and SAVI which have proved to be good indicators of vegetation vigour.

NDVI (Rouse et al., 1974) was calculated from the formula: NDVI = (Band 2 – Band 1) / (Band 2 + Band 1). SAVI (Huete, 1988) was calculated from: SAVI = (Band 2 – Band 1) * (1 + L) / (Band 2 + Band 1 + L). L is an adjustment factor for soil that can range between 0 and 1 and in this study it was set at 0.5. Image differencing (Mas, 1999) consisted of subtracting one VI image from another. VI images were subtracted to determine changes in the pixel values over time. The mean and standard deviations of each dataset were used to determine threshold values for change. The threshold point was set at 1.5 standard deviations. Therefore, the area between the mean ± 1.5 standard deviations was considered to represent no change, the area above this a positive change, and the area below this a negative change.

Method 2: Multidate unsupervised classification

Multidate unsupervised classification was applied to the images of interest. Such a method is based on a single analysis of a combined data set of two or more dates to identify areas of change. In a two-date NOAA data set with its five bands, a data set of ten bands was produced and then classified in an unsupervised mode using the ISODATA algorithm (Jensen, 1996). Inspection of the classification results was important for labelling all the possible combinations of the following classes: forest, agriculture, bare soil, cloud and water.

Detection of Land cover change: integration of the two techniques

A matrix of change/no change was constructed with the multidate classification classes, whereby each class of change or possible change was assigned a code. By integrating the two change techniques, multidate classification and VI differencing, a new detection map was obtained in which each change detected in the VI differencing image was assigned the multidate classification code. The changes attributed to cloud or no data were eliminated. Furthermore, areas of change in the image differencing that appeared as areas of no change in the unsupervised multidate classification (forest-forest, agriculture-agriculture, soil-soil) were considered to be possible changes. Visual analysis of the change detection integrated image, together with that of the appropriate RGB AVHRR images, was performed. In this way, it was possible to discard some changes because visually they were not identified as real changes. The remaining changes observed were kept and re-labelled. This also meant, for example, that inter-annual seasonal changes in agriculture-agriculture or soil-water could be kept.

Major Results and Discussion

The significant changes detected from the images taken between 1989 and 2002 were similar in the two different techniques applied, using the two different vegetation indices (NDVI and SAVI). Most of the changes occurred in bare soil areas converted to agricultural lands. This was due to new irrigation infrastructures which came into existence after the construction of new dams. An additional 217 000 hectares of agricultural land in Turkey were found to have been transformed from bare soil between 1992 and 1999, and in Syria another 449 000 ha had been converted from agricultural land to bare soil between 1990 and 1991, although this could have been due to inter-annual climate variability. Moreover, lands converted from bare to wetlands were detected between 1990 and 1996 after a series of small water harvesting plants had been built to collect rainfall. Additionally, a slight vegetation expansion was mapped in the area located north-west of the Nile, possibly due to the expansion of irrigated agriculture. The major changes were visually assessed by researchers from the different Mediterranean countries.

General Conclusions

This study demonstrated the use of NOAA-AVHRR imagery for detecting land cover change on a regional scale in the Eastern part of the Mediterranean. It also demonstrated that:

- vegetation indices such as NDVI and SAVI, proved capable of detecting land cover change using NOAA-AVHRR data in the Eastern Mediterranean;
- Multidate Unsupervised Classification also proved to be a good technique for the same purpose as above; and
- the integration of the two techniques (VI differencing and MUC) for the detection of land cover change resulted in the delineation of permanent changes and seasonal interannual changes.

In general, the major results obtained in this study showed that most of the changes occurred in bare soil areas converted to agricultural land. Although a formal accuracy assessment has not been performed due to lack of digital references and lack of visits to the sites of interest, the final products were very close to what each author has observed in his country.

Acknowledgements

The authors are grateful to the European Aid and Co-operation Office for the kind support they offered to this study, enabling Mediterranean-Non-Communtiy researchers to work together with European scientists and demonstrate the feasibility of using remotely sensed data and digital image processing/analysis techniques for a rapid evaluation of environmental changes in the Eastern Mediterranean.

References

[1] Asrar, G., Fuchs, M., Kanemasu, E. T., and Hatfield, J. L. (1984). Estimating absorbed photosynthetic radiation and leaf area index from spectral reflectance in wheat, *Agron. Journal*, 76, 300-306.

[2] Bannari, A., Morin, D., and Bonn, F. (1995). A review of Vegetation Indices. *Remote Sensing Reviews*, 13, 95-120.

[3] Holben, B.N., (1986). Characteristics of maximum-value composite images from temporal AVHRR data. *International Journal of Remote Sensing*, 7(11):1417-1434.

[4] Huete, A.R. (1988). A soil-adjusted vegetation index (SAVI). *Remote Sensing Environ*. 25:295-309.

[5] Jensen, J.R. (1996). Introductory Digital Image Processing (2nd ed.). Chapter *8, Thematic Information Extraction: Image Classification*. Upper Saddle River, NJ: Prentice-Hall. pp. 236-238.

[6] Khreim J. F., and Lacaze B. (1997). Land cover change detection in a Mediterranean area (Maritime Syria) from remotely sensed data. in *Geoscience and Water Resources: Environmental Data Modeling* (C.Bardinet & J.-J. Royers eds.), Springer-Verlag, Berlin-Heidelberg, pp.197-214.

[7] Mas, J-F. (1999). Monitoring land-cover changes: a comparison of change detection techniques. *International Journal of Remote Sensing*, 20, 139-152.

[8] Rouse, J. W., Haas, R. W., Schell, J. A., Deering, D. W., and Harlan, J. C. (1974). Monitoring the vernal advancement and retrogradation (Greenwave effect) of natural vegetation. *NASA/GSFCT Type III Final report*, Greenbelt, MD, USA.

[9] Tateishi, R., and Park, J.G. (1999). Preprocessing for global land cover change monitoring by time series AVHRR NDVI data, *Proceedings of the 20th Asian Conference on Remote Sensing*, Hong Kong, November 22-25, pp.623-628.