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 CO2 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 that of Natura 2000 sites overall. Overall, Natura 2000 sites demonstrated a mean NDVI trend of 9.3 ± 10^-3/year whereas the computed mean NDVI trend in urban areas is 13.8 ± 10^-3/year. Spatially, Natura 2000 sites demonstrate a higher increasing trend in Northern Greece compared to 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 areas. 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 software packages, i.e. QGIS and R, and using publicly available MODIS NDVI and CORINE land cover and use categories (Figure 1), with urban areas demonstrating a higher NDVI increasing trend. The study area covers Greece and falls within two adjacent MODIS sites, i.e., tile number h19v94 and h19v95. Time series comprised of 16 years of NDVI, i.e. from February 2000 to October 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:
1. The vast majority of examined areas demonstrate a greening pattern throughout the study period, irrespective of their land use.
2. There is a statistically significant difference in NDVI trends in the two examined land use types, with urban areas demonstrating higher increasing trends.
3. In spatial context, the greening rate was found to be much higher in North Greece than that of Peloponnese in protected sites, whereas urban areas did not demonstrate any spatial pattern.
4. 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 CO2 fertilization and N deposition as well as increased temperature and change of precipitation variability.
5. High increasing NDVI trends in urban areas are probably attributed to Urban Heat Island effect.

References
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Abstract
The developed methodology was applied to 40 selected terrestrial ecosystems which belong to the EU Natura 2000 network sites, 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 (LPC DAAC) (https://e4ftl01.cr.usgs.gov/MOLT/MOD13Q1.005). The study area covers Greece and falls within two adjacent MODIS sites, i.e., tile number h19v94 and h19v95. Time series comprised of 16 years of NDVI, i.e. from February 2000 to October 2017.

Methods and materials
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.

Results
Only pixels of the highest quality i.e. cloud free and error free pixels, were selected for processing. The 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 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.

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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