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Research article

Remote sensing and GIS to assess land degradation: A case study from Lebanon

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Abstract: Lebanon is known for its natural components, notably its natural resources. Nevertheless, inadequate management practices have led to the depletion of these resources in recent times. In the last few years, several aspects of land degradation in Wadi El Hjeir have been well-pronounced, and this has been associated with natural and human interference. This includes climate change, forest fire, quarrying, overgrazing, chaotic wastes disposal, and other unfavourable human activities For this reason, a set of satellite images (e.g., Sentinel-2) were processed to detect land cover changes between 2015 and 2020, although there is a short period of time between 2015 and 2020 because of sentinel-2 quality and its bands we were able to detect some differences in the land degradation that exists since the period of time should be 20 years to observe the differences but because sentinel-2 is modern as for its images we were able to observe the differences in this short time period. This has been accompanied by GIS application. The study aimed at determining the spatial and temporal changes in Wadi El Hjeir, a typical of Lebanese protected area, which has been designated lately as a Natural Reserve .The achieved work was based on identifying the major factors of land degradation, which were determined using satellite images for geo-spatial data extraction, and GIS for data analysis and manipulation where quantitative components were also addressed to identify changes in land use distribution over the last five years. This has been followed with field surveys to investigate in-depth the types and dimensions of land degradation in the area of study.

Keywords: Erosion, Forest fire, Sentienel-2, Land protection, Lebanon.

INTRODUCTION

Land degradation has several aspects and dimensions. This unfavourable land dynamic process has been lately exacerbated in many regions, notably where environmental legislations and controls are lacking, such as in Lebanon. The rate of deforestation and forest degradation in developing countries has been quite alarming in recent years. Around 13 million hectares of forest were converted to other uses, primarily agriculture, or lost through natural causes each year in the last decade FAO (2010). Howard (1991) observed that in a scenario of rapid expansion, where the world population increases, land-use transformations occur, and land cover diminishes, remote sensing plays a significant role. An emerging system, providing an essential and vital tool for remotely sensed data from various Earth observation satellites, is available for monitoring the spatial evolution of tropical forest ecosystems (Runge, 2006). Current technologies such as geographical information systems (GIS) and remote sensing provide ample opportunities for understanding landscape dynamics. They are potent tools to derive accurate and timely information on the spatial distribution of land use/land cover changes over large areas (Carlson & Azofeifa, 1999; 2003 *et al*., 2003; Rogana & Chen, 2004; Zsuzsanna *et al*., 2005).

Likewise, the degradation of many environmental components, land degradation, as well as unlikely land cover/use changes been well demonstrated in Lebanon in many studies (Dar El Handasah, 1996, Jomaa, 2008, Masri *et al*., 2002, MOA/MoE, 2002). This has been well developed due to the remarkable changes in the terrain components in Lebanon where natural components are under severe stress.

In this regard, environmental stress by wildfire has also continued to impact the ecosystem in Wadi El Hjeir. To ensure an accurate assessment of the scale and pace of natural tree conversion, it is crucial to utilize GIS and remote sensing technologies, given the reservation and observable alterations in "land use/land cover." It is expected that such information will enhance management decisions that will ensure sustainable management of the Wadi EL Hjeir. Notably that Wadi El Hjeir is lately subjected to land degradation and many other aspects of environmental distortion. This study aims at identifying the localities in Wadi El Hjeir which has been at risk. This can be well performed using remote sensing and GIS techniques which can have comprehensive terrain vision from space and that would not be easy to be done on the ground.

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MATERIALS AND METHODS

Study area

Wadi El Hjeir is situated in the mid-southern part of Lebanon, between Marje'youn, Bentjbeil, and Nabatieh. Stretching from the Litani River in Qaaqaiyet al-Jisr in the Nabatiyeh district to Aitaroun in Bint Jbeil, the valley is surrounded by several villages (Fig. 1). It is located at an altitude of 450-500 m. It is characterized by a Mediterranean climate with oceanic temperate, so vegetation is adapted to dry periods. The average temperature is 23°C, and the precipitation is about 700 mm per year.

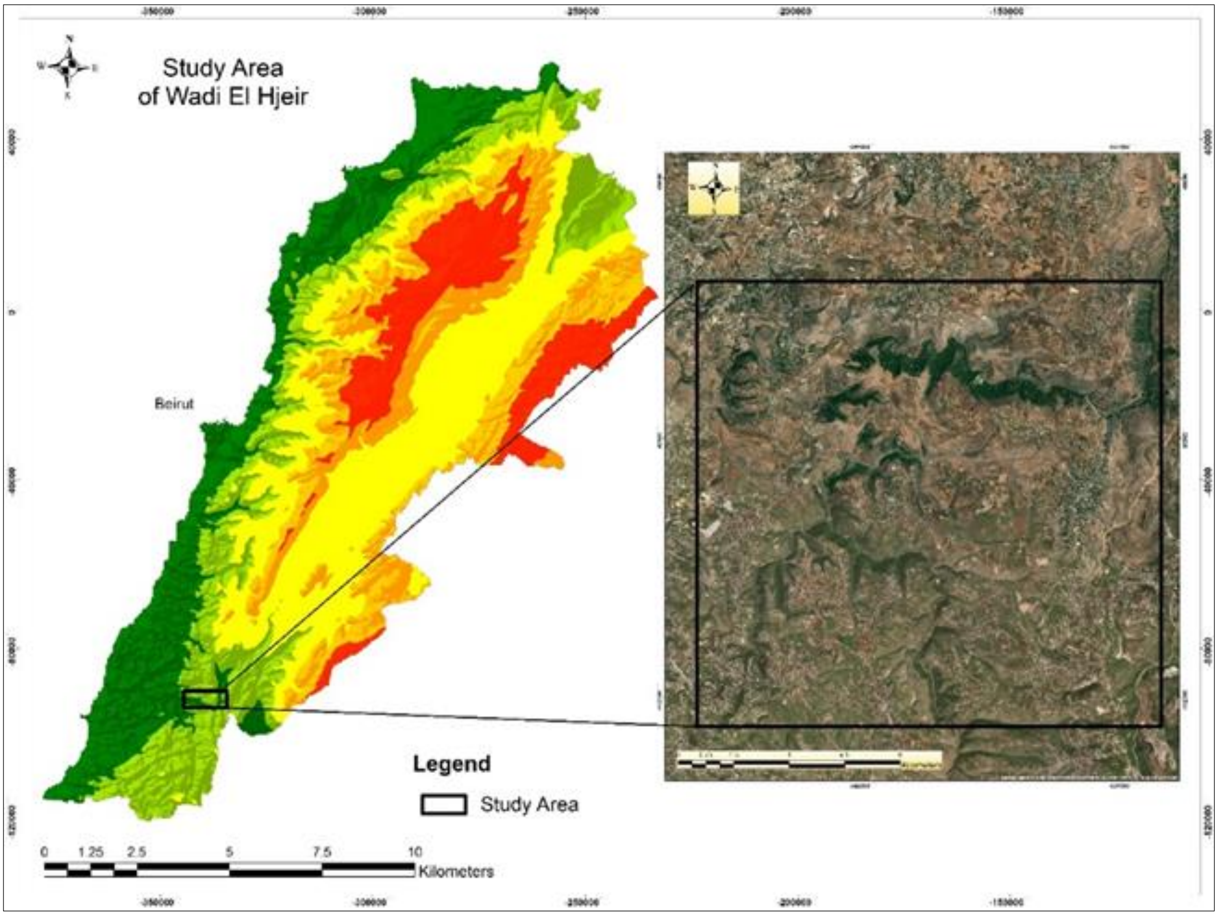

Figure 1. The Location of the "Wadi El Hjeir".

Materials

Satellite imagery

The images used in this study are due to the Sentinel-2 mission that is part of the Copernicus program by the European Commission in partnership with the European Space Agency (ESA) and repackaged by USGS into tile-based bundles. The Copernicus Sentinel-2 mission involves a pair of satellites that orbit together but are phased at 180◦, resulting in a revisit interval of 5 days (with a swath width of 250 km). The Sentinel-2 satellite is equipped with an optical instrument payload that captures data across 13 spectral bands, including four bands at a spatial resolution of 10 m, six bands at 20 m, and three bands at 60 m. Radiometric resolution quantifies the capacity of an imaging system to capture and distinguish various levels of brightness or tonal variations. The radiometric resolution of Sentinel-2 is 12-bit. This gives a potential range of brightness levels from 0.000-4.095. Satellite images were downloaded from USGS Earth (USGS Earth Explorer) to explore the L2 processing level, including geometric and radiometric correction. The selected 20-m resolution images were recorded in two different years (2015-2020). Even though, the time period is relatively short (6 years), the Seneinel-2 images proved to be capable to detect detailed signature differences even with this short time period, which reflects the powerful of this space technique tool. Mainly, bands 4 (central wavelength 665 nm) and 8A (central wavelength 865 nm) were used in this methodology because these are the bands needed in the NDVI calculation '2'.

Sentinel hub EO browser

The EO Browser is a web-platform for cloud computing processing of remote sensing data. As part of the Copernicus Programmer, it aims to contribute to achieving a global, continuous and easily accessible source of satellite data.

Methodology

The EO Browser was used as an essential material to approve our study by applying visual interpretation for two different (sentinel 2 LC) satellite images having time periods (October 2016 - October 2020). Many visual signatures were utilized to discriminate between different features that appear on the satellite images. Among these signatures are:

Visual interpretation

EO Browser, a freely accessible spatial data visualization tool, has been employed for visual interpretation, enabling users to explore and analyze extensive collections of satellite imagery. It combines many remarkable features that can be observed in the image. This depends on the comparison of data to quickly identify changes, various visualization options (actual colour, false colour, NDVI, etc.), custom band combinations, and even some data processing mechanisms, allowing users to run classification scripts to view the satellite images from sentinel-2 with a better and high resolution. So, we choose two images of dates 2017 and 2020 that were taken in October for different indices and compare them visually not mathematically interpretation, so it's important to post the two images of the different time zone to see where the change happen and help us to determine the type of these changes.

- **a- True color: Sensors:** Satellites are capable of capturing images of the Earth using various regions of the electromagnetic spectrum, with each region referred to as a band. The Sentinel-2 satellite, specifically, has a total of 13 bands. A true colour composite is created by utilizing visible light bands such as red, green, and blue in their respective colour channels. This process generates a natural-coloured output that closely resembles how humans would naturally perceive the Earth (Fig. 2).

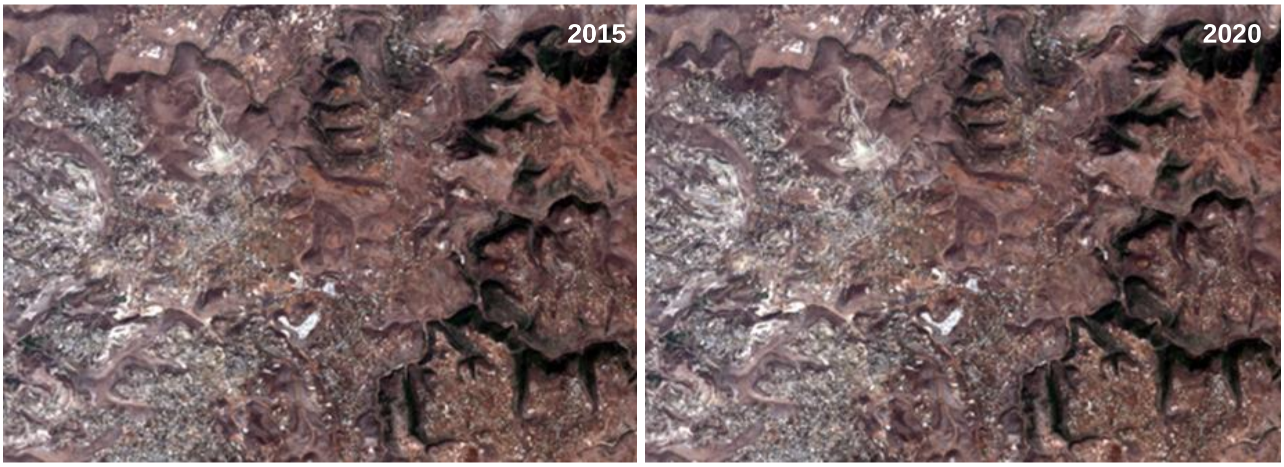

Figure 2. True Color Wadi El Hjeir 2015-2020.

- **b- False-colour:** In a false-color composite, Earth is imaged using at least one wavelength that falls outside the visible spectrum. The combination of near-infrared, red, and green bands in a false-color composite is widely favored. This technique leverages specific regions of the electromagnetic spectrum to create visually striking representations of Earth captured by satellite sensors. The false-colour composite is most commonly used to assess plant density and fertility since plants reflect near-infrared and green light while absorbing red. Cities and exposed grounds are grey or tan, and water appears blue or black (Fig. 3).

Figure 3. False-color Wadi El Hjeir 2016-2020.

- **c- Normalized Difference Vegetation Index (NDVI):** The normalized difference vegetation index is a simple but effective index for quantifying green vegetation. It measures the state of vegetation health based on how plants reflect light at specific wavelengths. The value range of the NDVI is -1 to 1 (EO browser) (Fig. 4). Negative values of NDVI (approaching -1) indicate the presence of water, while values near zero (-0.1 to 0.1) typically indicate barren areas such as rocks, sand, or snow-covered regions. Positive values on the lower end (around 0.2 to 0.4) signify the presence of shrub and grassland vegetation, whereas higher values indicate the existence of temperate and tropical rainforests (approaching 1).

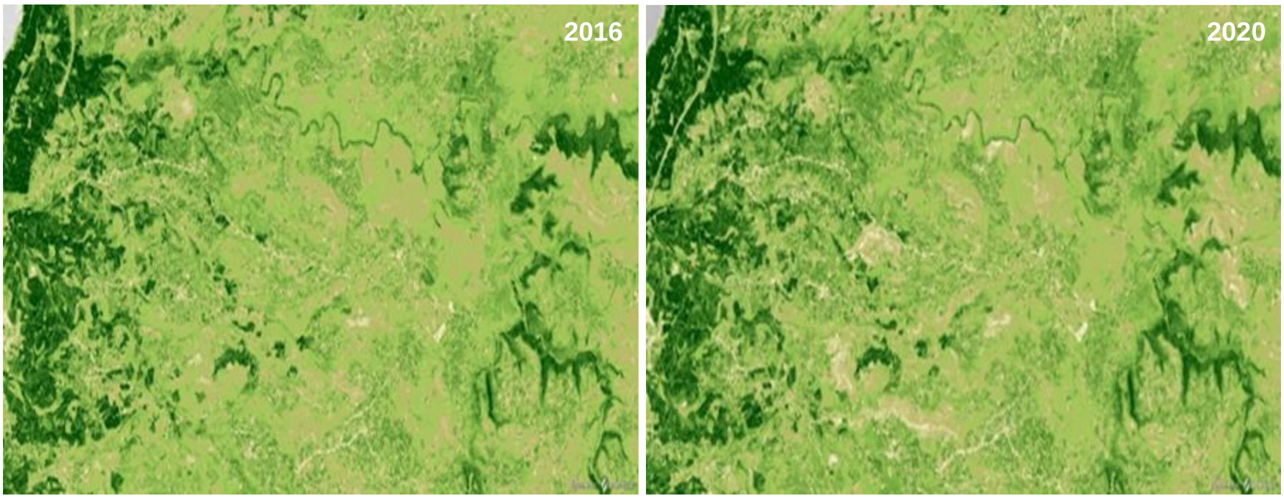

Figure 4. NDVI Wadi El Hjeir 2016-2020.

- **d- Detection of Wildfires:** This script, created by Pierre Markus, visualizes wildfires using Sentinel-2 data. It combines natural colour background with some NIR/SWIR data for smoke penetration and more detail while adding highlights from B11 and B12 to show fires in red and orange colours (EO browser) (Fig. 5).

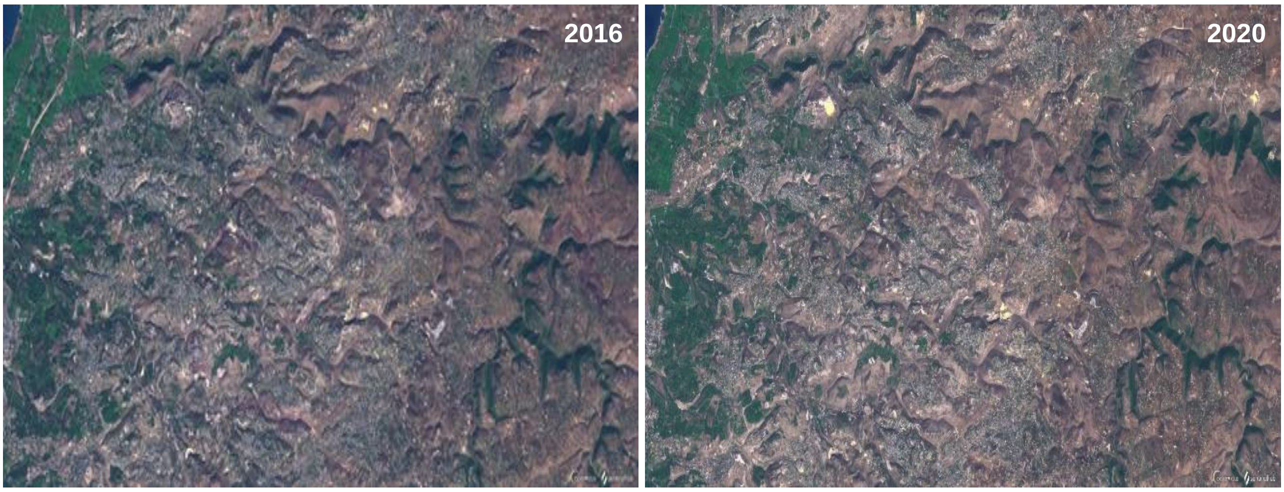

Figure 5. Wildfires Wadi El Hjeir 2016-2020.

ArcMap process

Then, a mathematical calculation through ArcMap was performed to achieve the percentage of these changes. The overall methodology adopted to achieve the objective of this study is illustrated in the Figures below for the two (sentinel 2) satellite images (October 2015 and October 2020.).

- **a- Band combination:** We combine the single band images (red, green, and blue) to obtain the natural colour of the two-time period images
- **b- Raster calculation “NDVI":** The Normalized Difference Vegetation Index (NDVI) assesses vegetation by quantifying the distinction between near-infrared light (which vegetation reflects strongly) and red light (which vegetation absorbs).
- **c- Classification of NDVI images by Python method:** We classify the NDVI raster of the two period into 5 classes:

```
>>> import arcpy
>>> from arcpy.sa import*
```

```
>>> m=Raster("ndviimage.tif")
>>> p1=Con((m>0.05) &(m<0.1),1,0)
>>> p2=Con((m>0.1) &(m<0.2),2,0)
>>> p3=Con((m>0.2) &(m<0.5),3,0)
>>> p4=Con(m>0.5,4,0)
>>> ndvi****=Fuzzy Overlay(["p1","p2","p3","p4"],"OR")
```

RESULTS

As a result of the comparative analysis between Sentinel-2 images at different time intervals, by using several visual and automated digital applications; therefore, the farmlands, trees, settlements, and crushers increased while the areas covered by the natural trees, settlements, and roads decreased from2016 (Fig. 6). This in turn indicates the exacerbated human activities in the area, which must be a protected area. The farmlands had the lowest percentage increase in area, while the highest reduction in the area was observed for the natural trees respectively. This reduction is mainly attributed to the wildfires, and wood cutting, and partially due to the excavation processes and quarrying. As of 2016, the natural trees covered a larger reserve area than each of the other land-use types, while in 2020, the disturbing trees were the land-use occupying the most significant area.

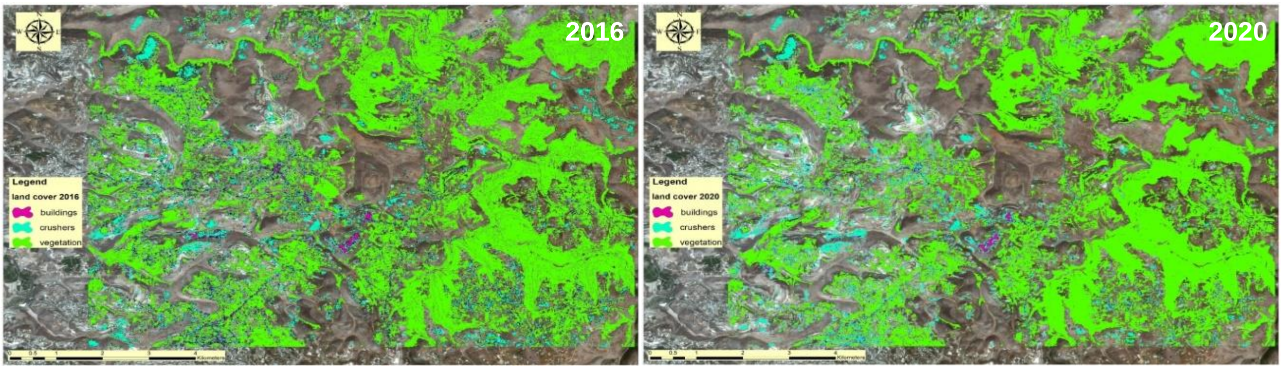

Figure 6. Land cover of Wadi El Hjeir 2016-2020.

Table 1. The changes in areas 2016-2020.

Terrain component Areas (km^{-2})	Areas 2020 (km^{-2})	Areas 2016 (km^{-2})	Changes in areas (km^{-2})
Urban areas	4.005	4.511	0.506
Crushers	0.533	0.829	0.295
Vegetation	28.605	31.506	-2.901

The natural trees cover of the Wadi El Hjeir was found to have been reduced by wildfire. The vegetation decreased from about (31.506 km^2) of the total area of the reserve to about (28.605 km^2) within the period under consideration; this is mainly due to unsustainable exploitation also crushers from (0.829 km^2) to (0.533 km^2), urban areas from (4.511 km^2) to (4.005 km^2). The change between 2016 and 2020 has become in vegetation (-2.901 km^2), crushers (0.295 km^2), and urban areas (0.506 km^2) (Table 1).

DISCUSSION AND CONCLUSION

The land use analysis revealed a remarkable change in land use within the Wadi El Hjeir. Between 2016 and 2020. The farmlands, natural forests, settlements and crushers increased in the area while the areas covered with natural trees decreased. The tremendous increase in farmlands could be attributed to increasing human populations, the need to produce more food to feed them, and income generation. As human populations grow, land-use intensity increases and natural trees' adverse effects worsen. Karimu (1999) equally noted that settlements in reserve have continued to increase in number and size. In the area between 2016 and 2020, the EO browser increased in the human population. A decrease in the areas covered with natural trees, crushers and roads, was expected. Close observation of the 2016 and 2020 land use maps of the natural trees reveals a wildfire. A more significant portion of the natural forest was found in the northeastern part of the natural trees as of 1987. However, the trend changed in 2011, with more of remaining natural trees.

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The study showed a remarkable land-use change in the natural trees between 2016 and 2020. There are solid indications that the disturbed forest, the most extensive land cover type in the reserve, will increase in the area shortly. It is expected that the information provided in this study will aid decisions that will enhance the sustainable management of the reserve.

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REFERENCES

Carlson T.N. & Azofeifa S.G.A. (1999). Satellite remote sensing of land-use changes in and around San Jose', Costa Rica. *Remote Sensing of Environment*, 70: 247-256.

Dar El Handasah (1996). *A national survey on quarrying in Lebanon*. Report prepared to the Ministry of Environment (MoE), Lebanon.

FAO (2010). *Global Forest Resources Assessment 2010*. FAO Forestry Paper No. 163. FAO, Rome, 373 p.

Guerschman J.P., Paruelo J.M., Bela C.D., Giallorenzi M.C. & Pacin F. (2003). Land cover classification in the Argentine Pampas using multi-temporal Landsat TM data. *International Journal of Remote Sensing*, 24: 3381-3402.

Howard J.A. (1991). *Remote Sensing of Forest Resources: Theory and Application*. Chapman and Hall Publisher, London.

Jomaa I. (2008). Analyse diachronique de la fragmentation des forêts du Liban, (Ph D dissertation). Toulouse University, 220 p.

Karimu S. A. (1999). *The role of surrounding communities on the management of Omo Forest Reserve*. Consultant Report for FORMECU, June 1999, 47 p.

Masri T., Khawlie M. & Faour G. (2002). Landcover change over the last 40 years in Lebanon. *Lebanese Science Journal*, 3: 2: 17-28.

MOA/MoE (2002). *Landcover map of Lebanon for the year 1998 (MOS: Mode d 'Occupation du Sol)*. Prepared by the Lebanese National Council for Scientific Research (CNRS)-Remote Sensing Center with the collaboration of IAURIF (Institut d'Aménagement et d'Urbanisme de la Région d'Ile de France). LEDO program,

Rogan, J, & Che, D. (2004). Remote sensing technology for mapping and monitoring land-cover and land-use change. *Progress in Planning*, 61: 301-325.

Runge J. (2006). Imperatives of remote sensing-based forest assessment: The example of Ngotto Forest, Central African Republic. In: Salami A.T. (Ed.) *Imperatives of Space Technology for Sustainable Forest Management*. Proceedings of an International Stakeholders' Workshop Sponsored by National Space Research and Development Agency (NARSDA), Abuja, pp. 62-71.

Zsuzsanna D., Bartholy J., Pongracz R. & Barcza, Z. (2005). Analysis of land-use/land-cover change in the Carpathian region based on remote sensing techniques. *Physics and Chemistry of Earth*, 30: 109-115.