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DYNAMICAL ASSESSMENT OF VEGETATION TRENDS OVER MARGALLA HILLS NATIONAL PARK BY USING MODIS VEGETATION INDICES

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The study aimed to assess the vegetation dynamics in Margalla Hills National Park (MHNP) by using 250 meter resolution data product of Moderate-resolution Imaging Spectroradiometer (MODIS). It focused mainly on vegetation indices (VI) as a proxy for vegetation activity. Long term trends in vegetation activity of MHNP and the factors that have affected the vegetation activity were identified. Normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI) were examined to count on both spatial and temporal trends. Seasonal Mann-Kendall (SMK) test was used to test the statistical significance of the data sets. The results showed significant variations in the vegetation activity in both NDVI and EVI. Results revealed about 3% and 31% of the total area is showing regressive and progressive trends for NDVI, respectively. Whereas EVI analysis exhibited 4% with regressive and an increase over 13.5% of the total area of MHNP. Besides hiking tracks, settlements, water course and fire activities; limestone exploration is the major cause of vegetation degradation, especially, in the western parts of MHNP. Degradation was found prominent near picnic spots and over the limestone extraction area. This study indicated that EVI is more sensitive to vegetation degradation as compared to NDVI.
Keywords: Satellite remote sensing, MODIS, vegetation activity, NDVI, EVI

INTRODUCTION

Vegetation is the most visible characteristic of the terrestrial ecosystems and is considered as an important biophysical parameter due to its specific role in the lithosphere, biosphere, hydrosphere and atmospheric interactions. It plays a vital role in the global hydrological cycle (Hutjes *et al*., 1998). Vegetation is very sensitive to environmental changes brought about by either natural processes or anthropogenic activities (Liu and Kogan, 1996). Rapid increase in human population has resulted in the exploitation of natural resources (Vitousek *et al*., 2008). The reduced vegetation cover has broad range impacts on various ecosystems (Pregitzer and Euskirchen, 2004; Song and Woodcock, 2003) such as loss of biodiversity, reduced water dynamics, soil hydrologic conditions, infiltration rate and sediment yield (Fearnside, 2005). Therefore, vegetation activity needs to be observed extensively on both spatial and temporal scales.

Earth Observation Science (EOS) Data Gateway offers the vegetation index (VI) data product and several studies have recommended the use of MOD13Q1 data products for the vegetation change detection (e.g. Coppin and Bauer, 1996; Franklin and Wulder, 2002; Coppin *et al*., 2004; Chuvieco *et al*., 2005; Fraser *et al*., 2005). The data set offer good quality, cloud free mosaics composites at 16-day intervals and is available free of cost from the Land Processes Distributed Active Archive Center (LPDAAC) data pool in HDF (Hierarchical Data Format).

One of the most widely and successfully used index for vegetation activity is normalized difference vegetation index (NDVI - Gitelson *et al*., 1996) derived from NIR and Red spectral wavelengths. NDVI acts as a biophysical parameter linking photosynthetic activity of vegetation with greenness which is based on chlorophyll content and energy absorption by the plant (Shabanov *et al*., 2002). It provides a significant basis to assess seasonal and inter-annual changes in both vegetation and photosynthetic activities (Huete *et al*., 2002). Although, NDVI differencing is a successful change-detection method (Lyon *et al*., 1998), it has limitations in estimating the variance in canopy structure and architecture. As it is potentially affected by soil background and saturates at high biomass (Huete *et al*., 2002; (Jackson *et al*., 2004) and at intermediate leaf area index (LAI) values (Carlson and Ripley, 1997). Therefore, the enhanced vegetation index (EVI - Justice *et al*., 1998) is used as an alternative to NDVI and is less sensitive to aforementioned limitations (Kim *et al*., 2007). Due to improved performance of EVI over NDVI; it has been considered as second best global vegetation index provided by the MODIS Landsat Discipline Group (Huete *et al*., 1994).

Pakistan with arid and semiarid climate is a forest deficient country and hardly contributing 2.5 percent of global forest cover. Forested area of Pakistan is much less than the many countries of South Asian region. An increase in deforestation rate of 2.1 percent for the years 2000-2005 has been observed as compared to 1.8 percent during 1990-2000 (FAO, 2009). Most of the forests in Pakistan are confined to the northern parts of the country including Margalla hills national park (MHNP). It is situated in the Islamabad Capital Territory (ICT) and forms the northern boundary of capital city of Islamabad, Pakistan. MHNP stretches between geographical coordinates of 33°40'01" to 33°42'43" N latitude, 72°45'01" to 72°52'32"E longitude (see, Figure 1) and covers almost 15883 hectares. It hosts one of the best protected forest areas of Pakistan. However, the existing human settlements in the MHNP are heavily dependent on the MHNP resources for timber, fuel wood, non-timber forest products and subsistence agriculture. Moreover, the forest fires have resulted in biodiversity loss and environmental degradation causing negative trends in the population of wild flora and fauna of MHNP. Therefore, assessment of vegetation trends over preserved forested regions on a regular basis is mandatory and satellite remote sensing plays a significant role in it.

The main objective was to monitor vegetation cover of the MHNP by using MODIS vegetation indices during the time period of 2000-2011 and to identify the vegetation degradation areas and factors in MHNP. It aimed to investigate the influence of human (rural settlements, hiking tracks, biofuel and roads, etc.) and physical factors (slope, aspect, elevation). Although, remote sensing and geographic information system (GIS) has been successfully used for the management of protected areas (Phua and Minowa, 2005) in various parts of the world, very few studies have been conducted to evaluate changes in vegetation cover over MHNP using RS and GIS techniques (e.g. Malik and Husain 2003; Khan, 2004; Malik and Husain, 2006; Zafar *et al*., 2011; Zafar, 2014; Munawwar *et al*., 2015).

MATERIALS AND METHODS

Vegetation indices are generally used as a proxy for estimating the physical and biological vegetation parameters such as biomass or leaf area index (Liang *et al*., 2005). Vegetation indices obtained from MODIS data were utilized to observe the spatial and temporal trends in vegetation cover

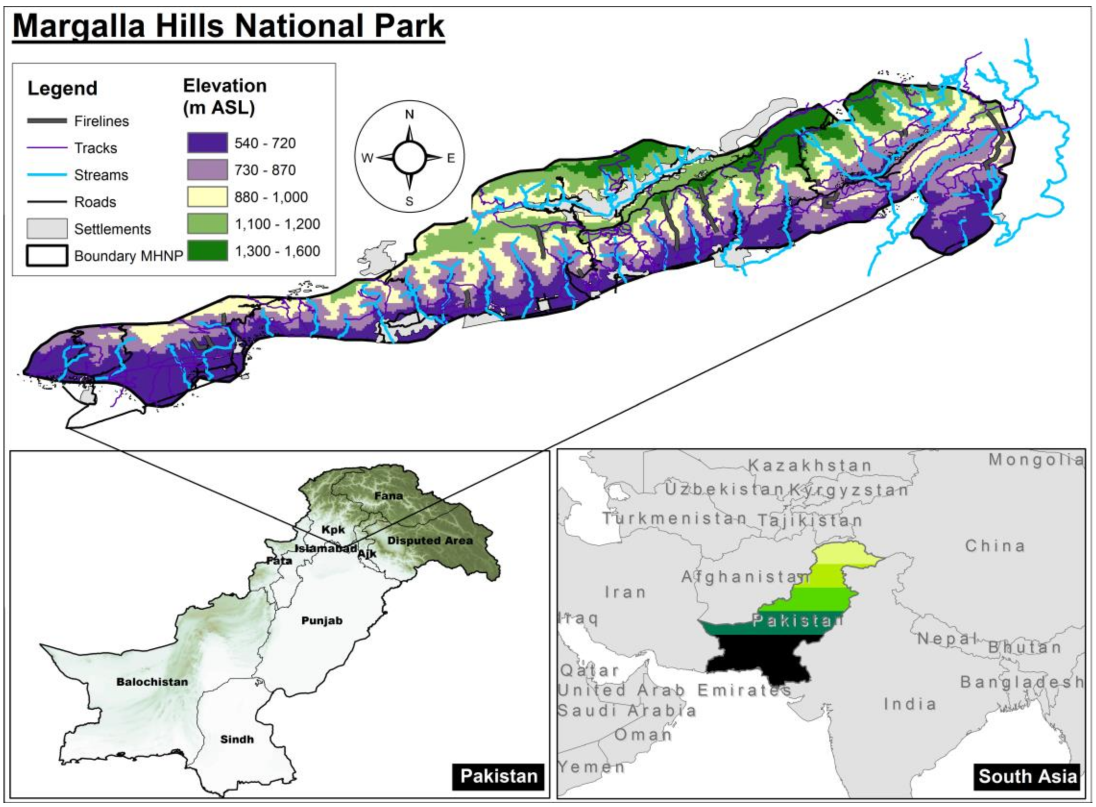

Figure1. Maps of South Asia (right bottom corner), map of Pakistan (left bottom corner) and an overview of Margalla Hills National Park (MHNP). Map shows the elevation of the study area along with other spatial feature like human settlements, roads, water streams and hiking tracks in the selected study area.

of MHNP. It comprised of the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI). The data was analyzed to identify spatial locations exhibiting significant positive (progressive) or negative (regressive) trends in vegetation activity. An attempt was made to correlate areas showing significant trends in vegetation activity to the possible factors. Scheme of all analytical procedures and tools adopted in this study is presented in Figure 2.

***Analysis of vegetation indices (NDVI and EVI)*:** Data from various remotes sensing instruments including: Advanced Very High Resolution Radiometer (AVHRR - Stroeve and Steffen 1998), Thematic Mapper (TM - Steffen and Heinrichs, 1994), Moderate Resolution Imaging Spectroradiometer (MODIS - Hui *et al*., 2014) and Satellite Probatoire d'Observation de la Terre (SPOT- Neuberg and Wahr, 1991; Nerem *et al*., 1994) are widely used for biosphere mapping and other relevant activities (Lu *et al*., 2004). In comparison to AVHRR, TM and SPOT; observations from MODIS has emerged as long-term remote sensing data sets of near-continuous and near-real time coverage of key ecological parameters with spatial resolution of 250 to 1000 m (Kerr and Ostrovsky, 2003). MODIS has been collecting data across the globe since 2000 with a revisit time of one to two days (Huete *et al*., 2002). It has a spectral range from visible to thermal infrared (0.405 - 14.385 mm) with 36 spectral bands. Among them only Band 1 (Red: 620 - 670 nm) and Band 2 (Near Infrared -NIR: 841 - 876 nm) are available at 250 m resolution (Justice *et al*., 2002).

In this study the data set used was consisted of 16-days composite images (MOD13Q1 product tile h24v05) having resolution of 250 m over the time period of February 2000 to March 2011. The dataset comprised of total 253 NDVI and EVI images per tile (23 images/year; except for the years 2000 and 2011) and was obtained from the Land Processes Distributed Active Archive Center (LPDAAC) data pool in HDF (Hierarchical Data Format).

***Trend analysis (Seasonal Mann Kendall Test)*:** NDVI and EVI anomalies were calculated for each pixel of NDVI and EVI time series data by means of Seasonal Mann-Kendall (SMK - Gilbert, 1987) test as followed by (de Jong *et al*., 2011). SMK test was performed to examine the directions (positive or negative) and statistical importance of variation in

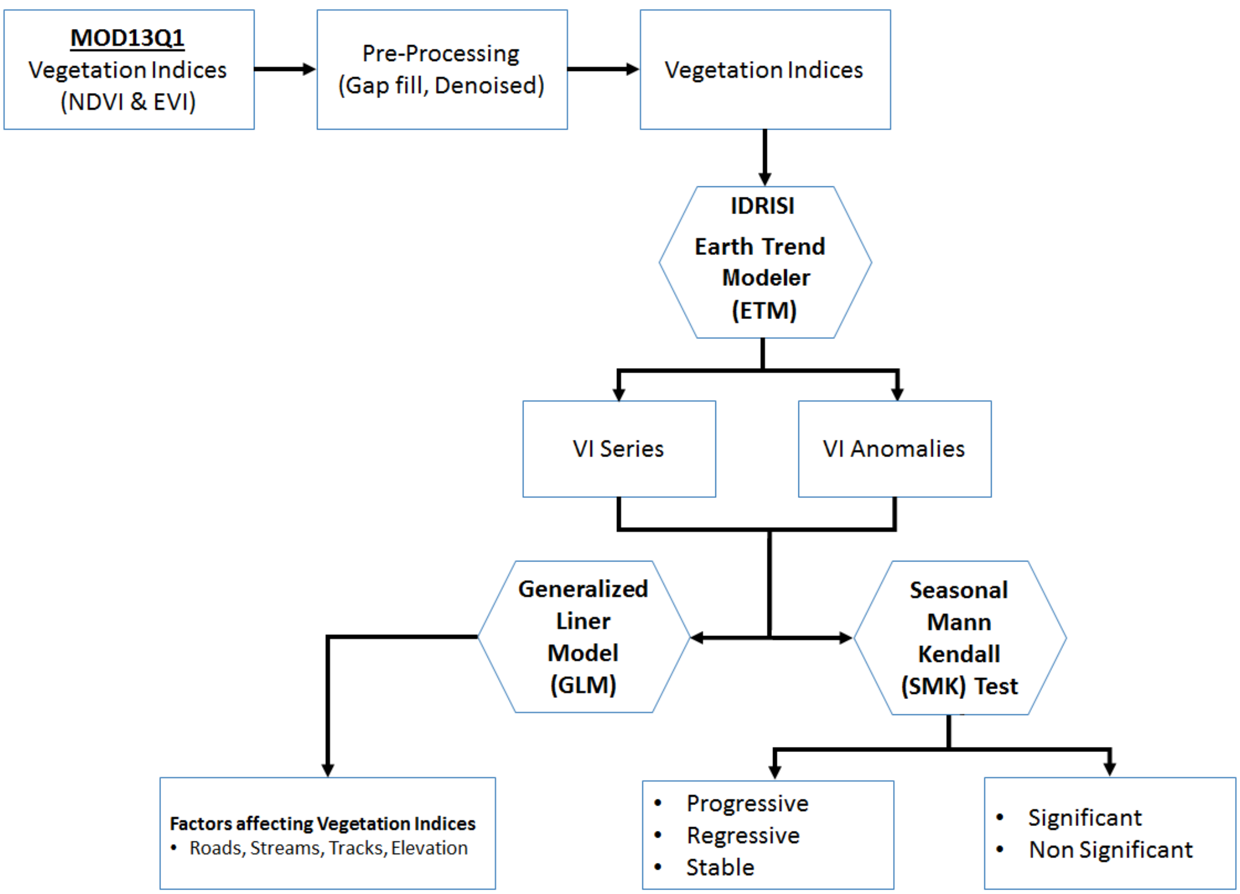

Figure 2. Schematic representation of analytical procedure tools adopted in this study in order to identify the spatial and temporal changes in vegetation activity over MHNP.

both time series and their anomalies. It is a non-parametric test which is robust against seasonality, missing values, non-normality and both inter and intra-annual autocorrelations (Hirsch and Slack, 1984; Van Belle and Hughes, 1984). The SMK test basically compares the relative magnitudes of data samples than the individual data values. Firstly, for significant monotonic trends, each periodic sub-annual interval is evaluated based on Kendalls “S” score and its variance. Normalized test statistic “Z” score and its associated probability were also calculated. If the value of “Z” is negative a decreasing trend is inferred, and if it is positive then increasing trend is inferred at a probability greater than the level of significance ($\alpha \leq 0.05$). No trend is assumed if the probability is less than the level of significance (Alcaraz-Segura *et al*., 2010).

RESULTS AND DISCUSSION

Urban development has increased in the study area from 2000 to 2010 and exhibited highly negative impacts on vegetation of MHNP. On the other hand, limestone exploration in the MHNP for development and construction is also affecting vegetation adversely. A recent study by Iqbal *et al.* (2013) stated that the limestone (LS) exploration activity has increased 5.72% during 2000-2009 in MHNP. LS exploration, in turn, has seriously disrupted natural ecosystems and vegetation in the respective area. The MODIS VI data were able to detect both progressive as well as regressive trends in the vegetation activity over MHNP. The results from a dynamical model (GLM - Guisan and Zimmermann, 2000) analysis exhibited that elevation and distance to roads are the two highly significant contributors

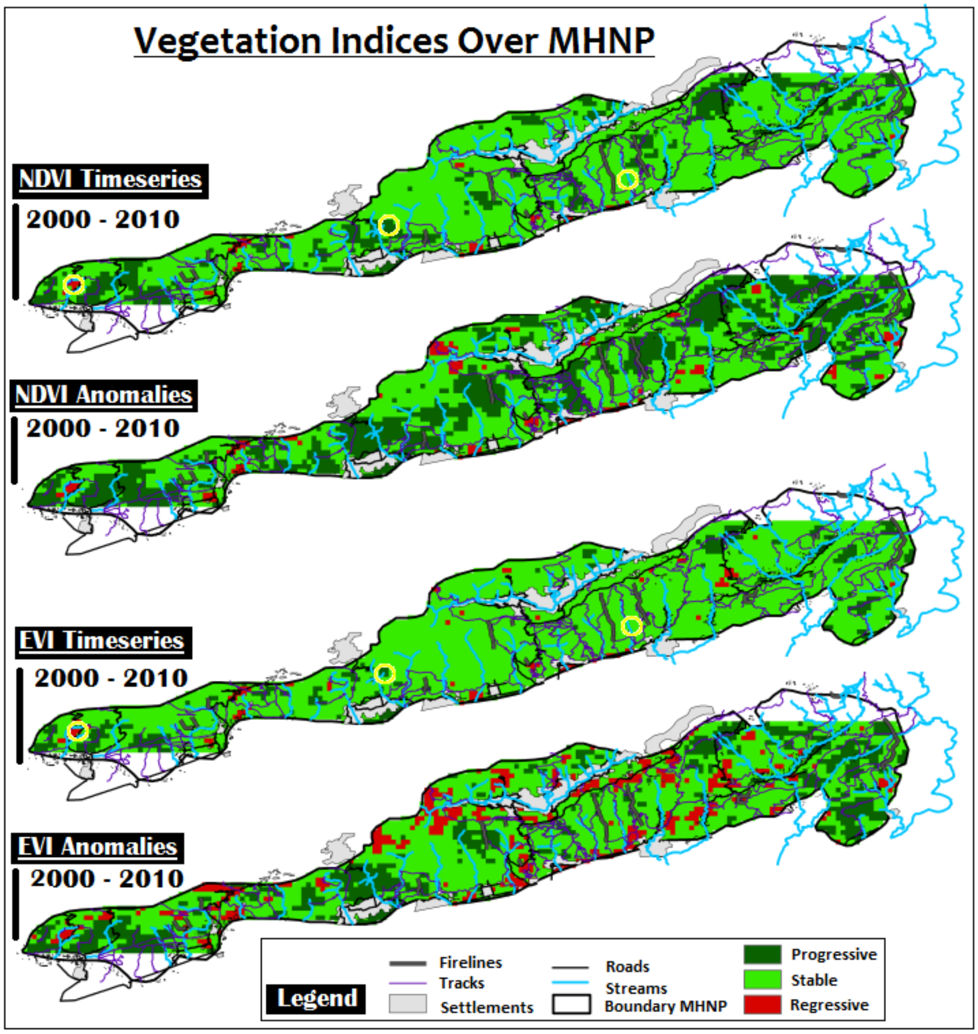

Figure 3. Vegetation indices (time series and anomalies) over MHNP derived for both NDVI and EVI during the time period of 2000-2011. Yellow circles are indicating the locations chosen for the calculation of vegetation profiles over the areas with regressive, progressive and stable trends.

to the degradation of vegetation in the MHNP. Other factors include forest fires, land clearing for agricultural use, high accessibility of people and livestock to natural vegetation has increased the intensity of damaging activities. The MODIS based NDVI and EVI time series and their anomalies presented in Figure 3 exhibited the similar trends in vegetation activity of MHNP. It shows the results of the per-pixel based analysis (spatial trend) on the time series and anomaly dataset. Dark green and red colour indicate progressive and regressive trend, respectively. Areas with little or no change termed as stable are represented by light green colour. Overall, progressive trend dominated, especially at the higher elevations - northern part of the National park. On the southern side, some vegetation increase is also observed over a few spots while vegetation degradation is observed mainly near the picnic spots, settlements and limestone extraction areas. The statistical significance of the calculated trends was tested through Seasonal Mann-Kendall's test over the study area. Figure 4 presents the trend of vegetation activity either progressive or regressive trend only for the pixels with statistically significant within a confidence interval of 95%. Red, green and white colours represent the regressive, progressive and statistically non-significant trends over MHNP, respectively. NDVI time series exhibited statistically significant increase in vegetation activity (progressive trend) for 4987.01 ha (31.39%) with 486.11 ha (3.06%) exhibited decreasing trend (regressive) and leaving 11646.44 ha (51.93%) of lands to be classified as stable in terms of vegetation activity. Whereas EVI time series and anomalies presented in the lower panel of Figure 4 exhibited a different result with 672.74 ha (3.95%) of total area with regressive trend relatively larger than as exhibited by NDVI (3.06 %). Progressive trend was observed over an area of 2148.45 ha (13.52% - two time less than NDVI) and rest of the area showed statistically non-significant trends in vegetation activity.

Furthermore, time series of both NDVI and EVI profiles calculated over randomly selected areas with statistically significant progressive, regressive and stable trends are presented in Figure 5. Results show that EVI and NDVI translate the spatial and temporal analyses of vegetation cover over MHNP. Both NDVI and EVI has shown a consistent inter-annual variability and seasonal fluctuation in the vegetation over selected time period. However, both

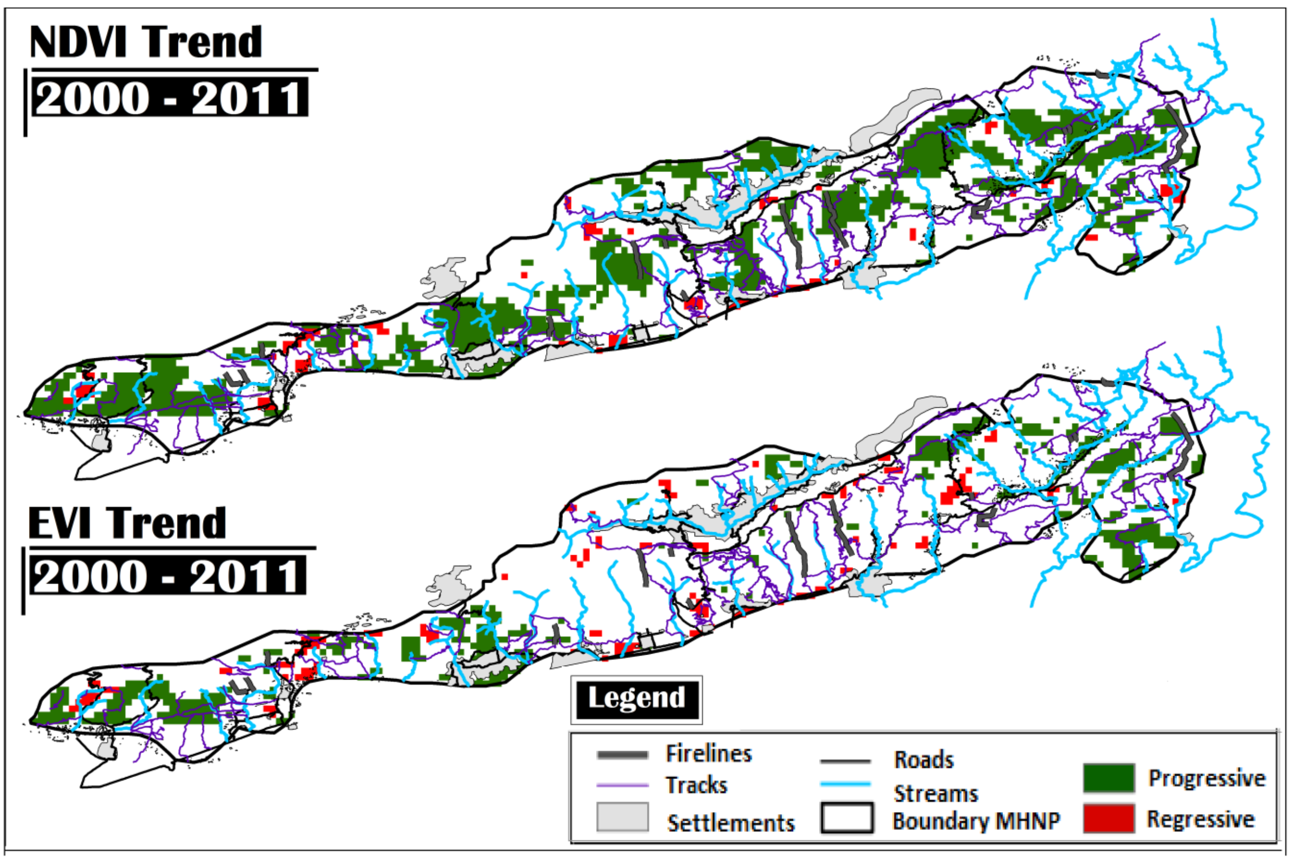

Figure 4. Pixel showing z values (trend) with 95% confidence interval (p values <0.05) over the study the seasonal Mann Kendall test. White areas are with statistically non-significant trends.

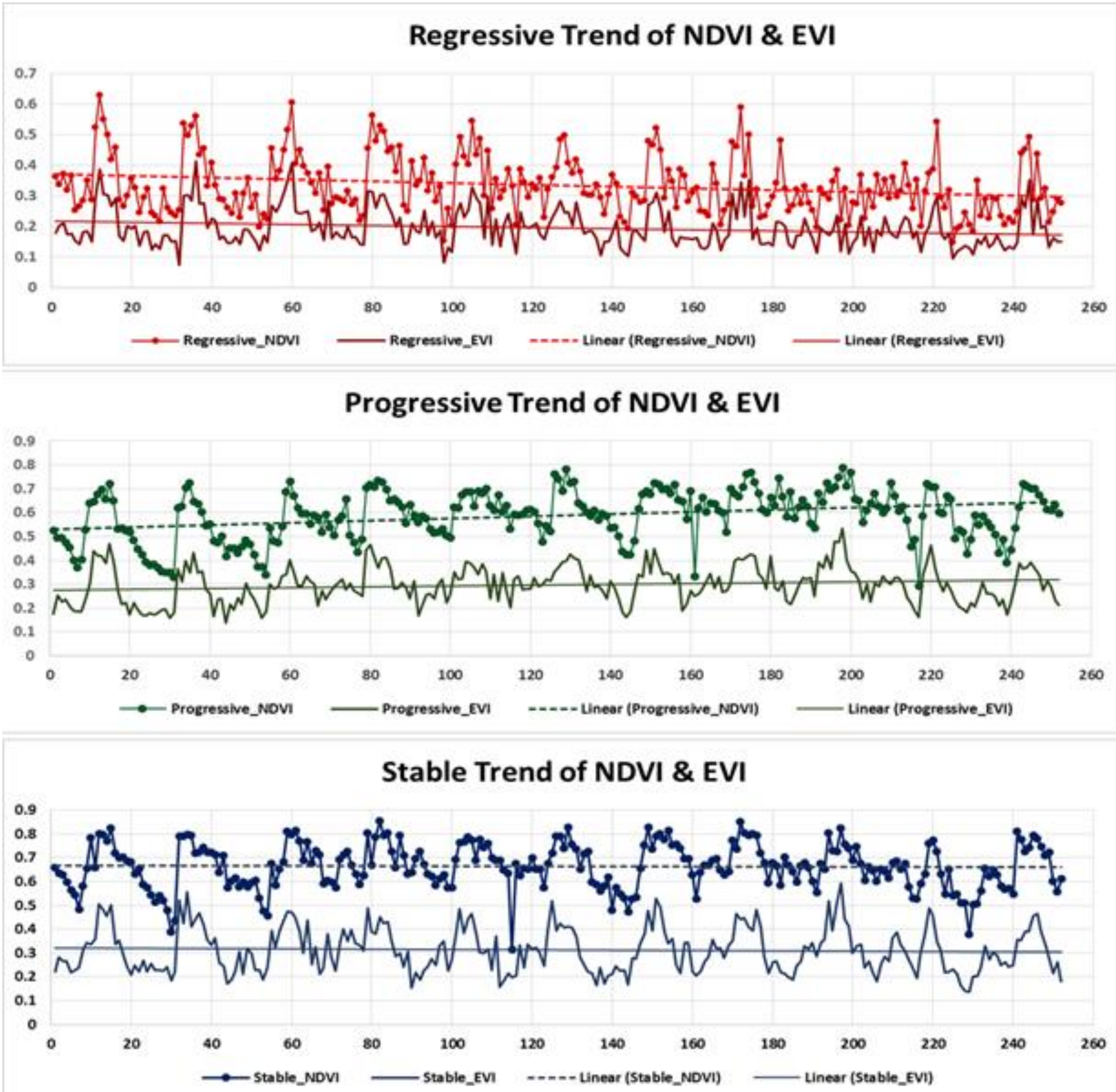

Figure 5. Time series of both NDVI and EVI profiles calculated over randomly selected regions with statistical significant regressive, progressive and stable trends in vegetation cover of MHNP. X-axis shows time period at rate of 16 days(one dot represents 16 days mosaic data) since January 2000 to December 2011.

indices differ significantly in magnitude of calculated changes for all progressive, regressive and stable trend. As EVI is showing a more regressive (21%) trend then NDVI (19%). The difference is even larger for progressive trends with EVI=15%, and NDVI= 22%, whereas both trends are consistent over region with stable trends.

The observed differences may be attributed to the fact that NDVI gets potentially affected by soil background and saturates at high biomass (Huete *et al*., 2002; Jackson *et al.*, 2004) and intermediate leaf area index values (Carlson and Ripley, 1997) as compared to EVI. Although NDVI and EVI anomalies have depicted quantitatively different results, however, regressive trend was mostly observed at lower elevations and near settlements while the progressive trend is observed near tracks and water streams in both data sets.

***Limestone exploration activities in MHNP*:** A case study was performed in the western parts of MHNP where both NDVI and EVI data sets have exhibited statistically significant decreasing trend of vegetation. The Google earth images of the selected area over different time periods were explored as presented in Figure 6 (upper panel). It is apparent from the Google earth images that vegetation has

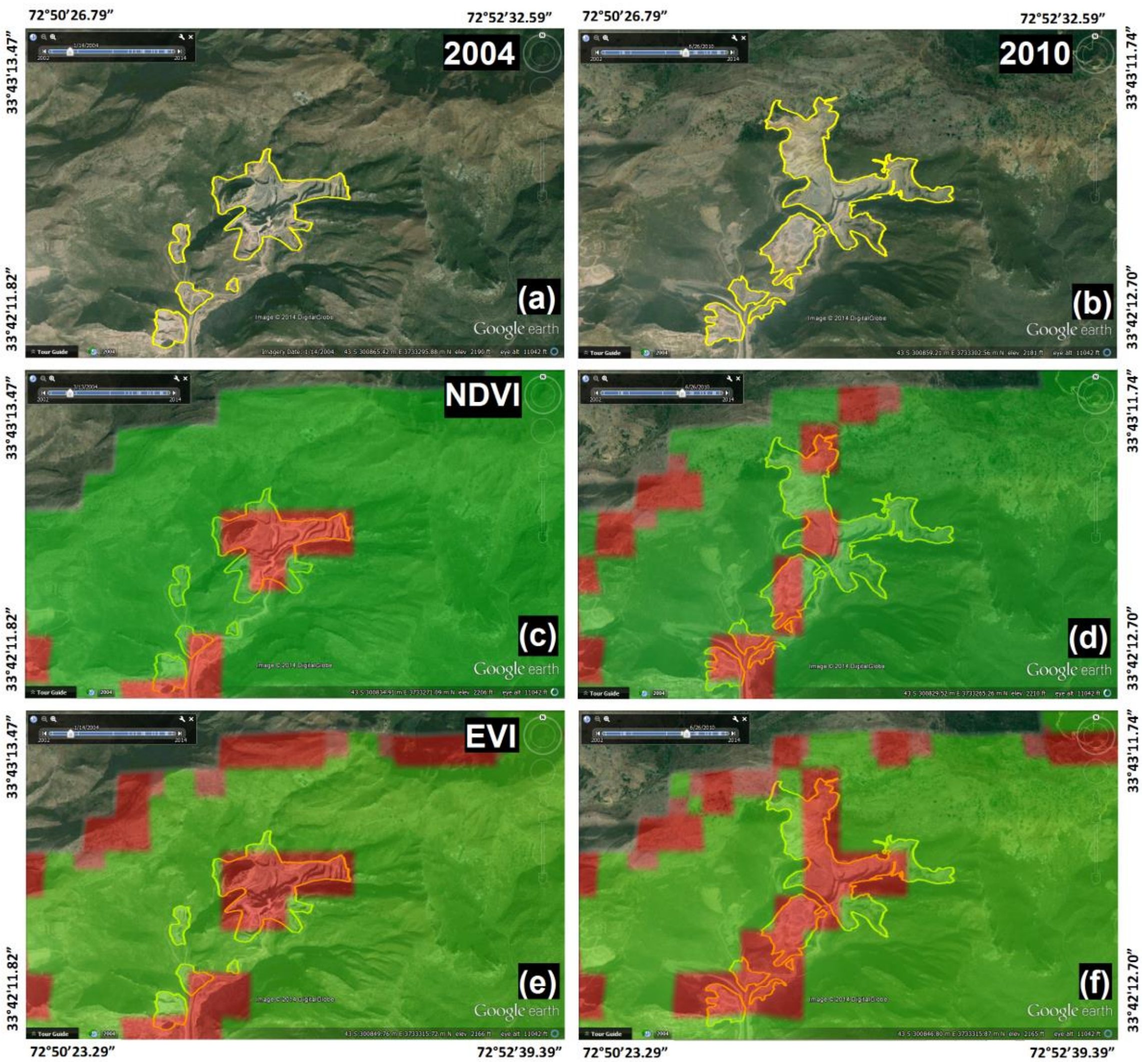

Figure 6. A comparison of Google earth images for the year 2004 (a), 2010 (b) and with overlaid NDVI (c and d) and EVI (e and f) maps for respective years over the limestone exploration area (yellow lines in all figures). Red colour is exhibiting the regions with vegetation degradation/deforestation indicated by NDVI (c and d) and EVI (e and f) during the time period of 2004 to 2010 due to LS exploration.

been substantially degraded (yellow lines) even with the visuals from year 2004 and was further enhanced during the year 2010. Figure 6 is showing Google images (a and b) during 2004 and 2010 and were overlaid with the maps of NDVI (c and d) and EVI (e and f) in the western part of MHNP, respectively. It was investigated and found that limestone exploration activities have caused this deforestation pattern. Red pixels in the figure demonstrate the degradation and, were found exactly over the deforested area of Google earth images (yellow polygons). Especially, the EVI map has more precisely/accurately identified the area affected by LS exploration activities as compared to NDVI map. Thus, one of the major causes of deforestation is the increase in limestone exploration in the study area from 2000 to 2010. Table 1 shows the comparison of vegetation deforestation/degradation area calculated from Google earth images (yellow lines- shape file was developed on visually degraded area) and MODIS images for NDVI and EVI for the year 2004 and 2010. Lime stone exploration area from MODIS images was calculated by selecting only those pixels which exhibited vegetation degradation (red colour) due to limestone exploration and are also statistically significant. The deforested area calculated from EVI map compares very well with Google images as compared to area calculated from NDVI maps for both years.

Table 1. Comparison of vegetation degradation/ deforestation area (in hectors) caused by limestone exploration activities in MHNP.

Data	Year 2004	Year 2010
Google earth	29.77	43.38
NDVI	21.70	26.04
EVI	30.38	43.40

Conclusions**:** The increasing human population and unsustainable use are resulting in the disturbance of vegetation in the study area during the time period of 2000-2011. Spatial and temporal analyses helped in monitoring and identifying the factors responsible for changes in vegetation activity in the MHNP. The results have shown both the regressive and progressive trends in vegetation activity (NDVI= 3.06% and 31.39% and EVI= 3.95% and 13.52%, respectively). The decrease in vegetation activity was more pronounced in the EVI results as compared to NDVI. Degradation was prominent mainly at lower elevations, near settlements, stone quarries (LS exploration) and the picnic spots which explain the role of human activities in vegetation degradation. The results showed differences in extent of vegetation activity trends devised from NDVI and EVI and their anomalies. These differences may be attributed to the fact that the enhanced vegetation index (EVI) is more sensitive to vegetation degradation; while NDVI has certain limitation due to atmospheric effects and saturation caused by back ground soil and vegetation canopy. Furthermore, EVI was introduced to avoid the influence of atmospheric conditions on vegetation index values and also minimize canopy soil variation. Especially, the case study presented over the areas with LS exploration activities in the western parts of MHNP indicated that changes detected by EVI data are more reliable than in the case of NDVI data.

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