DEMOCRITUS UNIVERSITY OF THRACE

Trends in vegetation changes over diverse land use environments over Greece using remote sensing data

UNIVERSITY OF SOUTH CAROLINA

X5.229

Alexandra Gemitzi[1], Venkat Lakshmi[2]

European Geosciences Union General Assembly 2018Vienna | Austria | 8–13 April 2018

Abstract

Land use and climate changes impact various ecosystems. Detection of vegetation changes is a key process for sustainable environmental management. Remote sensing has been providing relevant information regarding spatial and temporal changes on earth's surface. The present work aims at determining trends of vegetation productivity in the form of remotely sensed Normalized Difference Vegetation Index (NDVI) over Greece. Vegetation changes are attributed to both global and local scale drivers. Global drivers are increased temperature and increased CO_2 concentration, both related to climate change. Local scale drivers are land use changes attributed to human activities such as urban expansion and deforestation as well as increased fertilized and irrigated land, among others. To assess the role of climate and land use change in vegetation productivity, we examined trends in MODerate Resolution Imaging Spectroradiometer (MODIS) NDVI from 2000 to 2017, in two diverse land cover types, i.e. protected by the Natura 2000 network sites and urban areas. Natura 2000 are environmentally protected by legislation and these represent areas of minimum human intervention, and vegetation changes can be attributed mostly to climate change. Urban areas are regarded as sites where human impact is significant and local scale drivers dominate vegetation changes. Results showed that there is a significant ($p < 0.01$) increasing NDVI trend in all examined areas irrespective of their land cover type. Nevertheless, urban areas exhibited a higher increasing NDVI trend with magnitude greater than of Natura 2000 sites. Overall, Natura 2000 sites demonstrated a mean NDVI trend of $9.3 * 10^{-5}$/year whereas the computed mean NDVI trend in urban areas is $13.8 * 10^{-5}$/year. Spatially, Natura 2000 sites demonstrate a higher increasing trend in Northern Greece compared those in the southern parts of the country. Urban areas do not demonstrate any spatial trend of NDVI changes. The difference of vegetation productivity trends in urban areas compared to Natura 2000 sites, is indicative of the combined effect of human and climate in those urbanized locations. Our results indicate that the Urban Heat Island might be a possible reason for increased vegetation productivity in urbanized locations. Regarding protected sites, it seems that protection policies in combination with global scale drivers resulted in increased vegetation productivity and sustained ecosystem quality. The process has been developed integrating two popular and open source computer packages, i.e. QGIS and R, and using publicly available MODIS NDVI and CORINE land cover data. Results showed that the methodology constitutes an efficient and inexpensive tool of monitoring vegetation trends and ecosystem conditions.

Background

- 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).
- Climate changes are already evident in a wide variety of natural systems. The most prominent and indisputable change is global warming (IPCC, 2014).
- The Mediterranean is characterized as one of the main "hot-spots" as indicated by climate change projections (Giorgi, 2006; European Environment 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).
- 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).

Objectives

- The aim of this study is to determine temporal and/or spatial vegetation changes in two diverse land use environments, i.e. in protected areas of the Natura 2000 network in Greece and in urban areas. The protected areas receive the environmental protection under national and EU legislation and thus can be regarded as areas that correspond to least man intervention. On the contrary, urban areas are connected to the highest human impact.
- Our study also investigates the usefulness of remotely sensed data in order to highlight spatial and temporal trends in vegetation changes.
- The performance of the implemented protection policy is also evaluated within the present work.

Methods and materials

- The developed methodology was applied to 40 selected terrestrial ecosystems which belong to the EU Natura 2000 network, as well as to 40 urban areas. Therefore, we performed trend analysis of annual derived NDVI time-series to detect vegetation greening and browning trends and spatial variability of the trends in selected Natura 2000 and urban sites in Greece.
- The MODIS NDVI products were used for analysis of vegetation trends. Such 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/).
- The study area covers Greece and falls 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 October 2017.
- 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 and for the 40 urban areas. Trend analysis of NDVI values was conducted individually for each pixel, so as to detect any inter annual trends, that would suggest vegetation changes.

Methodology application

- Only pixels of the highest quality i.e. cloud free and error free pixels, were selected for processing.
- As protected sites over Greece cover a larger area compared to urban areas, the final results were acquired selected randomly 500 pixels from each distinct category.
- The NDVI trends were determined in the form of Least Square line fitting. Statistical significance of the trends was estimated for each of those areas by their *p*-values. Results were considered statistically significant when $p < 0.05$. In areas where p was found to be > 0.05 ($p > 0.05$), it was assumed that there was virtually no trend in the corresponding time series.

Results

Results have shown that there is a statistically significant difference in NDVI trends in those distinct land use categories (Figure 1), with urban areas demonstrating a higher NDVI increasing trend.

Spatially, urban areas demonstrate the highest NDVI increasing trend in Central Greece (Figure 2a), with no distinct spatial trend. NDVI trends in protected sites (Figure 2b) demonstrate a spatial pattern of highest increases in North Greece and lowest values in South Greece. This spatial pattern indicates the natural variability of NDVI, as Natura 2000 sites correspond to areas of least human intervention.

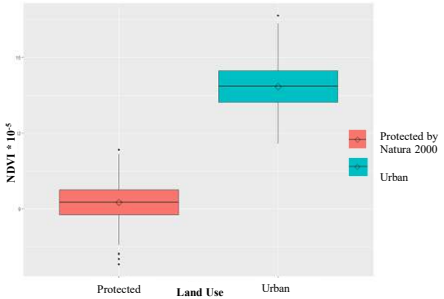

Figure 1. NDVI in protected and urban areas based on 500 randomly selected pixels for each category. ($p < 0.001$ for statistical significance in difference in means).

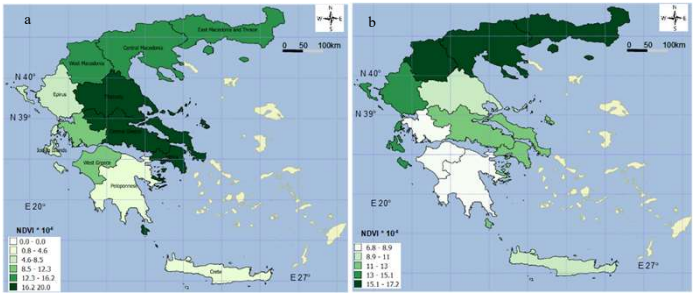

Figure 2. Annual NDVI changes a) in urban areas and b) in protected areas over regions of Greece during 2000 – 2017

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 spatio-temporal changes in diverse land use environments. Results showed that:

- The vast majority of examined areas demonstrate a greening pattern throughout the study period, irrespective of their land use.
- There is a statistically significant difference in NDVI trends in the two examined land use types, with urban areas demonstrating higher increasing trends.
- In spatial context, the greening rate was found to be much higher in North Greece than that of Peloponnesus in protected sites, whereas urban areas did not demonstrate any spatial pattern.
- Results showed that the protection policy had positive effects on protected 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.
- High increasing NDVI trends in urban areas are probably attributed to Urban Heat Island effect.

Authors - Acknowledgments

[1] Democritus University of Thrace, Environmental Engineering, Xanthi, Greece, agkemitz@env.duth.gr
[2] Professor, Earth and Ocean Sciences, Columbia, SC, United States, vlakshmi@geol.sc.edu

The first author acknowledges the Technical Chamber of Greece for its support through the project "Climate Changes and Dependent Ecosystems in Eastern Macedonia and Thrace" (Project ID: 81203 - Democritus University of Thrace).

References

Cong, N., Wang, T., Nan, H., Ma, Y., Wang, X., Myneni, R. B., & Piao, S. (2013). Changes in satellite-derived spring vegetation green-up date and its linkage to climate in China from 1982 to 2010: A multimethod analysis. *Global Change Biology*, *19*(3), 881–891. https://doi.org/10.1111/gcb.12077

European Environmental Agency. (2010). *The European Environment - State and Outlook 2010 - Assessment of Global Megatrends*.

IPCC. (2014). *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Core Writing Team, Pachauri , R.K. Meyer, L.A.* https://doi.org/10.1017/CBO9781107415324.004

Mishra, N. B., & Chaudhuri, G. (2015). Spatio-temporal analysis of trends in seasonal vegetation productivity across Uttarakhand, Indian Himalayas, 2000-2014. *Applied Geography*, *56*, 29–41. https://doi.org/10.1016/j.apgeog.2014.10.007