A VEGETATION COVER TIME SERIES ASSESMENT IN ERBIL, IRAQ USING VEGETATION INDICES DERIVED FROM MODIS IMAGERY

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Abstract
The Semi-arid regions of Iraq, particularly Erbil has experienced significant changes in vegetation cover over the past 15 years, due to factors like urbanization, population growth and economic development. The research aims to detect spatiotemporal changes in vegetation cover in and around the city of Erbil from 2000 to 2015. By using the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) derived from MODIS satellite imagery.
NDVI and EVI statistics captured monthly are compared over five year intervals to summarize temporal deviations. A five year interval time-series of NDVI and EVI images, and a change detection analysis comparing VI levels from 2000 to 2015, are presented to highlight spatiotemporal trends. Monthly rainfall, humidity and temperature over the 15 year period were also considered to enhance the understanding of vegetation change dynamics. Results illustrate a significant change in vegetation cover and health around the expanding urban area of Erbil due to increased human activities in the region over the 15 year period. Heavily built-up areas have limited green areas in comparison with the non-urban areas around Erbil's city.

Introduction

The rate of urbanization and vegetation loss is increasing throughout the globe. Urbanization can alter environmental conditions such as climate, biodiversity and the quality of water and air that has a substantial impact on human comfort and health. Impacts may become pronounced when they interact on a global scale. Therefore, a better understanding of the effect of urbanization is required to support greener sustainable development and climate change strategies (Imhoff, et al., 2010). Solutions may include the creation of urban green spaces, that are irrigated and fertilized, which are found to considerably reduce negative consequences associated with urbanization (Gregg, et al., 2003). The remote sensing of vegetation loss and urban expansion delivers evidence on spatiotemporal patterns of urban development and its impacts to the environment.

MODIS imagery provides data necessary for monitoring ecosystem dynamics at adequate spatiotemporal resolution using vegetation indices such as NDVI and EVI. Allowing biomass and health monitoring and the quantification of changes in vegetation cover (Colditz, et al., 2006; Mertes, et al., 2015; Rizzi, et al., 2006). Equations for NDVI and EVI are listed below (Huete, et al., 2002).

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

$$EVI = 2.5 \frac{NIR - Red}{NIR + (6 * RED) - (7.5 * BLUE) + 1}$$

NDVI was found to be highly sensitive to the vegetation presence as well as its density and dynamics (Zhang, et al., 2006). For this reason, the MODIS NDVI can be employed in the quantification of green biomass and vegetation cover. A recent study in China by Li et al. (2010) found that MODIS NDVI was highly correlated with the field verification data of vegetation cover and had obvious advantages for predicting natural vegetation coverage than EVI within their study area. EVI is designed to improve on a standard NDVI product by minimising canopy background variations and maintains sensitivity over dense vegetation conditions (USGS, 2016). Benefits of EVI include; enhancement of vegetation signal and sensitivity in biomass abundant regions, reduction of soil and atmospheric effects and the reduction of the smoke impact, generated as the result of biomass combustion in tropical area (Xiao, et al., 2009). The EVI uses the blue band to remove residual atmosphere contamination caused by smoke and sub-pixel thin clouds.

Study area

The study area is the city of Erbil and its surroundings, which is the capital of Iraqi Kurdistan Region (Fig. 1). The total numbers of Iraq Kurdistan residents is approximately 4.8 million. Agricultural areas form approximately 34% of Iraqi Kurdistan while the dominating land cover of this region is presented by grasses and forests.

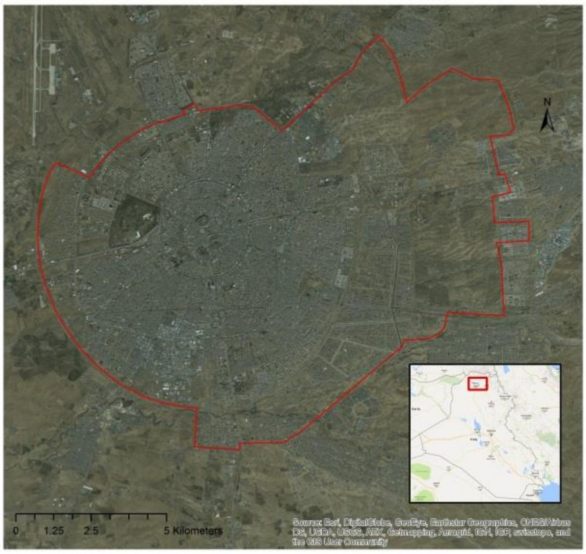

Fig. 1: Overview of the Erbil Study area

Erbil City is located in a transition area characterized by Mediterranean and Arid climatic features. The climate is characterized by mild winters and warm/hot summers. An average rainfall range in Erbil area is 300-400 mm per annum with the highest rainfall levels during the period between October and April. The climate of the study area is typically dry in summer with little to no precipitation, while winters are wet (Hameed, 2013).

Methods

MODIS NDVI & EVI

The study uses a 16 day composite for each NDVI and EVI raster (MOD13Q1), captured by the MODIS-Terra sensor. Blue, red, and NIR reflectance bands, centered at 469 nm, 645 nm and 858 nm respectively, are used to determine the MODIS vegetation indices, with a spatial resolution of 250m (USGS, 2016). MODIS products are computed from atmospherically corrected bi-directional surface reflectance that have been masked for water, clouds, heavy aerosols, and cloud shadows (USGS, 2016). Masked cells may vary between images however mean NDVI and EVI were generated to provide an average index over the complete study area, allowing the comparison between years to examine a temporal trend. Plots of monthly NDVI and EVI statistics (mean, minimum, maximum and standard deviation) are generated at 5 year internals from 2000 to 2015, identifying temporal variations. Plots, statistics and investigation of possible trends were completed in Microsoft Excel.

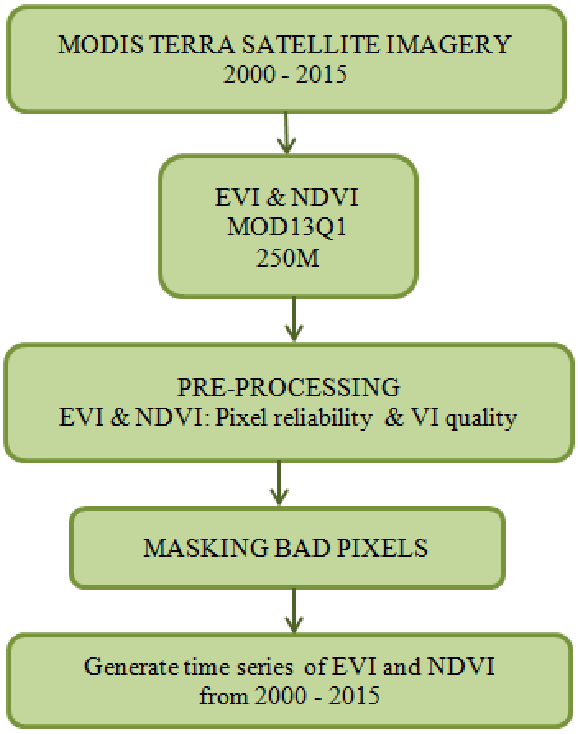

Fig. 2: MODIS time-series Methodology

The MODIS time-series methodology is summarized in Figure 2. Data pre-processing included checking pixel reliability and vegetation index quality. Bad pixels are omitted from the analysis as they represent clouds, shadows from the clouds and cover the true value of the ground reflectance. MODIS time series of NDVI and EVI images at 5 year internals from 2000 to 2015 are presented to highlight spatiotemporal trends. The change detection analysis comparing NDVI and EVI levels from 2000 to 2015 was completed in ENVI. Data compilation and maps were generated in ArcGIS 10.3.

Climate Data

Monthly average temperature, humidity and total rainfall were collected from Erbil station and plotted over the 15 year period. All climate data was sourced from the Ministry of Agriculture and Water Resources (2016). Correlation analysis between rainfall, humidity, temperature and vegetation indices (NDVI & EVI) was completed in Microsoft Excel.

Results

Both vegetation indices (NDVI & EVI) generally increased during March and April, then decreased to lower levels and remained constant from May to February over the 15 year period (Fig. 3). In January 2015 vegetation indices (VIs) start to gradually increase earlier than previous years. Both the NDVI & EVI levels peak in April 2000, then during 2005 the VIs peak earlier in March and during 2010 and 2015 the VIs peak later in March. There is a gradual pattern change from 2000 to 2015 during January to May. The duration of elevated VI levels has expanded in 2015 compared to 2000.

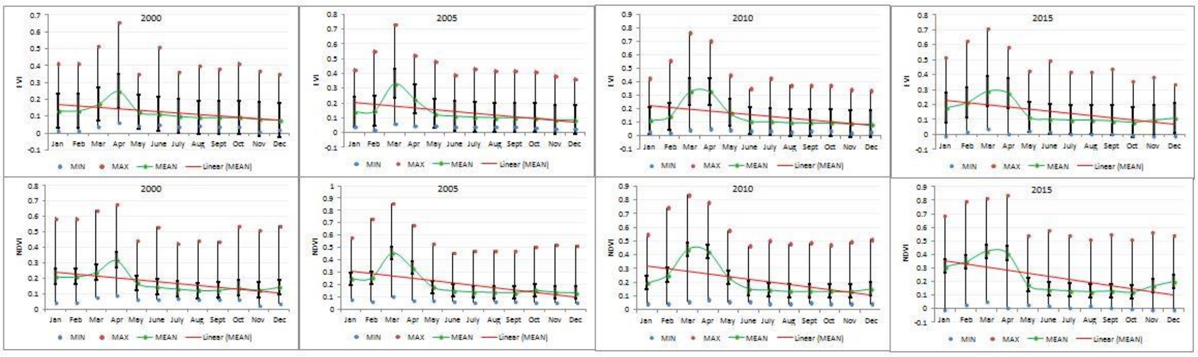

Fig. 3: NDVI & EVI monthly summary statistics for 2000, 2005, 2010 and 2015

The monthly plots in Figure 4 provide a detailed comparison between years 2000, 2005, 2010 and 2015. The plots reveal NDVI levels remained low (<0.2) and consistent between June to November over the 15 year period (Fig. 4). Temporal variation is particularly evident from December to May. Significant temporal deviations are evident in March 2005 with elevated NDVI levels and January 2010 when NDVI levels fall below averages from other years (Fig. 4). A gradual linear increase in NDVI levels from 2000 to 2015 is apparent in December through to May.

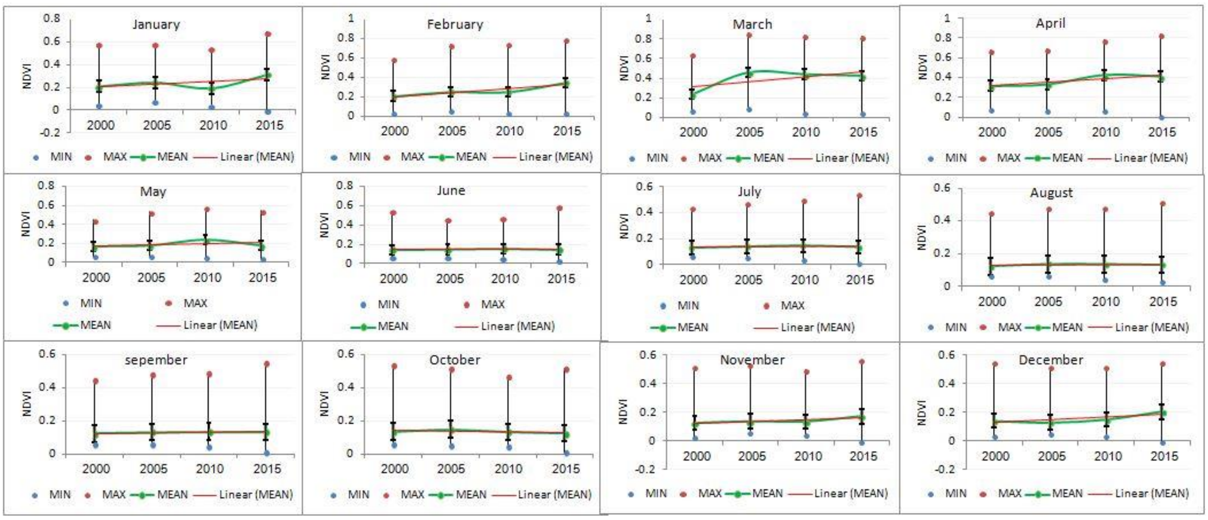

Fig. 4: Monthly plots of NDVI summary statistics for 2000, 2005, 2010 and 2015.

NDVI and EVI time-series maps from March 2000 to March 2015 are compared in Figure 5 and 6 to summarize the spatiotemporal variation of vegetation. The month of March had the highest vegetation growth, and will best represent differences in true vegetation coverage extent. It is evident that the spatial distribution of urban areas and/or bare or sparely vegetated areas with values less than 0.25 has expanded over the past 15 years. Consequently vegetation surrounding the urban center has been replaced by urban growth. The NDVI imagery appears to have greater areas of higher vegetation health compared to EVI. The EVI imagery has displayed a large area of poor vegetation health, which is more likely in the semi-arid regions of Iraq.

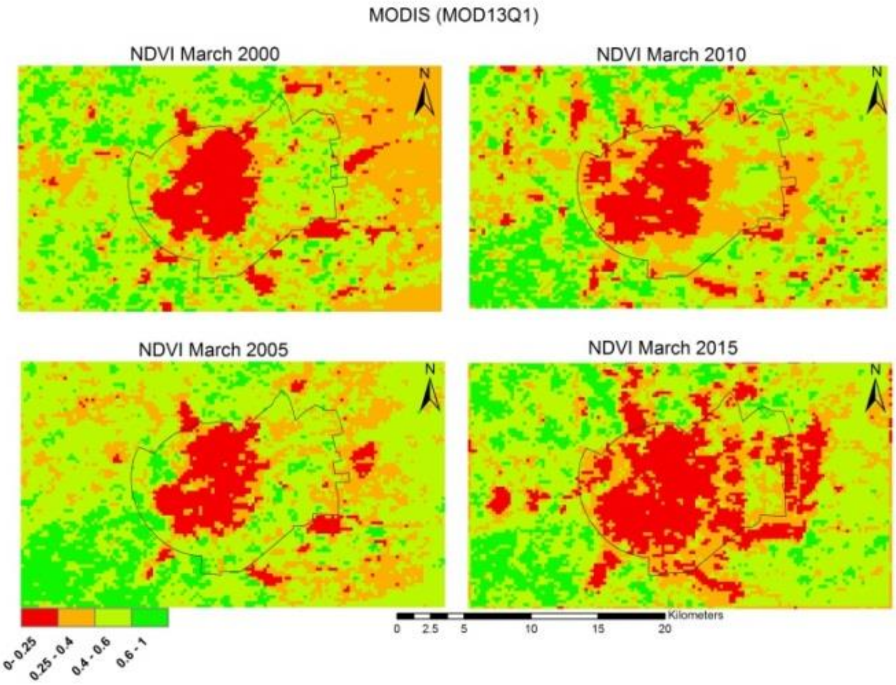

Fig. 5: March NDVI raster time series of Erbil from 2000 to 2015

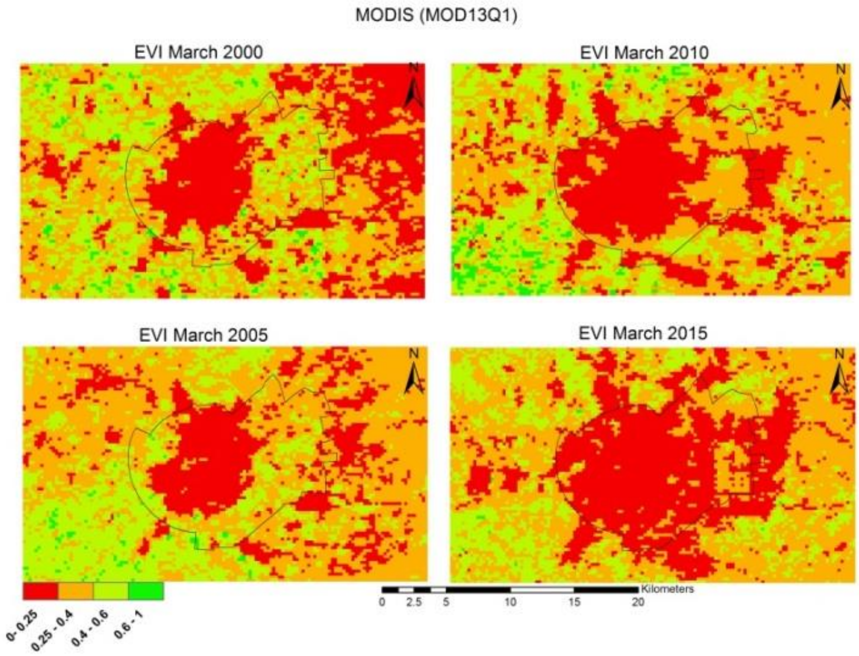

Fig. 6: March EVI raster time series of Erbil from 2000 to 2015

The change detection analysis compares NDVI and EVI levels from March 2000 to March 2015 (Fig.7). A significant decrease in vegetation cover is evident around the edges of the build-up area of Erbil and extends into some rural areas, indicating vegetation clearing and urban expansion (Fig. 7). However there has been a significant increase in both NDVI and EVI values in the outer rural areas of Erbil (Blue zones). This represents an increase in productive crop health and agricultural crop land.

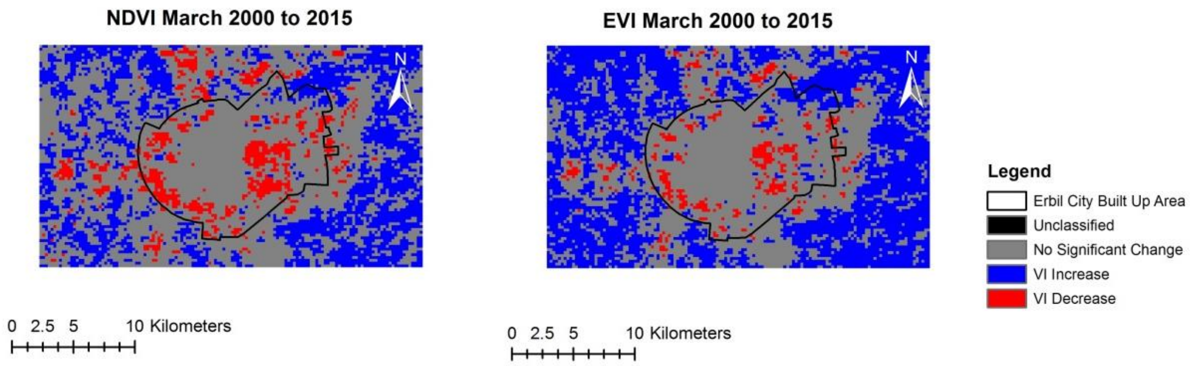

Fig. 7: Change detection of Erbil from 2000 to 2015

Figure 8 presents results from six correlation tests between the three climate variables and NDVI & EVI. Humidity had the greatest correlation to NDVI (R^2 = 0.83) and a weaker correlation to EVI (R^2 = 0.63). Rainfall and temperature both had weaker correlations to both NDVI and EVI (Fig.4).

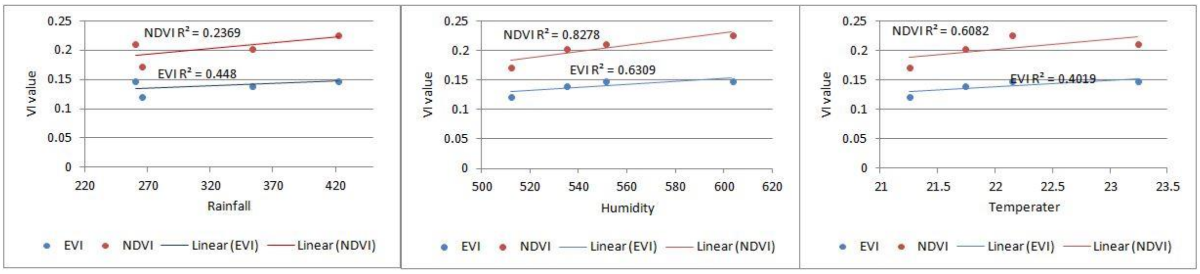

Fig. 8: Correlation analysis between rainfall, humidity, temperature and vegetation indices (NDVI & EVI)

Discussion

Considering the poor spatial resolution of the MODIS VI and the study area's sparse vegetation pattern, the VI values should remain unchanged. The fact that the results of the study show big variations between the February-May period and the rest of the year shows the vegetation's dependency to precipitations, even though the correlation analysis showed a very poor correlation between the VI values and precipitation.

The fact that 2015 was the year with the most abundant precipitations compared to the other three years considered within the study, it would be normal to have greater VI values, but both NDVI and EVI have lower values compared to 2005 and 2010. The big difference between the VI values in 2015 and the ones in 2010 can only be explained by an intense process of urban expansion in the 2010-2015 timeframe, considering the fact that none of the three climate indices analyzed in this study could be responsible for such a big vegetation loss.

The results of the study show the usefulness of the MODIS time series data and the fact that it can be helpful in the vegetation change detection process and the urban expansion detection process not only within densely vegetated areas, but also within sparsely vegetated areas. The decrease of MODIS's VI values within sparsely vegetated areas showcases an important loss of the vegetation cover within that specific region, regardless of the cause of the loss. Therefore the use of MODIS's VI spatiotemporal data in semi-arid areas can be useful to highlight important losses in the area's vegetation cover.

Conclusion

Spatiotemporal variations of vegetation indices (EVI and NDVI) between 2000 and 2015 was successfully observed using MODIS data. It is evident that the spatial distribution of urban or sparely vegetated areas surrounding Erbil has expanded over the past 15 years, and consequently vegetation surrounding the urban center has been replaced by this urban sprawl. Rural agricultural regions increased in health and productivity based on significant increases in NDVI and EVI levels from 2000 to 2015. Vegetation patterns in semi-arid regions of Iraq, particularly Erbil are highly manipulated and dependent on anthropogenic activity. Local governments should aim towards implementing green sustainable development polices and climate change strategies to reduce vegetation loss the associated effects such as climate change and biodiversity loss.

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