Vegetation changes in Natura 2000 sites in Greece using remote sensing data

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Abstract

It is widely accepted that land use changes due to human intervention have caused degradation in various ecosystems. Advances in remote sensing enable us to detect spatial and temporal changes on earth's surface. The present work deals with the determination of temporal and spatial vegetation changes in the Natura 2000 designated areas in Greece, using remotely sensed data. The MODerate Resolution Imaging Spectroradiometer (MODIS) Normalized Difference Vegetation Index (NDVI) was used as a proxy for the computation of changes related to vegetation during the time period 2000 - 2016. The seasonal changes have also been examined, so as to unveil any possible changes that might suggest potential degradation of protected sites in Greece. The whole process has been developed combining R statistical package with QGIS, both open and free software packages, and using publicly available MODIS data. Results showed that the methodology constitutes an efficient and inexpensive tool of monitoring protected sites and helps in finding out whether the implementation of a protection policy has resulted in sustainable ecosystems.

Keywords: Vegetation changes, NDVI, MODIS, Greece

1. Introduction

Energy production by use of fossil fuels has led to greenhouse gas emissions mainly evident as an increase of CO_2 concentration in the atmosphere from 280 ppm in preindustrial times to more than 387 ppm in 2008 (European Environmental Agency, 2010). A consequent rise of average global temperature by 0.7 - 0.8°C above the preindustrial level has already happened whereas future projections predict rise in mean temperatures as much as 1.8 – 4.0 °C by the end of the century (European Environmental Agency, 2010). Global vegetation and especially terrestrial ecosystems are impacted by increased temperature and CO_2 concentration. Effects are evident in the form of changes in spatio - temporal vegetation productivity phenology and range of species (Cong *et al.*, 2013). Terrestrial ecosystems offer valuable services including processes that support the production of consumable goods, processes that support, regulate and enhance life (Nelson *et al.*, 2013). Among those services, Quéré *et al.*, (2009) indicates the primary role of land vegetation as CO_2 sink, which is even greater than ocean CO_2 sink. It is also widely known that control of climate change requires the stabilization of CO_2 emissions. Besides the dominant contribution of global scale drivers on vegetation changes, drivers at the local scale also interact to produce a unique vegetation response in each geographical area. Those are mostly related to Land Use Chnages (LUC), imposed by various socioeconomic factors such as population growth and urban expansion. Changes in vegetation growth are reported in various previous works (Piao *et al.*, 2011; Cong *et al.*, 2013; Mishra *et al.*, 2015), attributed to both climatic and anthropogenic factors. Piao *et al.*, (2011) regarding boreal Eurasia, reported NDVI increase from 1982 to 1997 and a reversal thereafter up to 2006, particularly for summer NDVI, which is related to decrease in summer precipitation. Mishra *et al.*, (2015) showed that in African Savanna, both positive and negative trends were determined from 2000 to 2014 which were related to specific vegetation and land use types. An interesting finding was that the majority of protected areas demonstrated greenness decrease which were related to increase of fire frequency. It is therefore very important to monitor and assess the quality of terrestrial vegetation, especially in areas of terrestrial protected ecosystems. Advances in remote sensing have provided powerful tools to monitor and characterize vegetation changes (Brown *et al.*, 2012). NDVI , based on the red/infrared spectral region, is the most commonly used vegetation index (VI) used to monitor vegetation amount and photosynthetic activity (Myneni *et al.*, 1995). The aim of this study is to determine temporal and/or spatial vegetation changes in protected areas of the Natura 2000 network in Greece and to assess the performance of the implemented protection policy. Therefore, we performed trend analysis of both annual and seasonal satellite derived time-series of NDVI to detect vegetation greening and browning trends and spatial variability of the trends in selected Natura 2000 sites in Greece.

2. Data and Methods

2.1. Description of the study area

The developed methodology was applied to 40 selected terrestrial ecosystems which belong to the EU Natura 2000 network, receiving thus environmental protection under national and EU legislation. Mediterranean countries are designated as "Hot Spots" regarding their vulnerability or their climate response to climate changes (Giorgi, 2006). Therefore major changes are also expected in the vegetation, both in its spatial distribution as well as in its productivity (European Environmental Agency, 2010), altering thus the original character of many terrestrial ecosystems in this area. Greece is a typical Mediterranean country, with a diverse topography which also influences its climate to a great extent. Therefore, three climate zones occupy Greece, i.e. the Mediterranean with mild, wet winters and hot and dry summers, the Alpine with abundant rainfalls and the temperate climate zones. The first one is typical in the Aegean Islands and the Southeastern part of continental Greece. The Alpine type is dominant mainly in Western Greece. Finally the Temperate climate is present in the central and Northeastern part of the country. Precipitation in Greece is spatially variable, increasing from the south to the north, but also increasing from the east to west due to the division of the country in two distinct climatic areas, influenced by the Pindus mountain chain and its extension to Peloponnesus and Crete (Figure 1) (European Academies Science Advisory Council (EASAC), 2010; Pnevmatikos and Katsoulis, 2006). Thus annual precipitation in Western Greece amounts to more 1000mm/yr, while Eastern Greece along with the Aegean islands demonstrate considerably lower precipitation in the range of 400 - 600mm/yr. Land uses in Greece are shown on Figure 1.

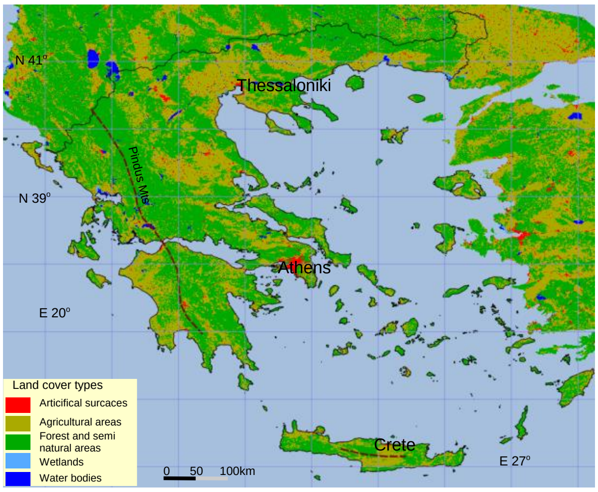

Figure 1. Corine Land Cover (CLC) 2012, Version 18.5.1 (European Environmental Agency, 1995)

One can see that agricultural areas are mainly located in the eastern areas, whereas most forested areas are found in the central and western parts of the country. Additionally, in southern regions of the country, intense touristic development takes place during the last few decades. Forty Natura 2000 sites, evenly dispersed all over Greece were examined in order to highlight any spatial or temporal trend in inter annual or seasonal vegetation changes.

2.2. Remote sensing data

The MODIS instrument onboard on both the Terra and Aqua satellites, map the entire surface of the Earth every one to two days. Its sensors detect 36 spectral bands at three spatial resolutions: 250-m, 500-m, and 1,000-m. Many previous works have shown that MODIS NDVI is an effective way of estimating vegetation changes in the form of greening or browning (Mishra *et al.*, 2015). The MODIS NDVI products are available at moderate spatial resolution, i.e. 250m. We used 16-day composites of MODIS NDVI (MOD13Q1) acquired from NASA's Land Processes Distributed Active Archive Center (LP DAAC) (https://e4ftl01.cr.usgs.gov/MOLT/MOD13Q1.005/ accessed December 2016). The study area is within two adjacent MODIS tiles, i.e., tile number h19v4 and h19v5. Time series comprised of 16 years of NDVI , i.e. from February 2000 to December 2016. The open source software R was used to develop a code for downloading, subsetting and processing MODIS data for the 40 selected Natura 2000 sites. Trend analysis was conducted individually for each site, for the monthly mean and maximum NDVI values, as well for their seasonal components, so as to detect any inter annual or seasonal trends, that would suggest vegetation changes.

3. Results and discussion

Trend analyses revealed areas where NDVI-mean and/or NDVI-max demonstrated statistically significant trends during the study period. Areas with significant trend in both NDVI-mean and NDVI-max were considered to have the highest potential of changing vegetation productivity. Following, areas with trend in NDVI-mean only, were evaluated as being probable sites of changing vegetation productivity. Trend in NDVI-mean was considered to be more robust indicator associated to changes in vegetation productivity compared to trend in NDVI-max (Mishra and Mainali, 2017). Trends were evaluated on inter annual and on seasonal basis. Results showed that the vast majority of examined sites demonstrated a greening pattern with an increasing trend in both NDVI-mean and NDVI-max, both inter annually and seasonally. Thus it seems that most sites encounter changes in vegetation productivity. Figure 2a shows the rate of change of annual NDVI-mean. Based on those results, NDVI changes seem to increase by increasing latitude. Northern Greece demonstrates almost double greening rate than Peloponnesus and Crete. No major trend in rate of NDVI change is evident on the east west direction. Areas with negative trends are located in island or coastal ecosystems. However, MODIS signal in those areas might have been influenced by the surrounding sea and therefore no safe conclusion can be drawn for those specific areas. Seasonal patterns of NDVI-mean and NDVI-max changes are shown on Figures 3 and 4. All seasons except summer demonstrate positive changes of both NDVI-mean and max. During summer, almost all eastern parts of continental Greece demonstrate negative NDVI-max trend, probably due to the decrease of summer precipitation in those areas. Another interesting finding is the increase in the number of areas demonstrating negative NDVI-mean values in spring (yellow areas in Figure 4b). In general, results have shown that the vast majority of protected sites in Greece, show positive vegetation changes, corresponding to greening of the respective areas. Taking into account that the Natura sites correspond to areas of minimum man intervention, it can be concluded that the protection policy has been successfully implemented in Greece. Areas affected by man induced land use changes, usually demonstrate a browning pattern as it has been observed in other cases elsewhere

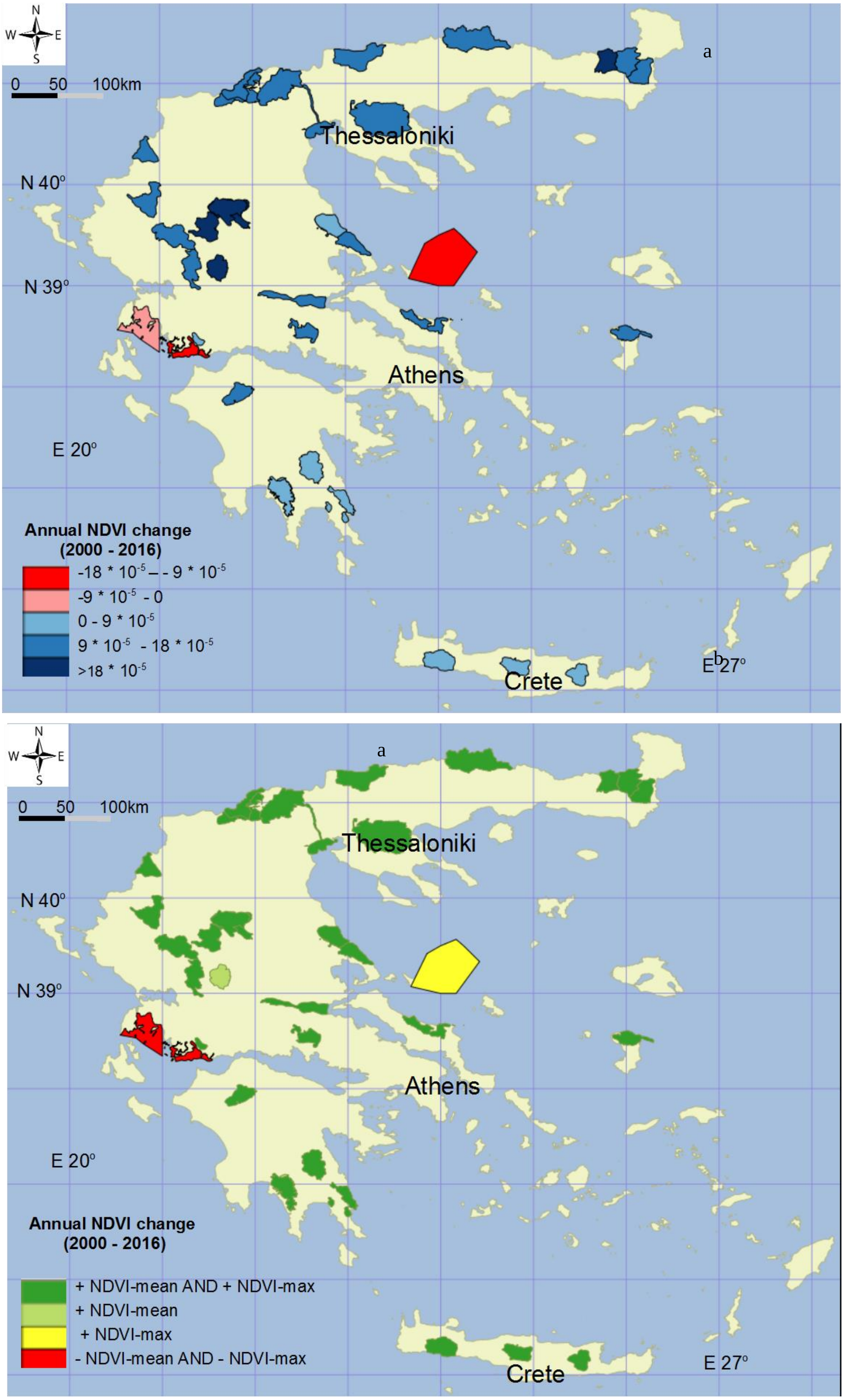

Figure 2. Annual NDVI changes a) as slope of the mean NDVI trend line, b) as sign of NDVI mean and max

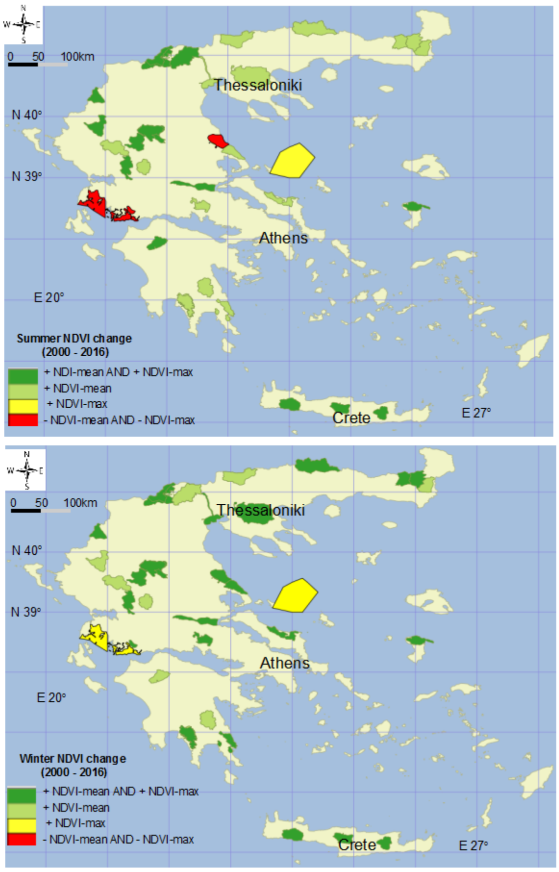

Figure 3. Suumer and winter NDVI changes

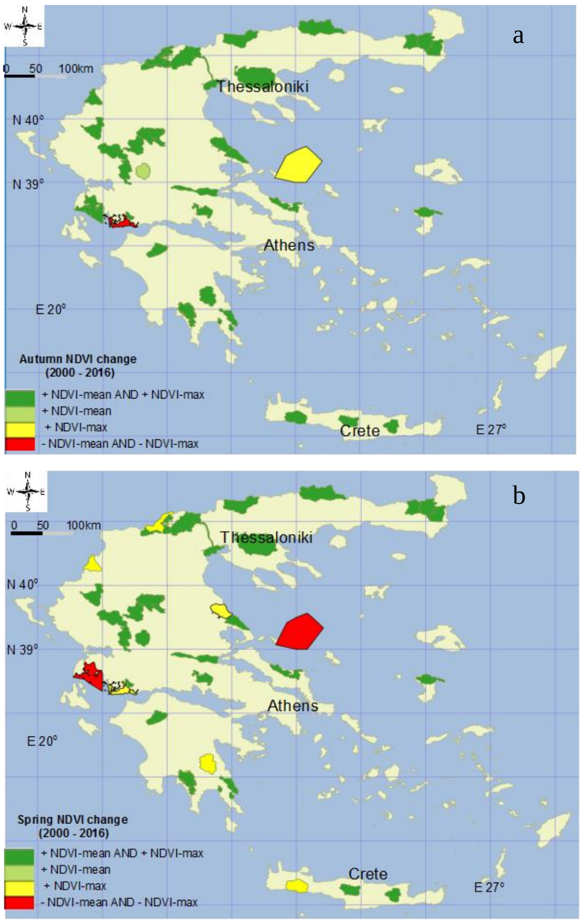

Figure 4. Autumn and spring NDVI changes

(Mishra and Chaudhuri, 2015). The greening pattern observed in the examined sites herein is attributed to drivers related to climate changes such as increased CO_2 concentration and nitrogen deposition and the associated temperature rise and change of precipitation variability, as found in other works as well (Mishra and Mainali, 2017)

4. Conclusions

In the present work trend analysis of freely available remotely sensed NDVI was used to demonstrate the utility of such methodology in identifying regional and local changes in vegetation of protected sites of the Natura 2000 network. Results showed that the majority of examined areas demonstrate a greening pattern throughout the study period, both on annual and on seasonal basis. In spatial context, the greening rate was found to be much higher in North Greece than that of Peloponnesus and Crete. Seasonal analysis showed that during summer, most eastern parts of continental Greece demonstrate a negative trend in peak NDVI-values, attributed to the decrease of summer precipitation in those areas. Results showed that the protection policy had positive effects on those sites, whereas the general greening pattern was attributed to factors related to climate changes such as increased CO_2 fertilization and N deposition as well as increased temperature and change of precipitation variability

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